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No. 6, Individual Variation in the Rugose Coral Species

HELIOPHYLLUM HALLI E. & H.

By

JOHN W. WELLS

April 3, 1937

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INDIVIDUAL VARIATION IN THE RUGOSE CORAL SPECIES *HELIOPHYLLUM HALLI* E. & H.

By

John W. Wells

THE HAMILTON CORAL BEDS

The coral bed in the Hamilton shales of the Middle Devonian on the east shore of Skaneateles Lake (Onondaga County, New York) has been described in detail by Smith (1912, 1935). A re-description here is therefore unnecessary, although it may be noted that Cooper (1930, 228) has indicated that the stratigraphic position of the bed lies near the base of the Ludlowville formation about 50 feet above the Centerfield member, and that Smith (1935, 46) applied to it the name "Staghorn Point Submember". Cooper has also noted the outcrop of the coral-bearing horizon as far eastward as New Woodstock (Madison County), giving it an East-West extent of about 22 miles and an indeterminate North-South limit, its thickness varying from a few inches to about four feet and averaging around three and one-half feet. It has not been observed on the west shore of Skaneateles, or farther west. A second bed, lying about 90 feet above the Centerfield, outcrops at Lord's Hill, near Joshua (Onondaga County), and elsewhere in the vicinity, consists of an upper bed about 65 feet thick and several thinner lower ones, the whole aggregating about 110 feet, and rapidly thins eastward and westward from this point (see Smith, 1935, fig. 24).

The greater mass of the beds is composed of simple cyathophylloid corals closely packed, lying horizontally in a soft dark gray calcareous shale matrix, almost to the exclusion of other fossils, of which there are found scattered specimens of bryozoans, brachiopods, and lamellibranchs. The corals may occur unworn and in their original position of growth, or rolled and in various conditions of wear. They vary in size from neanic individuals less than a centimeter long up to 40 centimeters. Some of the massive colonies of *Favosites* are several feet in diameter.

The following list, with the exception of the "species" of *Heliophyllum* which are the subject of this paper, includes the corals identified from this horizon by the author:

CORAL FAUNA OF THE HAMILTON CORAL BEDS IN ONONDAGA COUNTY

1. *Stereolasma rectum* (Hall)
2. *Amplexus hamiltoniae* (Hall)
3. *Heterophrentis ampla* (Hall)
4. *Heterophrentis simplex* (Hall)
5. *Siphonophrentis halli* (E. & H.)
6. *(Cyathophyllum) robustum* Hall
7. *(Cyathophyllum) galerum* Hall
8. *(Cyathophyllum) conatum* Hall
9. *Eridophyllum subcaespitosum* (Nicholson)[1]
10. *Prismatophyllum sp. cf. P. davidsoni* (E. & H.)
11. *Cystiphyllum varians* Hall
12. *Cystiphyllum conifollis* Hall
13. *Cystiphyllum corrugatum* Hall
14. *Cystiphyllum americanum* E. & H.
15. *Favosites placenta* Rominger
16. *Favosites arbuscula* Hall
17. *Favosites hamiltoniae* Hall
18. *Favosites limitaris* Rominger
19. *Favosites 3 species*
20. *Ceratopora sp. cf. C. jacksoni* Grabau

Smith (1912, 453) concludes that the beds represent "a transitory return to Onondaga-like conditions" of clear water with at least a partial cessation of mud deposition, "followed again by the mud-bearing waters and mud-loving fauna of the typical Hamilton." Most of the corals listed above were related to, if not identical with, those of the Onondaga limestone of lower middle Devonian age which had scattered at the close of that epoch in New York. Returning once more in the early Ludlowville, they remained more or less abundant until the end of Tully time.

THE "SPECIES" AND "VARIETIES" OF HELIOPHYLLUM HALLI

The only important descriptive work yet published on the corals of the Hamilton of New York is that included in James Hall's "Illustrations of Devonian Fossils", hurriedly issued without text in 1876 (edition of 130 bound copies), just before the publication of Rominger's great work on the Michigan corals. In this are figures of five new species, one old species, and two new varieties of *Heliophyllum:*

1. *H. arachne* Hall	Pl. 24, figs. 8-12; 14
2. *H. confluens* Hall	Pl. 26, figs. 3, 4. Pl. 27
3. *H. degener* Hall	Pl. 25, figs. 8-11
4. *H. halli* Edwards & Haime	Pl. 23, figs. 1-5; 12. Pl. 25, figs. 1-7
5. *H. halli, var obconicum* Hall	Pl. 25, figs. 12-13
6. *H. halli, var reflexum* Hall	Pl. 23, figs. 6-11
7. *H. irregulare* Hall	Pl. 24, figs. 1-7; 13
8. *H. proliferum* Hall	Pl. 26, figs. 1, 2, 5

All of these forms were based upon specimens from the Ludlowville and Moscow formations of central and western New York. Of these, the types of *H. degener* and *H. halli* var. *obconicum* were from the coral bed on Skaneateles Lake.

[1] *E. archiaci* (Billings), a closely related species, occurs higher in the Hamilton Group in the Moscow and Tully formations.

The differentiation of these "species" and "varieties" is a relatively easy task when one has only a few specimens to determine. Reference to Hall's figures shows that he considered that each "species" or "variety" has a characteristic growth-form, and further that the form of the calice is very diagnostic. Species based upon such characters are considered very good by some workers today, notably Wedekind, who has created species for the Eifelian and Gothlandian corals with a prodigal hand, using as his main criteria the shape of the calice, the growth-form of the corallum and the number of septa. In many cases these may be perfectly satisfactory, but, as will be shown on succeeding pages, when individual variation occurs they are the most subject to change.

The writer had identified many specimens of each of Hall's "species" and "varieties" of *Heliophyllum* and got along very well until he had accumulated several hundred specimens from the two principal localities, Skaneateles Lake and Lord's Hill. It became necessary to identify each new specimen only from Hall's figures, because reference to the previously determined material was too confusing,—so much variation in each "species" and even "variety" had been found that no dividing line could be drawn between any of them.[2] It became increasingly clear that *only one real species was present,—the others were only individual varieties, all of them being found at each of the two localities* mentioned. The purpose of this paper, then, is to endeavor to show that there is only one species of *Heliophyllum* in the Hamilton coral beds of Onondaga County, and that it is the type species of the genus, *Heliophyllum halli* Edwards & Haime.

INDIVIDUAL VARIATION IN CORALS

Practically no work has been done on the problem of individual variation in fossil corals, and even the recent ones have received less attention than is needed. In the latter case, while considerable progress has been made toward elucidating the causes of local variation in growth-form, individual variation under the same environmental conditions has had almost no attention.

Vaughan's study of *Porites compressa,* a living colonial reef-building hexacoral of the Hawaiian Islands (1907, 174-193), is a good example of the variation of one species within a restricted geographical area. He distinguished 16 *formae* and 4 *subformae,* besides the typical form. Some of these forms intergrade with each other; others are end-points on lines developing away from the least modified types. He notes that "the variation appears to be continuous, but with a number of secondary modes, should they be plotted into a specific curve," but does not undertake to demonstrate its causes. The features affected by variation are the form and dimension of the calice, characters of the wall and other skeletal structures, and form of the corallum, the last considered of minor importance.

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[2]The same situation was experienced by Crossland in dealing with two living species of *Fungia* in Tahiti: ". . . odd specimens can usually be placed in one species or the other, but, if a series of fifty to a hundred specimens be taken, division becomes impossible, even if the specimens are of good size." (*Proc. Zool. Soc. London,* 365. 1931.)

Kranz, in his study of the Tertiaries of northern Italy (1914), after a careful examination of the species of *Hydnophyllia*, also a hermatypic hexacoral, occurring in the lower and middle Oligocene, concluded that but one species is involved, of which there may be 29 *formae*, depending upon the form of the corallum, relative age of individuals, and morphological characters. Most of these *formae* had been given specific names by previous workers. In this case, however, the "species" had considerable temporal distribution within a limited area, and the *formae* of *Hydnophyllia* will perhaps prove to represent several orthogenetic trends.

On his first examination of the species of *Montlivaltia* of the Middle Jurassic coral fauna of Cutch, Gregory (1900, 18 *et seq.*) found four types apparently identical with known European species, but further study of some 2000 specimens showed that the typical forms were linked together by a continuous series of intermediate forms homoplastic with the European species and with different ancestry. He finally named several new "species", calling them "circuli", each with a number of variants radiating outwards from a central type, but was still doubtful whether more than one species of *Montlivaltia* existed in the Cutch region. He argued that while conditions may have favored the development of a number of good species of this genus in the Middle Jurassic of Europe, the same was not necessarily true for India, and invited later workers who disagreed with his naming of but a few "species" or "circuli" to make as many as they wished, and gave a wide choice of old specific names that might well have been applied to the Cutch forms.

Among the rugose corals, as previously mentioned, practically nothing has been done on their individual variation, although their "mutations" and orthogenetic trends have been somewhat investigated. The present paper presents the results of a study of the causes of the variation in one species occurring in an area particularly suited for such an investigation. The results, to anticipate, are opposed, more or less, to the ideas of Grabau, who has considered the problem eclectically (1922, 6), and who states that "forms otherwise alike, may vary . . . in different localities, and this variation may be induced by different environmental conditions, such as the composition of the water, the food supply, etc., which affect the physiological condition of the polyps; this effect finding expression in the relative rates of increase in diameter and of lime separation. *Where such variation, however, exists in the same locality, it must be regarded as expressing a fundamental, even if slight, inherent difference in the organism, and may lead to the development of distinct genetic series.*" (Italics not Grabau's.)

There can be no doubt of the validity of the first statement in the above quotation. The second statement, although logical, is open to modification. There are certain factors inducing variation in the same locality, not as obvious as those resulting from those mentioned, but just as effective in their action, some of which may be:

1. Reproductive precocity.
2. Stability:
   a. Stability: straight or regularly curved corallum.
   b. Instability: contortion of corallum.
3. Gerontism.
4. Irregularity of rejuvenescence.
5. Differential growth-rate of polyp or parts of polyp and corallum.

Individual varieties of *Heliophyllum halli* resulting from the operation of each of these factors are known and will be described.

Described Forms of Heliophyllum in the Hamilton Coral Bed

1. Typical **Heliophyllum halli.**

Plate 1, figs. 1-4

Edwards and Haime (1851, 408, pl. 7, figs. 6, a, b) based their description of their new species *H. halli* upon specimens in their collection from the Moscow and Ludlowville formations at several localities in western New York and upon Hall's description and figures of his *Strombodes helianthoides* (1843, 209-210, fig. 87.3) (non *S. helianthoides* Phillips) from the Ludlowville formation at York, Livingston County, New York. This last locality is here taken as the type locality of *Heliophyllum halli.* The following is a revised description:

The coral, which often attains a diameter of 5 or 6 cm., varies in shape from turbinate specimens, only a few centimeters in height and broader than high, to tall cylindrical individuals 10 to 15 cm. long and not much more than 4 cm. in diameter. Specimens over 20 cm. long are known. The coralla are regular and nearly smooth or very irregular and strongly annulated. The species is typically simple, but may give rise to a few offsets. The calice has a moderately deep axial pit surrounded by a wide peripheral platform sloping gently inward. There are about 85 thin septa in the mature coralla which, within the dissepimentarium, are strongly carinate with the yard-arm type of carinae. A few of the major septa extend across the tabularium and meet at the axis, usually twisted, but most of them only extend inwards for about three-quarters of the radius. The minor septa attain about half or rather more than half the length of the major. The stereozone, when developed, is confined to dilatation of the septa in the tabularium. The tabulae are incomplete, small, numerous, and arched, the dissepiments globose and fairly regular in size. The epitheca is thin.

In 1876 Hall published excellent new figures of the species (1876, pl. 23, figs. 1-5; 12. Typical specimens are shown in figs. 1 and 4). The outline figures (in the present paper) 1-7 show the variation in form among specimens that are regarded as being typical.

Table 1

Dimensions of Typical H. halli

Locality	Horizon	Diameter of Calice	Depth of Calice	Height	Number of Septa
		cm.	cm.	cm.	
E. & H.	Moscow?	4.0	2.0	5-6	80
Livingston Co.	Ludlowville	3.4	0.9	2.3	70
Livingston Co.	Ludlowville	4.0	1.4	4.0	80
Livingston Co.	Ludlowville	4.7	1.2	9.5	84
Erie Co.	Ludlowville	5.0	1.5	7.0	82
Livingston Co.	Ludlowville	5.3	1.6	22.5	90
Tompkins Co.	Ludlowville	8.0	2.3	10.0	90
Skaneateles Lake	Ludlowville	4.7	1.5	5.5	80
Lord's Hill	Ludlowville	5.0	1.3	6.7	100
Lord's Hill	Ludlowville	6.5	1.6	6.0	108
Lord's Hill	Ludlowville	6.5	1.3	14.0	120

Although there is apparently much variety in these specimens, they are fundamentally the same. In the matter of the number of septa the differences are slight, except for two from Lord's Hill which have more than 100; both of these are unusually large specimens. The average number for ephebic individuals is 85. The shape of the calice is constant in the ephebic stage, but varies in the neanic and early ephebic, as indicated by a comparison of figure 2 with the others. The ephebic calice has the margin as the highest point, whence inward the slope toward the bottom is slight at first, then very steep to the bottom which occupies about 40% of the total diameter. The ratio of calicular depth to diameter is between 1:3 and 1:4. A comparison of the heights of the specimens is conclusive of little except the relative ages, as indicated by figures 2 and 3. The former shows a young corallum, the latter a comparatively old one which has retained the same shape for some time after reaching maturity. Older specimens tend to be cylindrical above the initial neanic curving.

2. **Heliophyllum confluens** Hall

The specimen figured by Hall on plate 27 of his "Illustrations of Devonian Fossils", from the Ludlowville formation at York, Livingston County, is taken as the holotype. It is simply a colonial form of *H. halli* resulting from peripheral increase. In the polyp new stomodaea appeared on the disc of the polyp outside the tentacular ring; if there were many of them the parent was rapidly obliterated while the daughters fused laterally, forming a cerioid or plocoid corallum. The number of septa in individual calices of this form varies, of course, with the relative size:

TABLE 2

Calicular Diameter and Septal Number in H. confluens

Locality	Horizon	Calicular Diameter	Number of Septa
		cm.	
York (Hall's Type)	Ludlowville	—⎫	62
York (Hall's Type)	Ludlowville	—⎭	64
Erie Co.	Ludlowville	2.0⎫	54
Erie Co.	Ludlowville	3.0⎬	62
Erie Co.	Ludlowville	4.0⎭	70
Erie Co.	Ludlowville	5.0	100
Lord's Hill	Ludlowville	3.2	80
Lord's Hill	Ludlowville	3.5⎫	85
Lord's Hill	Ludlowville	5.5⎭	90
Lord's Hill	Ludlowville	3.5⎫	100
Lord's Hill	Ludlowville	6.0⎭	120
Lord's Hill	Ludlowville	4.0⎫	96
Lord's Hill	Ludlowville	4.5⎭	100
Skaneateles	Ludlowville	6.0	128

(Brackets indicate calices are part of same colony.) The form of the calice, as shown in fig. 8, is the same as that of *H. halli.*

3. **Heliophyllum proliferum** Hall (*non* Nicholson 1874)[3]

The type is a specimen from Darien, New York, figured on Hall's Plate 26, figs. 1 and 2. This is *H. halli* in which budding occurred (peripheral increase) at a late period in the life of the mother-polyp. Such buds, although they themselves often budded again, were rarely as vigorous as the parent and seldom attained full growth (fig. 9). Occasionally specimens are found in which budding of the *H. proliferum* type occurred in late neanic stage (figs. 10, 11, pl. 1, figs. 5, 6, 12) (precocious budding). This last may be termed *H. halli* FORMA *praecoquus*. *H. proliferum* is distinguished from *H. confluens* by the fact that the offsets rarely fused laterally in the former, but tended to form a caespitose head. The survival of the mother-polyp is also a character of *H. proliferum*.

4. **H. halli** VAR **reflexum** Hall

Differs from typical *H. halli* by the reflexed or downturned margins of the calice (figs. 12-14). The highest part of the calice is not the outer margin but at the point just before the commencement of the steep slope to the bottom of the calice begins.

TABLE 3

Calicular Diameter and Septal Number in H. halli reflexum

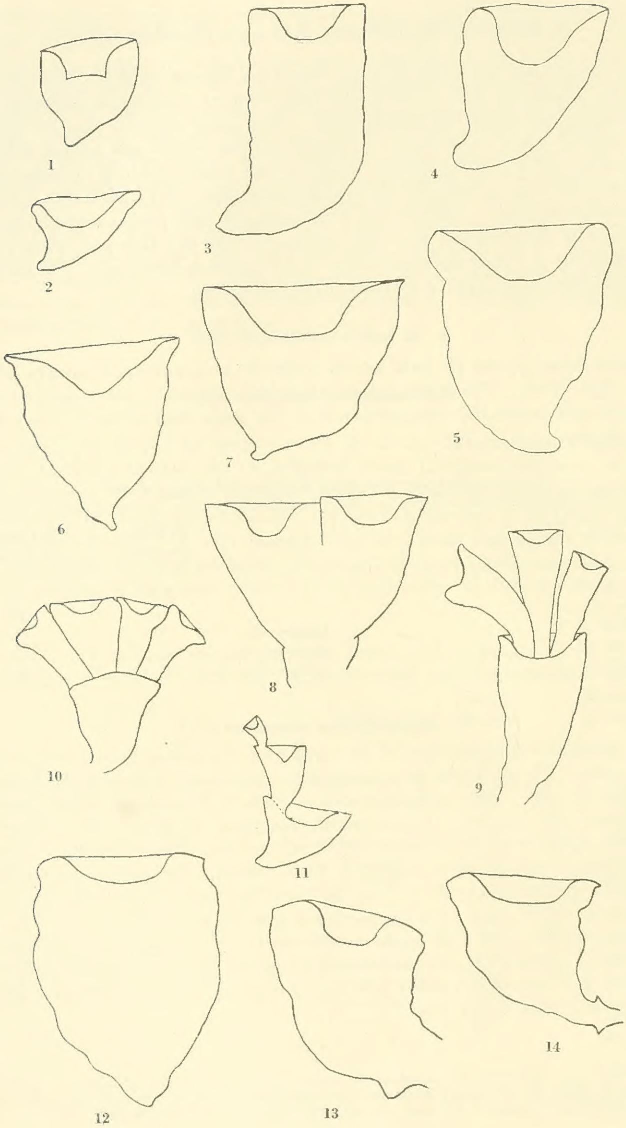
Locality	Horizon	Calicular Diameter	Number of Septa
		cm.	
Hall, Fig. 8		—	90
Lord's Hill	Ludlowville	4.2	90
Lord's Hill	Ludlowville	5.0	116
Lord's Hill	Ludlowville	6.0	120

5. **Heliophyllum irregulare** Hall

The irregular, contorted form of the corallum is the distinguishing character of this "species." Typical specimens are usually small, rarely attaining the diameter of typical *H. halli*. The contortions were the result of instability of the corallum which now and then, by accident or topheaviness, toppled over, causing the polyp to reorient itself with respect to the substratum. The expenditure of much of the polyp's energy in re-adjusting itself explains the undersized corallum. Calicular diameter in specimens from the Hamilton coral beds is rarely more than 3.5 cm., with 70-85 septa. Specimens of this form are not common.

Some specimens of *H. halli* might be classified as *H. irregulare* because uneven rejuvenation produced a contorted corallum (figs. 15, 16). The rejuvenation may have been induced by instability, and such forms may be named *H. halli* FORMA *pravum* (pl. 1, figs. 13, 14, 15).

[3]Further on in this paper the conclusion is reached that *H. proliferum* Hall is only an individual variety of *H. halli*,—*H. halli* FORMA *proliferum*. In these circumstances it does not seem necessary to rename Hall's form as would be the case were two distinct species *proliferum* involved.



Heliophyllum halli E. & H.

(×¾)

Figures 1–14

Figures 1-7, Typical *Heliophyllum halli.*

1. E. and H. 1851, pl. 7, fig 6a, Moscow (?) formation; 2. York, Livingston Co., Ludlowville formation, topotype; 3. York, Livingston Co., Ludlowville formation, topotype; 4. York, Livingston Co., Ludlowville formation, topotype; 5. Eighteen-Mile Creek, Erie Co., Ludlowville formation; 6. Skaneateles Lake, Ludlowville formation; 7. Lord's Hill, Onondaga Co., Ludlowville formation.

Figure 8. *H confluens,* Lord's Hill.

Figure 9. *H. proliferum,* Lord's Hill.

Figure 10. *H. halli,* FORMA *praecoquus,* Skaneateles.

Figure 11. *H. halli,* FORMA *praecoquus,* Skaneateles.

Figure 12. *H. halli reflexum,* Lord's Hill.

Figure 13. *H. halli reflexum,* (After Hall, pl. 23, fig. 9.)

Figure 14. *H. halli reflexum,* Skaneateles.

Heliophyllum halli E. & H.
(×¾)

Figures 15–30

Figure 15. *H. halli* FORMA *pravum*, Moscow formation, Livingston Co.

Figure 16. *H. halli*, FORMA *pravum*, Skaneateles.

Figure 17. *H. arachne*, Skaneateles.

Figure 18. *H. arachne*, Skaneateles.

Figure 19. *H. arachne*, Lord's Hill.

Figure 20. *H. degener*, Skaneateles.

Figure 21. *H. halli obconicum*, Skaneateles.

Figure 22. *H. halli—reflexum*, Lord's Hill.

Figure 23. Diagrams illustrating the principal hypotheses of the morphogenesis of the rugose corallum. A. Bernard, 1904. B. Yakovlev, 1917-1932. C. Weissermel-Schindewolf, 1897-1932.

Figure 24. *H. halli*. Base of corallum showing root-like processes (talons) developed to maintain vertical position. Moscow formation, Livingston Co.

Figure 25. *H. halli—reflexum—obconicum*, Lord's Hill.

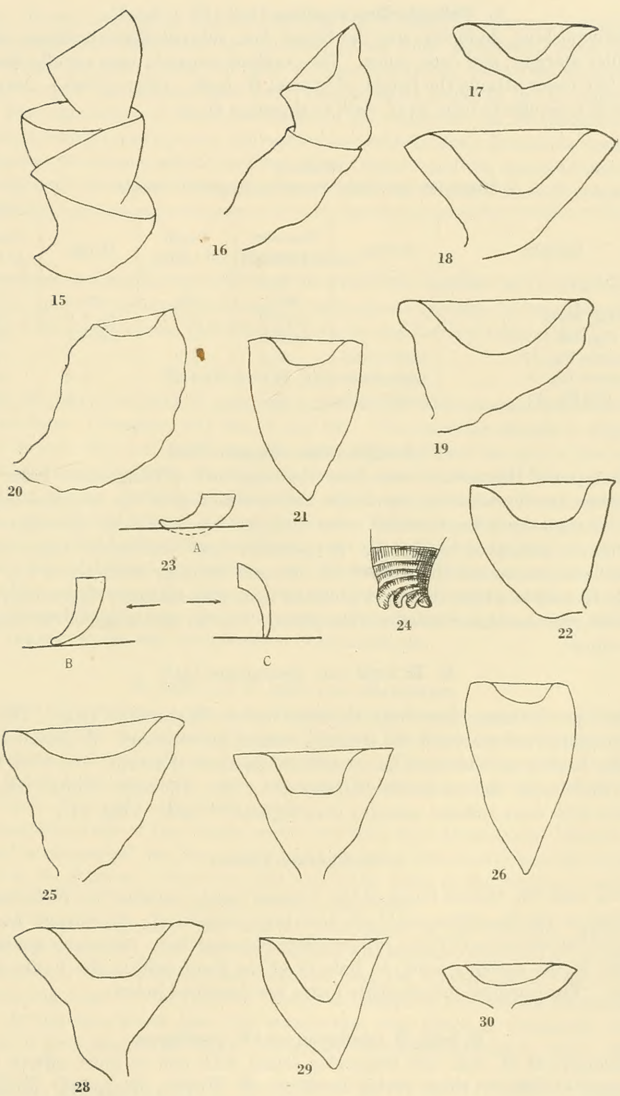
Figure 26. *H. halli*, "*degener—reflexum—obconicum*," Lord's Hill.

Figure 27. *H. halli—arachne*, Skaneateles.

Figure 28. *H. arachne—halli*, Skaneateles.

Figure 29. *H. halli*, FORMA *infundibulum*, Skaneateles.

Figure 30. *H. halli*, FORMA *aplatum*, Skaneateles.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6. **Heliophyllum arachne** Hall (Pl. 1, fig. 7)

Distinguishing characters are the broad, low, sub-patellate corallum, reflexed calicular margins, and deep calice. The corallum expands very rapidly from the base but never attains the height of typical *H. halli*. (Figs. 17-20.) In neanic stages it is similar in form to *H. halli* as shown in fig. 2.

TABLE 4

Dimensions and Septal Number in Typical H. arachne

Locality	Horizon	Diameter of Calice	Depth of Calice	Height	Number of Septa
		cm.	cm.	cm.	
Hall's Fig. 10-12............		ca. 6.0	—	ca. 4.0	92
Hall's Fig. 8-9..............		ca. 5.0	—	ca. 3.5	80
Skaneateles Fig. 17..........	Ludlowville	4.5	1.0	1.9	76
Skaneateles Fig. 18..........	Ludlowville	6.0	1.7	3.5	88
Lord's Hill Fig. 19..........	Ludlowville	5.7	1.4	3.5	96

7. **Heliophyllum degener** Hall

The types of this species were from the coral bed on Skaneateles Lake. The characters are the relatively small size and contraction of the corallum near the calice so that the latter is rarely more than half the maximum diameter of the corallum, as indicated by fig. 20. A specimen from Skaneateles Lake with 55 septa, has a maximum diameter of 4.0 cm. and calicular diameter of 2.8. It is simply *H. halli* in which vitality diminished soon after maturity (gerontism), and in which rejuvenescence failed to take place. Typical specimens of this form are uncommon.

8. **H. halli** VAR. **obconicum** Hall

The type specimens were from the coral bed on Skaneateles Lake. The principal distinctive character is the straight, conical growth-form. A specimen from the type locality with 96 septa has a calicular diameter of 4.9 cm. One from Lord's Hill with 92 septa has a calicular diameter of 4.7 cm. The calice is often relatively broader with more reflexed margins than typical *H. halli*. (Fig. 21.)

INTERMEDIATE FORMS

So far only the typical forms of the "species" and "varieties" of *Heliophyllum* occurring in the Hamilton coral beds have been considered. No account has been taken of the existence of forms intermediate between them, but many are known, enough, in the author's mind, to link all of the forms within the limits of one species. The principal intermediate forms are described below.

H. halli, H. confluens, and **H. proliferum**

Specimens of *H. halli* are frequently found with one or more offsets which developed at different times during development. FORMA *praecoquus,* previously noticed, includes such forms where budding took place before the polyp reached its full size. FORMA *proliferum* includes those in which budding occurred during late ephebic stages, and specimens are common which show increase to have taken place at times between these. In none of these was colony-formation successful, although some of the intermediate forms may be early stages of the *H. confluens* type. The abundance of good specimens of *H. confluens* (or of specimens of *H. halli*) in which there is every evidence of successful colony-formation, some of them having 40 or more adult corallites closely fused together, seems to indicate an orthogenetic trend, here recognized as a variety of *H. halli: H. halli confluens* Hall 1876.[4]

H. irregulare

As has been said above, this is *H. halli* in which the corallum was contorted by instability, and can be separated from *H. halli* FORMA *typicum* by no other character save the negative one that the polyp rarely reached the normal size.

H. halli and H. halli reflexum

Figure 22 shows the form of a specimen from Lord's Hill intermediate between these two forms (compare with figs. 7 and 14). The calicular margin is slightly reflexed on one side, not at all on the other. The reflexed margin is the only point of separation between the supposed variety and the typical form, and the importance of this distinction disappears when specimens are found showing both the varietal and typical characters in one. Reflection of the margins of the calice was produced when the peripheral part of the polyp (laying down the epitheca) lagged behind the central part (lumen) in skeletal secretion. Such forms as the one shown in fig. 22 have been seen by the author in recent corals. As well as external factors, very slight physiologic disturbances in the polyp produce marked changes in the rate of deposition of the skeleton.

H. halli and H. halli VAR. obconicum

The variety *obconicum*, as its name implies, has a straight, conical corallum as contrasted with the curved one of typical *H. halli*, but there are numerous specimens showing an intergradation between the two. The author can see no orthogenetic trend here, especially since non-genetic factors appear to control the development of straight or curved coralla.

The morphogenesis of the simple rugose corallum and its supposed relation to the septal arrangement has been the subject of some controversy among several students of the Rugosa. Since the relations of the septa to the corallum are not of interest here, only morphogenesis will be considered.

Bernard (1904) suggested that lateral attachment of the corallum, when it occurred, was secondary, and that the corallum was normally attached by its base (axial fixation). The corallum soon broke off from the substratum and lay on its side, becoming fixed in that position. Later it tended to re-establish its upright position by growing away from the substratum into which it frequently sank farther as it grew larger (fig. 23A). Yakovlev, in a series of papers (1917, 1923,

[4]Dr. Stanley Smith, *in litt.*, notes that the American "'*confluens*' is the *Heliophyllum* common in Europe while *H. halli* is rare, if indeed it occurs at all."

1926, 1932) considers that "The Rugosa typically present a conical corallum, bent on account of lateral fixation", the bending being caused by the tendency of the soft parts to avoid the substratum. Lateral fixation was the result of life in shallow seas, tending to a greater stability, with the convex side turned in the direction of the current (fig. 23B). Weissermel (1897), thinks that the corallum was orientated in the opposite direction so that the disc faced the current and source of food (fig. 23C). Schindewolf (1932) believes that both axial and lateral fixation occurred among the Rugosa, and that the curved corallum in both cases resulted from the orientation of the disc toward the current, agreeing with Weissermel.

The occurrence of both conical and cornute forms of the same species in the same locality would appear to indicate that such forms result, not necessarily from inherent characters of the polyp, but from external conditions in the immediate environment. The author is inclined to think that very few of the larger simple rugose corals remained fixed, either axially or laterally, for any time after approaching maturity, and considers that Bernard's hypothesis more nearly covers the actual circumstances than those advocated by Yakovlev or Weissermel-Schindewolf. On the basis of the latter it seems impossible to reconcile the presence side by side of a tall straight corallum and a long cornute form of the same species such as occurs everywhere in the Hamilton coral beds. Currents may have played some part in determining the orientation of the disc, but it is more likely that the position of the disc was more affected by its position with respect to the surrounding individuals or colonies and was normally directed vertically.[5]

Some of the straight forms attained remarkable lengths, one specimen of *Cystiphyllum americanum* E. & H. in the author's collection measuring 36 cm. in length with an average diameter of 4 cm. This patriarchal individual, contrary to the general rule, must have remained firmly fixed throughout its career and

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[5]Direct observations on living corals are productive of conclusions tending to support Bernard's views. There are no living simple horn-shaped forms comparable in size to those of the Paleozoic, and those which do have similar (although smaller) growth-forms are dwellers in deep water. Living simple corals of the littoral zone such as *Caryophyllia*, *Balanophyllia*, and various astrangids, have low squatty coralla with broad base of attachment equal to if not greater than the diameter of the rest of the corallum adapted to an existence in turbulent waters. The caryophyllids, eupsammids, etc., of the neritic and deeper environments do not require such firm fixation and are more turbinate in shape. Some species, such as *Caryophyllia communis* (Seguenza), are often free, either having been attached to some very small loose fragment or having broken off at their point of attachment which is usually less than 2 mm. across, and lying on their sides on the bottom, sinking slightly into it if it be soft enough. The calice of such forms, in common with that of all living simple corals, is directed upwards, its plane horizontal or tending to be so. When the coral topples over the polyp grows upward away from its previous direction, trying to re-align the calice. Continued growth adds more weight to the calicular end, unbalancing the corallum which rolls on its (now) basal side, gradually lifting the small tip away from the substratum. Gravier has noted the same change in growth-form in the case of *Caryophyllia clavus* (Scacchi) of the Mediterranean and eastern Atlantic (*Res. Camp. Sci. Albert Ier, Monaco*, No. 55, p. 8, 1920). Specimens which had remained fixed throughout their lifetime had straight upright coralla; those which had broken loose from their basal support had a horn-shaped form. A specimen of the first species mentioned above, in the author's possession, from a depth of 582 fathoms off the Dry Tortugas (bottom: globigerina-ooze), shows this type of growth-form well. When laid on a level surface in any position it rolls to its point of equilibrium, the calice directed upwards about 25° off the horizontal, the tip inclined upwards at about the same angle from the substratum. During the life of this coral the plane of the calice revolved through 90° as the polyp attempted to regain its normal position, never quite succeeding. Apparently this specimen arrived at its present ceratoid form in much the same manner as the extinct Paleozoic Rugosa.

fallen over either after the death of the polyp or else to cause death, rather than grown upward as rapidly as the corallum sank into the mud, because of its present slightly compressed shape and its horizontal position in the rock when collected.[6]

Specimens of typical *H. halli* with well-preserved basal portions frequently show evidence of overflow of the soft parts toward the substratum while a spoon-shaped epithecal diverticulum (producing a talon in the corallum) developed to add support for the growing corallum and help maintain the approximately horizontal position of the calice. The original attachment in these cases was lateral (fig. 24).

H. halli obconicum and H. halli reflexum

A specimen intermediate between these two forms is outlined in fig. 25, from Lord's Hill. In it are combined the two characters of the *formae* or "varieties",—the reflexed margin of *reflexum* and essentially straight corallum of *obconicum.*

H. halli and H. degener

The "species" *degener* is connected to *halli* by several intermediate forms both directly and through FORMA *obconicum* and FORMA *reflexum.* Fig. 26 shows the form of a specimen from Lord's Hill combining the characters of all three,—reflexed margin of *reflexum,* straight corallum of *obconicum* and gerontic contraction of the corallum near the calice of *degener.* Typical *degener* is simply *reflexum* with the corallum contracted toward the calice. When the corallum grew

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[6]The annulations or growth-rings on this specimen are particularly well-marked and average 0.5 cm. apart for a total of 70 or a few more, becoming closer together near the calice. They afford opportunity for speculation on the age reached by the coral. They reflect externally the position of relatively close-set or more widely-spaced endothecal layers within the corallum, and if they represent seasonal variation of temperature as indicated by Ma (1933, 1934) we might conclude that this specimen was about 70 years old at the time of its demise! But, in accordance with Krempf's suggestion (1934), if we suppose that they represent intervals between periods of sexual activity, which in many invertebrates including modern reef corals roughly approaches a lunar periodicity, then 70 ÷ 13 gives an approximate age of 5½ years, surely a more reasonable figure. Some support to this last estimate is given by the major annulations of the specimen which divide it into 5 nearly equal sections and part of a sixth. The major annulations mark the close of a period of increasing diameter, followed by a short period of decrease, then returning increase, and may represent seasonal variations in water temperature.

Testing this method on a large specimen of *Siphonophrentis halli* (E. & H.) from Skaneateles Lake having a length of 22 cm., the annulations averaged 0.36 cm. apart, giving an estimated age of 4½ years, while the major annulations numbered 5. In the case of *S. halli* the tabulae are spaced an average of 3.6 mm. apart in large specimens and correspond in position to the expanded part of an annulation. The annulations on *H. halli* are more difficult to trace, but one corallum of *H. halli* FORMA *degener* from Skaneateles Lake having a length of 6.4 cm. has about 18 annulations, one major annulation and part of a second. A specimen of *H. halli typicum* from the same locality 5.5 cm. in length has about 17 annulations and 1½ major annulations. A very large specimen of the same form from the Moscow formation in Livingston County, 22.5 cm. in length has more than 122 annulations and 10 major annulations. The ages of these specimens might be estimated at about 1½ years for the first two, and 10 for the last. If these observations were true, the annual growth-rate of the three species examined would be:

Cystiphyllum americanum	6.5	cm./annum
Siphonophrentis halli	5.0	"
Heliophyllum halli	1.9-4.2	"

These figures are not excessive, although somewhat greater than the general average of modern reef-builders.

straight the *obconicum* character was added, and such a specimen might bear the name *H. halli*, FORMA "*degener-reflexum-obconicum*". Since it is clear that the three characters mentioned might have occurred singly or simultaneously or under various combinations, seven different forms of *H. halli* might have resulted, —and all of them have been found.

H. halli and H. arachne

H. arachne is linked directly with *H. halli* by intermediate forms as shown by figs. 27 and 28. Fig. 27 shows the rapidly expanded corallum of *arachne* with the typical calice of *halli*. Fig. 28 shows a similar form with the reflexed margins characteristic of *arachne*. Two extreme results of variation in the *arachne* direction are seen in figs. 29 and 30. The *arachne* form of corallum was produced by the radial growth-rate of the polyp being greater than the vertical. Further, if the growth of the periphery lagged behind that of the lumen (producing the septa and tabulae) the typical *arachne*, with reflexed margins, resulted. If polyp-growth was excessively rapid a patellate corallum resulted (fig. 30 and pl. 1, figs. 10, 11), to which the name *H. halli* FORMA *aplatum* is applied. On the other hand, if the peripheral parts grew faster than those of the lumen, then a growth-form like that of fig. 29, with a very deep axial pit and narrow tabular zone, came about. This form is termed *H. halli* FORMA *infundibulum* (pl. 1, figs. 8, 9).

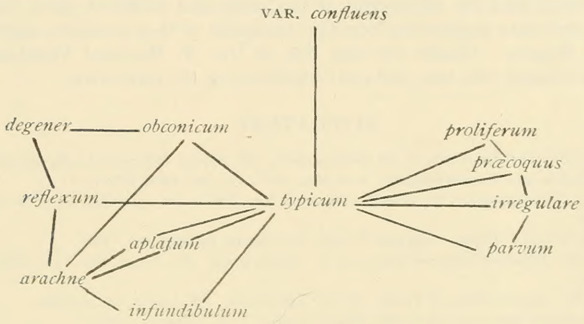
SUMMARY OF FACTORS CAUSING LOCAL VARIATION AND THE FORMAE OF HELIOPHYLLUM HALLI

1. Reproductive precocity .... *H. halli* FORMA *praecoquus*
2. Stability:
    - a. Stable:
        - aa. Straight conical corallum .... *H. halli* FORMA *obconicum*
        - bb. Curved corallum .... *H. halli* FORMA *typicum*
    - b. Unstable .... *H. halli* FORMA *irregulare*
3. Gerontism:
    - a. Senility .... *H. halli* FORMA *degener*
    - b. Gerontic budding .... *H. halli* FORMA *proliferum*
4. Irregular rejuvenescence .... *H. halli* FORMA *pravum*
5. Differential growth-rate:
    - a. Growth-rate of polyp faster than development of corallum:
        - aa. Corallum broadly conical .... *H. halli* FORMA *arachne*
        - bb. Corallum patelliform .... *H. halli* FORMA *aplatum*
    - b. Variation in growth-rate of parts of polyp:
        - aa. Rate of lumen faster than periphery .... *H. halli* FORMA *reflexum*
        - bb. Rate of periphery faster than lumen .... *H. halli* FORMA *infundibulum*

Heliophyllum confluens, considered as a true variety, *H. halli* VAR *confluens*, is not included above.[7]

[7]In the light of the present investigation, it is not out of place, perhaps, to examine some of the "species" Wedekind (1927, 52-57, pls. 9-16) has created for Gothlandian corals of the genus *Ketophyllum* (near *Omphyma*). From the "*Ketophyllum*-beds" at the one locality of Eksta, Djupvik, Gothland, he has described the following species: *K. pseudoannulatum, hedströmi, cylindricum, stanley-smithi, bulbosum, involutum, conicum, elegantulum, richteri, djupviki*. There is little variation of internal structure in these forms, no more than is to be expected when variations in growth-rates alone are considered. Rapidly-growing forms produce more widely spaced tabulae and larger dissepimental vesicles, and vice-versa. On the basis of the figures and descriptions, *K. bulbosum* corresponds to the *degener*-form of *H. halli, djupviki* to the *arachne*-form, *K. richteri* to the *infundibulum*-form, *pseudoannulatum* perhaps to the *reflexum*-form, *involutum* possibly to the *typicum*-form, and *cylindricum, stanley-smithi, elegantulum, conicum*, and *hedströmi* to the *obconicum*-form. In this case, however, it seems likely that the last-named forms probably represent the typical form of the *Ketophyllum* species at this locality.

DIAGRAM TO ILLUSTRATE THE INTERRELATIONS OF THE FORMAE OF HELIOPHYLLUM HALLI



CONCLUSION

While the author does not wish to convey the impression that he concludes from the foregoing study that not more than one species of a rugose coral genus is likely to occur in the same horizon at the same locality, he does conclude that in describing or identifying the coral fauna of one or more closely connected horizons within a limited geographical area, the several factors causing individual continuous variation, expressed as *formae,* should be taken into account, inasmuch as differences of growth-form, even if well-marked, may not necessarily indicate orthogenetic trends.

It may be asked whether the representatives of other genera of Rugosa in the Hamilton coral beds show variation like that of *Heliophyllum halli,* and if not, why not? Some of them do, but none so much as *H. halli,* the rest do not. Among those that show some variation are *Cystiphyllum americanum* and *Siphonophrentis halli.* Not all "species" of a coral fauna are equally plastic or variable in the same region. Vaughan's study of the Hawaiian corals may be instanced in this connection: the reef-coral fauna of that area contains 45 species and 5 varieties, but only 2 species of *Porites* show sufficient variation to be noticed as *formae.*

SUMMARY

Six species and two varieties of the rugose coral *Heliophyllum,* among them the genotype, have been described from the coral beds of the Middle Devonian Ludlowville formation of central New York. On the basis of a large number of specimens showing intermediate stages between these "species" and "varieties", it is concluded that only one species, *H. halli,* with one variety, *H. halli confluens,* is present, the former showing 11 *formae,* the results of continuous individual variation caused by 5 main factors: reproductive precocity, growth-forms, gerontism, rejuvenescence, and differential growth-rate.

ACKNOWLEDGMENTS

The writer is deeply indebted to Drs. Stanley Smith and H. Dighton Thomas, both of whom read the manuscript of this paper and proffered much valuable criticism and many suggestions from the standpoint of their extensive experience with the Rugosa. Thanks are also due to Drs. T. Wayland Vaughan and G. Arthur Cooper, who also read and commented on the manuscript.

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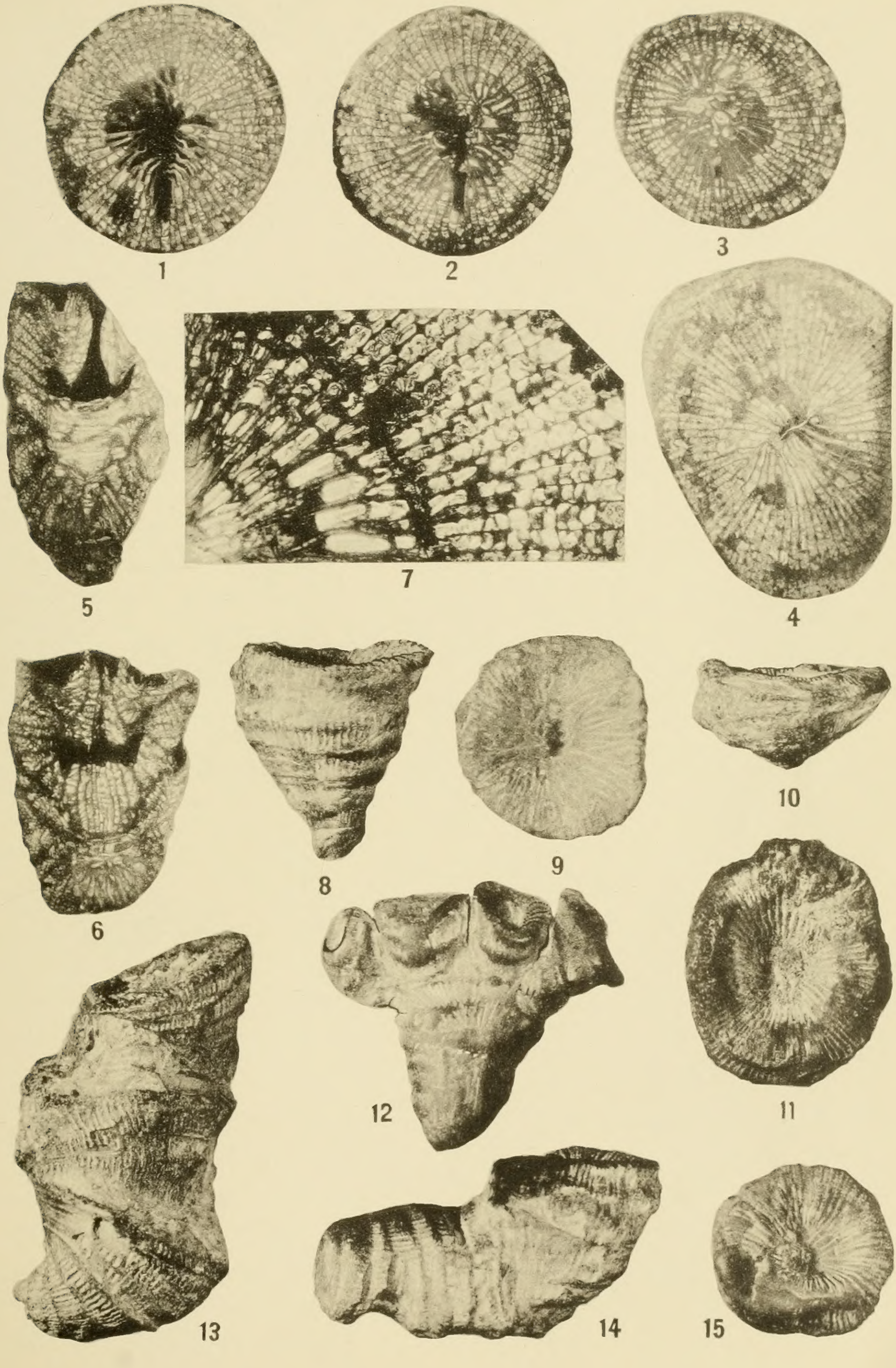
PLATE I

EXPLANATION OF PLATE 1

Individual Variation of HELIOPHYLLUM HALLI *Edw. & Haime*

Figure		Page
1-3.	*Heliophyllum halli* FORMA *typicum* Three serial transverse sections from (1) lower part of calice, (2) bottom of axial pit, (3) just below bottom of axial pit. Stereozone present; x 1½; Coral bed, Skaneateles Lake	9
4.	*H. halli* FORMA *typicum* Transverse section from below axial pit of specimen lacking stereozone; x 1½; Coral bed, Skaneateles Lake	9
5.	*H. halli* FORMA *praecoquus* Wells Median longitudinal section of specimen with two offsets; x 1½; Coral bed, Skaneateles Lake	11
6.	Same specimen as fig. 3, but cut 3 mm. nearer periphery	
7.	*H. halli* FORMA *arachne* Hall Part of transverse section just below axial pit; stereozone present; x 3; Coral bed, Skaneateles Lake	14
8, 9.	*H. halli* FORMA *infundibulum* Wells Holotype; x 1; Coral bed, Skaneateles Lake	18
10, 11.	*H. halli* FORMA *aplatum* Wells Holotype; x 1; Upper coral bed, Lord's Hill, Onondaga County.	18
12.	*H. halli* FORMA *praecoquus* Wells Holotype, an immature individual with four offsets; x 1; Coral bed, Skaneateles Lake	11
13.	*H. halli* FORMA *pravum* Wells Fine example of this type of individual variation; x 1; Ludlowville Formation, York, Livingston County	11
14, 15.	*H. halli* FORMA *pravum* Wells Holotype (basal portion lacking); x 1; Coral bed, Skaneateles Lake	11

All figured and type specimens are deposited in the Paleontological Research Institution, Ithaca, New York.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PALAEONTOGRAPHICA AMERICANA

Vol. 2, No. 7

PALAEONTOGRAPHICA AMERICANA

ILLUSTRATED CONTRIBUTIONS

TO THE

INVERTEBRATE PALEONTOLOGY

OF

AMERICA

VOL. II

NO. 7, TURRID ILLUSTRATIONS

Mainly Claibornian

By

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May 14, 1937

Paleontological Research Institution
Ithaca, New York, U. S. A.

FOREWORD

Forty-four years ago the writer completed a monograph on the Tertiary Mollusca of Texas for the Geological Survey of that State. The plates illustrating the faunas were engraved and a few proof copies struck off; but the finances of the Survey seemed at that time scarcely ample to warrant immediate publication. The Survey was soon discontinued. Some of the new or otherwise interesting material of this monograph was excerpted and published in the Proceedings of the Philadelphia Academy (Nat. Sci.) for 1895*, but the bulk of the material has remained unpublished to this day.

After collecting Tertiary fossils in France and England in 1894 a series of publications was projected by the author in 1895 and the first Number of Bulletins of American Paleontology was published May 25 of that year, on *Claiborne Fossils*. The summer of 1895 was spent collecting along the Midway-Cretaceous border from Tennessee to South Carolina and No. 4 of the Bulletins was published in June, 1896, on *The Midway Stage.*

During the summer of '96 a second expedition covering some higher horizons, but especially the Sabine, then styled the *Lignitic stage* was carried out, and Bulletins No. 9 of volume II and No. 11, vol. II were completed by the summer of 1899.

From this date ten years elapsed before the completion of the first part of the Claibornian fossil fauna appeared. This represented No. 31, volume VI, of the Bulletins and was styled *Pelecypoda of the St. Maurice and Claiborne Stages,* June 30, 1919.

Stratigraphic work in this country and South America occupied much of the author's time from this date nearly to the present and the Gastropoda of the Mid-Eocene did not receive continuous attention until the summer of 1936. Fortunately a former student, friend and colleague has taken the responsibility of studying anew the Texas material, and that in other collections from the Gulf States, and now has a memoir on the Mid-Eocene Gastropoda practically ready for press. This will be the long-delayed volume VII of these Bulletins. That this work might not be too burdensome and still longer drawn out, the author has prepared these notes on the Mid-Eocene turrids. Virtually they will be part of volume VII.

De Gregorio in 1890 and Cossman in 1893, with material sent them by collectors at Claiborne, with some of the literature at hand but without access to type materials, published memoirs on the Claiborne fauna with results that can scarcely be said to have added materially to our knowledge of this well-known fauna.

*G. D. Harris; *New and otherwise interesting Tertiary Mollusca from Texas, op cit.* pp. 45-88, pls. 1-9.

But the greatest draw-back in the study of our Tertiary turrids for the last one-third of a century has been the two papers by Capt. Thos. L. Casey.** Not that this entomological writer had not a keen eye for fine distinctions in organic forms and a remarkable daring in founding new generic designations, but all diagnoses were brought out without accompanying figures, no matter how trivial, obscure or embryonic the "types" might be. Of late these "types" have become the property of the U. S. National Museum, and thanks to the generosity of the officers in charge we have been able to obtain photographs that show something of the character of the Casey material. In a study of the same, during the summer of 1936 the author was not able to find all of Casey's new species; but only a very few were missing. Not all of these species are Mid-Eocene, but it has seemed worth while to publish them here though they may belong even to Oligocene formations. Some of our material from lower and higher horizons are included for comparison with Mid-Eocene species. The work has therefore expanded beyond the bounds primarily contemplated. Yet it is believed everything included will be of value to a true understanding of our early Tertiary turrids.

No attempt is made to pronounce a final judgment on generic or specific nomenclature; but the illustration of our Mid-Eocene and other as yet ill-defined turrid forms has been the chief object for which we have striven. The true meaning of varition, mutation, evolution and migration cannot be grasped until the whole sweep of organisms under discussion from their beginning to the present, from one World's end to the other is assembled in vast museum collections, or more practically still, amply illustrated in our paleontologic literature. Accordingly, the various sub-divisional designations like genera, sub-genera, sections, species, sub-species, formæ &c. based on glimpses of individual workers in limited fields are of temporal value only and will suffer modification, substitution and even deletion as time goes on. For present purposes we are employing such local designations as have been proposed for the various "genera" of turrids discussed knowing full well that with the study of Tertiary and recent faunas throughout the world such terms will be found inappropriate, inadequate.

In discussing the molluscan fauna following that of the Midway, in volumes II and III (Bull. Amer. Pal.) they were referred to the "Lignitic" stage as no suitable geographical term for the same then was available. Soon work in Louisiana rendered it desirable to have such a geographic term and the name Sabine was proposed and used. Subsequently the name Wilcox was proposed for the same series of beds and attained quite general usage. The introduction and general application of this name to a Paleozoic horizon in the mid-continental area render it undesirable for Tertiary nomenclature. We therefore shall continue to use the prior designation, Sabine.

In discussing the mid-Eocene bivalves of the Gulf States (vol. VI, Bull. Amer. Pal.) attention was called to the considerable difference between the famous and

**_Notes on the Conrad Collection of Vicksburg Fossils_, Phila. Acad. Nat. Sci., Proc. 1903, pp. 261-283. —_Notes on the Pleurotomidae with description of some new genera and species_, St. Louis Acad. Sci., Trans., vol. 14, 1904, pp. 123-170.

extensive Claiborne sand (Gosport) fauna and that of the widely distributed faunules below usually designated as "Lower Claiborne", and hence the geographic term, St. Maurice, suggested nearly a decade before, (Science, Apr. 1, '10, p. 502) was used in place of "Lower Claiborne". If, however, this custom is followed and the real "Claiborne sand" is styled Gosport, then the term Claiborne, which we all desire to perpetuate is practically deleted from the literature. Just at present it seems that no serious harm will arise from continuing the general term Lower Claiborne in the sense suggested above till subsequent work along various lines gives a proper foundation for formational or stage nomenclature.

We are under special obligation to Mr. L. R. Cox of the British Museum of Natural History for furnishing us with excellent photographs of *Pleurotoma gemmata* Hinds, the genotype of Weinkauff's *Gemmula;* for, thus far, we have failed to find a specimen of this species in America. For access to the type matereial in the Philadelphia Academy of Natural Science as well as for certain illustrations as will appear in the text he is indebted to Curator H. A. Pilsbry. For facilities in studying and having the Casey collection of turrids of the National Museum photographed he is under great obligation to Curator Paul Bartsch and his staff. Very satisfactory library facilities have been furnished by the Library of Cornell University with its system of exchanges; while the courtesies extended by the Librarian of the United States Geological Survey at Washington have indeed been unique.

PALEONTOLOGICAL RESEARCH INSTITUTION
Ithaca, N. Y.
April 10, 1937

The Pleurolirids

One of the outstanding types of Turrids in the Carribbean area is that usually referred to as "*Pleurotoma albida* Perry" with its close relative *barretti* Guppy. Conrad described a *cochlearis* from the Vicksburg Oligocene beds in 1847, having much the general aspect of some varieties of "*albida*". De Gregorio in 1890 described two species, *supramirifica* and *tizis* referring them to a new sub-genus *Pleuroliria*. Casey in 1904 uses this term in a generic sense and states that *cochlearis* is the type of the genus. This procedure seems scarcely proper since de Gregorio definitely defines *supramirifica* and only refers to *cochlearis* as perhaps being conspecific. Until topotypes of *supramirifica* are found we shall be in the dark relative to just what this species and genus are like since de Gregorio's material is not now available, at least here in America. The figures herewith given (Pl. 1, fig. 5a, b) are from de Gregorio's work and leave considerable doubt as to what the specimens are like. Still the enlargements (5a and 5b) indicate the general type of ornamentation.

Casey (St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 131) divides his Pleurolirias into two groups: 1, embryo multispiral and acute; 2, embryo small, obtuse and paucispiral,—the former including such species as *cochlearis* and *crenulosa;* the latter, *albida* and *barretti*. To the latter group Woodring (Carn. Inst. of Wash., Publ. No. 385, 1928, p. 145) has given the generic designation *Polystira*. (See Pl. 1, fig. 1 for the obtuse apex of *barretti* after Woodring).

De Gregorio states neither the locality, nor horizon, of his two species but we infer that he thought they came from Claiborne, Ala.

Casey's species *simplex* and *crenulosa* are from the lower Claibornian beds of St. Maurice, La., his *jacksonella* from the upper Jackson Eocene of Montgomery, La., and his *subsimilis* from the Red Bluff [Oligocene]. Our material as figured on Pl. 1, figures 9-11 is from the St. Maurice or lower Claibornian of the Sabine River section, La.

Pleuroliria De Gregorio, 1890

Monographie de la Faune Eocénique de l'Alabama, 1890, p. 38.

"Testa fusiformis, turrita, sine costis axialibus; costis spiralibus liratis, cariniformibus; striis accretionis linearibus, filosis; labro externo intus costato; rima in angulo peripherico contempta."

"Je réfère a ce groupe pour type la *Pl. supramirifica* De Greg., *tizis* De Greg., décrites ci-après. . etc".

Pleuroliria cochlearis (Con.)

Plate 1, figure 2

Pleurotoma cochlearis Con., Phila. Acad. Nat. Sci., Proc., 1847, p. 284; Jour. *idem.*, 2d Ser. vol. 1, 1848, pl. 11, fig. 23.

A detailed discussion of this species must await a future contribution; but a figure is herewith included as Conrad's seems misleading and Casey holds this to be the genotype of *Pleuroliria*. The specimen is from the Oligocene beds of Vicksburg and is preserved in the Paleontological Research Institution; No. 2358.

Polystira barretti (Guppy)
Plate 1, figure 1

Figure from Woodring's Bowden treatise, 1928, Carn. Inst. Publication, No. 385, Pl. 4, fig. 7, here inserted to show the blunt apex of the more recent "*albida*" forms.

Pleuroliria subsimilis Casey
Plate 1, figures 3? and 4

Pleuroliria subsimilis Casey, St. L. Acad. Sci., Tr., vol. 14, 1904, p. 132.

As this species has never before been figured it seems advisable to here insert a figure of the holotype (fig. 4) from Red Bluff Mississippi. (Now regarded as Oligocene, not Eocene as stated by Casey). His original characterization reads:

The strong and rather acutely elevated subsutural carina separated from the coarser pheripheral carina by a relatively much shorter concave space, which is always very much shorter than the interval between the subsutural carina and the peripheral keel of the whorl above; sculpture otherwise nearly similar, the embryo narrower and with more feebly elevated riblets; shell smaller in size and of slightly more slender form. Length of specimen having six body whorls, 8.5 mm; width 2.7 mm. Red Bluff Eocene.

Holotype (Fig. 4).—U. S. Nat. Museum. No. 494,345.

Figure 3, from the Red Bluff, probably of this species is better preserved than the type. Paleontological Research Inst., No. 2359.

Pleuroliria supramirifica De Greg.
"an. var. **cochlearis** Con."
Plate 1, figures 5, a, b

Pleurotoma (*Pleuroliria*) *supramirifica* De Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 38. pl. 2, figs. 46-48.

Testa elegantissima fusiformis; spira conica, vix subpupoides; anfractibus bicarinatis; carinis funiculiformibus, crassis, notatis; filis linearibus spiralibus interpositis; signis accretionis filosis, erectis, linearibus, elegantissimis, angulatis, juxta carinam anticam, in ultimo infractu juxta carinam secundam; ultimo anfractu costis spiralibus plurimis ornato; canali antico erecto angustoque L. 14mm., Ang. sp. 34°.

Jolie petite coquille bien caractérisée par les deux carènes qui sont presque égales enter elles, semblables à celles de certain *Turritella* etc.

De Gregorio gives neither locality nor horizon for this species but we must suppose it is from Claiborne and probably the "Claiborne Sand" horizon. It will be observed that he questions the possibility of this species being a form of that described from Vicksburg by Conrad under the name *cochlearis* (Pl. 1, fig. 2).

Pleuroliria tizis De Gregorio
Plate 1, figure 5c

Pleurotoma (*Pleuroliria*) *tizis* De Greg., Mon. Faun. Eoc. de I'Ala., 1890, p. 39, pl. 2, fig. 49.

Testa fusiformis, turrita, angusta; anfractibus tricarinatis, ex carinis media vix majore quam aliis; signis accretionis filosis; rima in carina mediana contempta; labro externo intus plicato; canali antico satis angusto L. 18mm., Ang. sp. 27°.

The tricarination of the spiral whorls of this species would seem to be what the author relied upon in distinguishing this species from the bicarinate *supramirifica*.

Neither locality nor horizon given. Presumably Claiborne.

Pleuroliria simplex Casey
Plate 1, figure 6

Pleuroliria simplex Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 131.

Casey's original description.—Shell rather slender, each of the spire whorls with a moderate subsutured carina, the surface immediately below it being concave and rather rapidly expanding to a stronger peripheral carina perfectly smooth and uniform, and situated at some distance above the middle, the surface thence cylindric or very feebly descending to the suture below and having two slightly smaller and somewhat approximate carinæ at the middle, the lower margin also carinulate. The two carinæ below the periphery become more widely separated on the larger whorls, subequally trisecting the space between it and the lower margin, and, on the body whorl, continue thus unaltered to the base of the shell. The concave surface above the periphery has a fine spiral thread above the middle. Embryo moderately stout, conical, closely coiled, rather higher than wide with five whorls, the four upper smooth, broadly, evenly convex and polished, the lowermost with longitudinal riblets; beak moderately long, the aperture proportioned nearly as in *cochlearis*. Length of specimen having 5 body whorls, 9mm.; width, 2.7mm. Lower Claiborne Eocene of St. Maurice, La.

The relationship of this to *crenulosa* is perhaps closer than Casey suspected, for there seem to be traces of crenulæ on the uppermost whorls of this form. The specimens referred to *crenulosa* are certainly immature. The middle rib on the body whorl seems to be an intercalation upon larger whorls. A suggestion of the same is seen in fig. 11 and even fig. 10.

Figured holotype.—St. Maurice, La. Lower Mid-Eocene. U. S. Nat. Mus. No. 494,342.

Pleuroliria jacksonella Casey

Plate 1, figure 7

Pleuroliria jacksonella Casey; St. Louis Acad. Sci., Tr., 1904, p. 131.

Casey's description.—Embryo four whorls, evenly conical, short, fully as wide as high, the upper three whorls smooth, polished and broadly convex the lowermost bearing acute rather widely spaced longitudinal riblets. Shell rather short and stout with slender beak the spire whorls very short each with two strong thick and equal carinæ, one just below the suture, the other near basal third; between the latter and the basal margin there is a fine spiral thread first appearing on about the third whorl; lines of growth only moderately distinct and somewhat irregular. Length of specimen having three body whorls, 4.5mm.; width 1.7mm. Jacksonian Eocene of Montgomery, Louisiana.

The great development of the sub-sutural collar is what strikes one as most characteristic of this seemingly immature specimen.

Holotype.—U. S. Nat. Mus., No. 494,344.

Pleuroliria crenulosa Casey

Plate 1, figures 8, 8a

Pleuroliria crenulosa Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 131.

Casey's original description.—Shell nearly as in the preceding [*simplex*] but with the embryo shorter and stouter, fully as wide as high and not evenly conical but becoming substyliform toward the very acute tip, of five whorls, the lowermost covered with riblets. Spire whorls shorter; carinæ below the periphery more equal and close-set, the peripheral carina finely, obtusely crenulate. Length of specimen of 2 whorls, 3.4mm.; width, 1.2mm. Lower Claiborne Eocene of St. Maurice.

Cotypes figured.—U. S. Nat. Mus., No. 494,343.

Figures 9 and 10 are of specimens in the Paleontological Research Institution (No. 2360) from the vicinity of Columbus, west Louisiana showing the more mature conditions of the species and the probable relationship to *simplex*.

Pleuroliria crenulosa var. crescens, n. var.

Plate 1, figure 11

As remarked above, here is a specimen showing the trace of a third carinule being intercalated between two stronger ones and it is very doubtful whether too much stress should be placed on the tri-carinate feature of *simplex* as compared with the bi-carinate feature of *crenulosa*. Note how in figure 10 of general *crenulosa* aspect there is the beginning on the body whorl of an intercalated carinule. The anterior canal of figure 11 has been broken away, thus giving a misleading idea of the general form of the shell, which must have been quite "*albida*"-like.

Holotype and specimen figured.—Figure 11; vicinity of Columbus, La.; Lower Claibornian. Paleontological Research Institution. No. 2361.

THE DENTICULIDS

In the Tertiaries, especially in the older stages, there are numerous Turrids bearing the slit or retral sinus in the central or carinate portion of the whorl, as in the Pleurolirids, but having less accentuated spiral liræ, with the carinal one showing generally very brief costæ incised medially hence giving the appearance of a twinned row of nodules or crenulæ. Basterot early (1825) described and figured from the region of Dax a form under the name of *Pl. denticula.* This was used by Lyell in the earlier editions of his *Principles* as a characteristic species of that terrane. Edwards in 1849 describes six varieties of this species in his *Eocene Mollusca of England* ranging from London Clay to Bartonian. Heilprin and others have referred American forms to this species. But with the narrower limits now assigned to "species", such references will doubtless be considered incorrect. In 1876 Weinkauff assigned the living *Pl. gemmata,* among others, to his new division, *Gemmula,* and it would appear that a large number of denticuloid forms may likewise be here included. Cossmann in the revision (1896) of his genus *Hemipleurotoma* (1889) clearly attempts to delimit this great denticuloid stock, using as his "Neotype", *Pl. denticula* Bast. De Gregorio in 1890 felt the need of some special name for this branch of the Turrids and instituted a subgeneric designation *Coronia,* using Conrad's *Pl. acutirostra* as a typical form; but unfortunately adding many unrelated species to his representative list.

The type specimen of *Pleurotoma gemmata* Hinds is herewith figured (Pl. 1, fig. 33, a) through the kindness of Dr. L. R. Cox of the British Museum of Natural History. This species is the genotype of Weinkauff's *Gemmula,* 1876. The whorls are decidedly carinate centrally as in *Pl. archimedis* Bell., used by Cossmann as genotype for his *Hemipleurotoma* ('89). Transitions from this to the Eopleurotomoid forms are brought about by lengthening the riblets, moving the retral sinus somewhat upward or backward and increasing the strength of the crenulation of the subsutural collar. The *Pl. desnoyersi* Lea is a good transitional form.

Gemmula lerchi (Vaughan)

Plate 1, figures 12, 13

Pleurotoma lerchi Vaughan, U. S. Geol. Surv., Bull. 142, 1896, p. 32, pl. 2, fig. 1.
Microdrillia lerchi Casey, Phila. Acad. Nat. Sci., Proc. 1903, p. 277.

Vaughan's original description reads.—Form and size as indicated by the figure. Whorls, 9; 1 and 2 smooth, 3 and 4 costate; remaining whorls devoid of costæ or longitudinal folds. Suture in a depression bordered above and below by a prominent elevated revolving line. The whorls of the spire are concave; the concavity is bordered above and below by a strong revolving line; the upper of these lines is just below the suture, while the lower is just above it. In the medial portion of this depressed region is a beaded revolving line, and sometimes several faint plain revolving lines. The beaded line corresponds in position to the retral sinus. On the body whorl the lower of the above-described prominent revolving lines forms a slight carina. Immediately below this carina is a space, in which is a very fine line, bordered below by a rather prominent line. The position of the suture corresponds to this prominent line. Anterior to this line are fine but distinct revolving striæ, usually alternating in size. Lines of growth indistinct.

Localities.—Hammetts Branch, near Mt. Lebanon (type Vaughan) St. Maurice (Vaughan).

Type.—U. S. National Museum.

Specimens figured.—Fig. 12, Claiborne, Ala.; fig. 13, near Columbus, La. Upper and Lower Claibornian Eocene. Paleontological Research Institution. Nos. 2362-2363.

Gemmula sublerchi, n. sp.

Plate 1, figure 14

Specific characterization.—Size and general appearance as indicated by the figure; whorls about 10; 1, 2, small, smooth rapidly increasing in size; 3, 4, and sometimes 5 obliquely costate from suture to suture; remaining whorls showing a central series of dots or costules, as in *lerchi* but much larger; whorls with the sub- and supersutural collars well marked; lines on space above nodules distinct; alternating large and strong spirals on body whorl and beak; nodules on last whorls sometimes becoming obsolete.

Holotype figured.—Smithville, Tex., Lower Claiborne Eocene. Paleontological Research Institution, No. 2364.

Gemmula childreni (Lea)

Plate 1, figures 15-18

Pleurotoma childreni Lea, Cont. to Geol., 1833, p. 137, pl. 4, fig. 132.
Pl. acutirostra Con., Fos. Sh. Tert. Form., 2d ed, 1835, p. 52, pl. 17, fig. 21.
Surcula childreni Con., Am. Jr. Conch., vol. 1, 1865, p. 18.
Pl. (*Coronia*) *childreni* de Greg., Mon. Faun. Eoc. l'Ala., 1890, p. 25, pl. 1, figs. 73-76.
Pl. childreni Har., Bull. Amer. Pal., vol. 1, p. 10.
Pl. acutirostra Cossm., Notes Compl. &c. 1895, p. 44.
Gemmula childreni Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 135.

Lea's original description.—Shell fusiform, turreted, transversely striate, granulate on the larger part of the whorl; substance of the shell rather thick; spire elevated, obtuse at apex; whorls about nine, subcanaliculate above; mouth long and narrow, one third the length of the shell.

Length .9, breadth .3 of an inch.

Observation.—This is a beautiful species, distinct by its granulations, the row of which is disposed to be double. About the middle of the whorl the striæ are large. On the superior part there are two or three minute ones.

Of the three specimens in the Academy's collection, to which I gave the numbers 5714-16, none seems to be the type. The specimen figured by Meyer for Aldrich, in the Academy's collection and labelled "type" is but 7/16 of an inch in length and hence cannot be the real type. Meyer remarks: "This species from Claiborne occurs in the collection of the Academy labelled *"Turris" Surcula nodocarinata* Gabb, Claiborne. The handwriting of it is by Gabb, with the exception of the word *Surcula* which is written by Conrad." No. 5717 of the Academy's Catalog may be taken as the lectotype for this species. The typical forms as here illustrated are from the Gosport sand at Claiborne (Upper Mid-Eocene) Ala. I have never seen a specimen at all approaching .9 in. in length.

Childreni seems to be characterized by somewhat larger or less concentrated carinal nodules than one finds on most closely related forms. The spiral lines seem to draw over and somewhat obscure the costal ornamentation.

The medial row of nodules often has a twinned or duplex appearance and gives to the whorl a slight medial carination. In a varietal form that may be called *novoppidi* the twinning is less noticeable, the carination stronger and the subsutural collar more pronounced. In both typical and varietal forms apical whorls 1 and 2 are smooth and rapidly expanding, but 3 and 4 are more nearly alike.

Specimens figured.—Paleontological Research Institution, Nos. 2365, 2366.

Var. **novoppidi**, n. var.

Plate 1, figures 19 and 20

The specimens from Newton, Miss., are decidedly fusiform, show a clear-cut sub-sutural collar, a wide range of medial crenulations, and a more sharply defined or projecting median carination.

Figure 20 may be regarded as the holotype; it is decidedly coarsely crenulate.

Paleontological Research Institution. Nos. 2368, 2369.

"Pleurotoma denticula" (Bast.) Heilprin

Plate 1, figure 21

We give herewith an enlarged illustration of the specimen in the American Museum of Natural History styled by Heilprin (U. S. Tert. Geog., 1884, p. 94) *Pleurotoma denticula* Bast. The specimen is clearly very imperfect, but the very detailed illustration furnished by the Museum shows that it is but a slight variation form of *childreni*. Heilprin has also referred specimens of *nodocarinata* Gabb to *denticula*.

Var. **acutirostra** Conrad

Plate 1, figure 22

Pleurotoma acutirostra Con., Foss. Sh. Tert. Form., 2d ed., 1835, p. 52, pl. 17, fig. 21.

The beak in this form seems somewhat longer proportionally than in typical *childreni* and the strong lines are stronger and the weak ones weaker than in the type species. The costæ are not quite so numerous, reminding one of the Lower Claiborne *novoppidi*. The whorls are convex as in *childreni* and not flat as in *sublerchi*.

The specimen figured seems to be of this general aspect and is from the Gosport sand at Claiborne, Ala.

Paleontological Research Institution. No. 2370.

Var. **montgomeryensis**, n. var.

Plate 1, figure 25

Here is a *childreni* type with very fine spiral lines and costal crenulations. It is rather more sharply carinate at the middle of the whorls and does not show that marked increase in size of the body whorl that the typical species does.

Specimen (holotype) figured is from Danville Landing on the Ouachita River. Jackson Eocene.

Paleontological Research Institution. No. 2371.

Gemmula conjuncta Casey

Plate 1, figures 23, 24 and 24a

Gemmula conjuncta Csy., St. Louis Acad. Sci., Trans., 1904, vol. 14, p. 135.

Casey's original description.—Embryo forming a regular sharply pointed cone, much higher than wide, the upper three of four whorls smooth, the lower two with riblets, those of the basal whorls coarser, those of the one immediately above it very feeble; space between the peripheral carinæ and the subsutural usually with a single spiral thread. Length of a specimen having four body whorls, 9.5mm.; width, 3.2mm.

Jacksonian Eocene of the Red River Kimbrel bed.

Holotype.—U. S. Nat. Mus. No. 494, 349, small, poorly preserved specimen.

Specimens represented by figs. 24 and 24a may be conspecific with *conjuncta* but they seem to have considerably coarser markings and have considerable resemblance to *amica* Csy of Red Bluff Oligocene horizon.

Specimens Figs. 24 and 24a are from the Jackson Eocene, Danville, La.

Paleontological Research Institution, No. 2372.

Gemmula amica Casey

Plate 1, figures 26, 27, and 28

Gemmula amica Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 134.

Casey's description.—Form stout, the apex of the beak distinctly reflected; subsutural concavity with only about two fine revolving threads which are situated at the middle of the concavity; embryo rather large and well developed, higher than wide, with two or three very small, smooth whorls at the summit, followed by three larger whorls which are conspicuously costulose, the riblets of the lower whorls coarser and generally more widely spaced than the others. Red Bluff Oligocene.

Holotype.—U. S. Nat. Mus., No. 494,346. See fig. 26.

Figure 27 shows usual appearance, from Red Bluff, Miss. Oligocene. Figure 28, from our collections at Red Bluff shows somewhat more clearly the details of the ornamentation. Paleont. Resh. Inst. No's 2373 and 2374.

Gemmula nucleata Casey

Plate 1, figure 29, a

Gemmula nucleata Csy., St. Louis Acad. Sci., Trans., 1904, vol. 14, p. 135.

Casey's description.—Embryo forming a regular sharply pointed cone, much higher than wide, the upper three whorls smooth, very small and together higher than wide, the three lower having a beautifully regular system of strong closeset equal ribbing, occupying the entire embryo except the very small smooth 3-coiled tip; feebly concave surface above the periphery generally having close-set spiral threads. Length of a specimen having 4 body whorls, 8.9mm., width, 2.8mm.

Lower Claiborne Eocene of St. Maurice, La.; and also of Lee Co., Tex. (Aldrich).

Probably it was the high nuclear whorls that suggested the specific name. We have seen only the small, rather indistinct holotype and so do not feel sure as to the appearance of a well-developed specimen.

Holotype.—U. S. National Museum No. 494,350.

Gemmula ancilla (Casey)

Plate 1, figures 30 and 31

Gemmula ancilla Casey, St. Louis Acad. Sci., Tr. vol. 14, 1904, p. 137.

Casey's description.—Costules not extending across the rather more deeply concave surface above the somewhat narrower and more strongly elevated peripheral band, the subsutural carina finer and almost even, not at all beaded, the concave surface with three or four close-set and distinctly defined spiral lines; body whorl below the periphery with coarse and widely spaced lyræ; shell similar in form to *tenella* but a little smaller. Red Bluff Eocene [Oligocene].

This *denticula*-like form varies from *childreni* by the greater difference in strength of spiral ornamentation, by a stronger carination of the whorls and by a more pointed apex.

Holotype.—Figure 30, 14mm., Red Bluff, Oligocene. U. S. Nat. Mus. No. 494,354.

Figure 31 shows characters somewhat more clearly. Paleont. Res. Inst., from the same locality. No. 2375.

Gemmula nodulina Casey

Plate 1, figure 32

Gemmula nodulina Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 137.

Casey's description.—Costules abruptly confined to the peripheral band as in *ancilla*, the subsutural collar very large, obtusely elevated and coarsely beaded, separated from the peripheral costulose band by a deep abrupt concavity about equal in width to the raised band and bearing a fine and almost even median thread; space below the band with about two close-set and rather fine spirals which are more or less nodulose; shell differing from the two preceding in its smaller size, shorter and much stouter form and thicker substance, the embryo small and more rapidly pointed. Length of a specimen of five body whorls, 9.5mm; width, 3.6mm. Jackson Eocene of Moody's Branch, Miss.

Holotype.—Pl. 1, fig. 32, 9.5mm. Jackson Eoc. U. S. Nat. Mus. No. 494,355.

Var. **bunkerensis**, n. var.

Plate 2, figures 1 and 2

This variety shows very strong sculpturing especially as to double beaded carina and subsutural collar.

Holotype.—Figure 1 may be regarded as the holotype; both specimens are from Bunker Hill landing on the Ouachita River and are of Jacksonian Eocene age.

Paleontological Research Institution, No. 2376.

Gemmula tenella (Con.)

Plate 2, figure 3

Pleurotoma tenella Con., Acad. Nat. Sci. Proc. 1847, p. 284. Jour. 1848, vol. 1, pl. 11, fig. 22.

Specimen from Vicksburg here inserted for comparison with the foregoing forms.

Specimen from the Paleon. Res. Inst. collections. No. 2377.

Gemmula carodenta, n. sp.

Plate 2, figures, 4, 5

Specific characterization.—Shell of the denticuloid type as indicated by the figures; 2 to 3 fairly smooth embryonic whorls followed by two finely and vertically ribbed whorls; carinal denticules small and somewhat unevenly spaced, occupying the central portion of each whorl; above the carina the whorls slope rapidly inward to the suture above; below, they are nearly vertical to the suture below; two strong spiral liræ show below the carina on the body and larger spiral whorls, are submerged by the subsutural collar in the smaller whorls; beak somewhat deflected anteriorly; columellar callosity thin.

Holotype.—Orangeburg, S. C., 13mm. Paleont. Res. Inst.. No. 2378.

Gemmula coraliger, n. sp.

Plate 2, figure 6

Specific characterization.—Shell small and terebraform as figured; whorls about eight; apex rather pointed and showing two smooth whorls; remaining whorls, showing a moderately defined subsutural elevation, are marked by fine and distinct spirals and longitudinal ribbing; ribs above seem to pass nearly from suture to suture as seen by a strong light from the left; but below, limited largely to a duplex central band.

The comparatively fine, even sculputre of the body and the brevity of the aperture serve at once to distinguish this species.

Holotype.—Vicinity of Columbus, La. Lower Mid-Eocene. Paleontological Research Institution. No. 2379.

Gemmula weisbordi, n. sp.
Plate 2, figures 7, 8

Specific characterization.—Shell of moderate size and mesalia-form as illustrated: whorls about ten, the upper two smooth and the third with vertical ribbing; remaining whorls with inconspicuous subsutural collar becoming fainter below; duplicate beaded carinal band located just below the center of each whorl; crenular costation continued above and below the carinal region but disappearing above and below before the sutures are reached; spiral striæ clearly defined but faint above and below the carinal band.

When more and better material of *conjuncta* has been gathered this may turn out to be a variety of that species, though it lacks the strong subsutural collar of that species, has many more spiral striæ, fewer costæ on each whorl and is a more slender form.

Holotype.—Fig. 7, Montgomery, La. Jackson Eocene. Paleontological Research Institution. No. 2380.

Gemmula lancea Casey
Plate 2, figures 9 and 10

Gemmula lancea Csy. St. Louis Acad. Sci., vol. 14, 1904, p. 136.

Casey's original description.—Spire elongate, gradually and evenly acuminate, about twice as long as the aperture and canal combined; beak gradually acuminate and straight from the abrupt contraction below the convexity of the body whorl; embryo of the Gemmula type, well developed, of two or three small smooth whorls followed by about three covered with arcuate riblets; spire whorls each with a strong subtumid subsutural collar which is fully as large and prominent as the obtusely crenulate and obscurely double, generally narrow and feebly elevated peripheral carina, the latter distinctly below the middle; space below this carina with a single spiral carinule; space above it to the subsutural collar, broadly, evenly and rather feebly concave, with numerous very fine spiral threads; peripheral crenulation of the body whorl apparently rather less distinct; they become constantly longer in a spiral sense from one whorl to the next below. Length of a specimen having 6 body whorls, 14mm.; width 3.9mm. Lower Claiborne Eocene of Lisbon, Ala.

The finer characters of the holotype are but obscurely shown. The nearly basal position of the carina bearing faint suggestions of carrying the retral sinus place this form among the denticuloids rather than the *drillia*-like species. By consulting plate 1 figures 21 and 22, vol. 3 of these Bulletins it will be seen that turrids of this general form were in our southern Tertiaries in early Sabine times.

Holotype.—Pl. 2, fig. 9. Lisbon, Ala. Lower Claibornian. U. S. Nat. Mus. No. 494,352.

Figure 10, likewise from Lisbon, is probably of this species and shows more clearly the specific characteristics. Paleontological Research Institution, No. 2381.

Gemmula genitiva Casey
Plate 2, figures 11-13

Gemmula genitiva Csy., St. Louis Acad. Sci., Tr. 1904, vol. 14, p. 135.

Casey's original description.—Peripheral double carina distinctly below the middle of the whorls, broader, the denticulation coarser and more close-set; form not quite so slender though about equal in length to *rotædens*; aperture and canal combined more than a third of the total length. Length of specimen having 6 body whorls, 11.5mm.; width, 3.4mm. Lower Claiborne Eocene of Lee Co., Texas.

This is a slender form with regular and clearly defined carinal crenules. The carina seems about central in the holotype, but the spire is more rapidly tapering than in our Moseley's Ferry specimens.

Holotype.—Fig. 11, 11.5mm. U. S. Nat. Mus. No. 494,349.

Figures 12 and 11 are from Moseley's Ferry, the former 6.5, the latter 11mm. in length. Paleontological Research Institution, Nos. 2382, 2383.

Gemmula margaritosa Csy

Plate 2, figures 14-18

Gemmula margaritosa Csy., St. Louis, Acad. Sci., vol. 14, 1904, p. 135.

Casey's original description.—Whorls with two rather widely separated carinæ below the suture; embryo relatively small in size, somewhat higher than wide, with about three small smooth apical whorls, gradually increasing as usual and two whorls covered with coarse and rather widely spaced riblets; peripheral duplex carina not strongly elevated the space between it and the lower and larger of the subsutural carinæ about twice as wide as the peripheral band and having two spiral threads and sometimes three other smaller ones in addition; space below the periphery with several spiral carinules; shell rather large, the beak straight but somewhat feebly, obliquely swollen toward tip; length of the aperture and canal together nearly two-fifths the length of the shell. Length of a specimen having 9 body whorls, 27mm.; width, 7.3mm. Lower Claiborne Eocene of Smithville, Texas.

Representatives of this species are widely distributed in Texas and western Louisiana, and were early described and figured by us for a Texas Survey report which was never published. In 1904 Casey gave a name and description (without figure) of what appears to be this form as indicated by the above description. It has not the long fusus form of *alternata* nor the tendency to obliterate the carinal costation as in that species. Yet more or less transitional forms do occur. At Smithville one finds such forms as are here registered under *alternata* showing considerable similarities with *margaritosa*. In one form or other it occurs from Lisbon, Ala., to Smithville, Texas.

Holotype.—Fig. 14, U. S. Nat. Mus. No. 494,348, Smithville, Texas.

Figure 15. from Smithville, Tex., No. 2384.
16. from Hickory, Miss., No. 2385.
17. from Smithville, Tex., No. 2386.
18. from Hickory, Miss., No. 2387.

Paleontological Research Institution.

Gemmula alternata Conrad

Plate 2, figures 19-23

Pleurotoma alternata Con., Foss. Sh. Tert. Form. No. 4, 1833, p. 46; 2d ed., 1845, p. 50, pl. 17, fig. 13.
Surcula (Pleurot.) alternata Con., Amer. Jr. Conch., Vol. 1, 1865, p. 18.
Pleurotoma (Surcula) alternata de Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 31, pl. 2, fig. 23.
Surcula alternata Cossm., Notes Compl. &c 1893, p. 43.
Gemmula alternata Casey, St. Louis Acad. Sci., Trans., Vol. 14, 1904, p. 136.

Conrad's description, p. 46, *op. cit.*—Subulate or subfusiform; cancellated; spiral striæ distinct; middle of each whorl crenulated; beak somewhat produced.

Conrad's description, p. 50, *op. cit.*—Fusiform with revolving close unequal wrinkled lines; whorls angular, carinated in the middle; carina on the superior whorls crenulated; beak produced.

Syn. P. lesueuri Lea. Con. p. 137, pl. 4, f. 133.

Locality.—Claiborne, Ala. No. 5 first edition, p. 46.

This is a somewhat rare species at Claiborne. Lea, de Gregorio and Cossmann evidently never saw a specimen of the same. It may be further characterized thus:

Apex pointed, of about two smooth, and two plicated whorls; early adult whorls with well defined central peripheral carina with rather fine crenulations; on later whorls the crenulation tends to become effaced; the subsutural collar is typically very broad, with lower edge prominent and with surface finely striate. On some varieties the crenulation becomes very fine and basally located.

Holotype.—By monotypy, Phila. Acad. Nat. Sciences.

Figure 19, (No. 2388) from Claiborne, Ala.; figs. 20 (No. 2389) and 22, Newton, Miss.; fig. 21 Smithville, Tex. (No. 2390); 23, roadside west of Decatur, Miss. Paleontological Research Institution.

Gemmula ludoviciana Vn

Plate 2, figs. 24, 25, 26
Plate 3, figure 1

Pleurotoma ludoviciana Vn., U. S. Geol. Surv. Bull., 142, 1896, p. 33, pl. 2, fig. 3.
Gemmula ludoviciana Casey, St. Louis Acad. Sci., Tr., 1904, vol. 14, p. 137.

Original description.—Size and form indicated by figure. Unfortunately the apex of the specimen is broken off. The figure shows the number of whorls in type. Whorls slightly concave between suture and the shoulder. Suture margined above by a row of nodules, which project outward beyond the suture. Surface marked by minute revolving striæ. Retral sinus situated on the humeral angle, and corresponds in position to the nodules that margin the suture superiorly.

Locality.—Hammetts Branch, near Mount Lebanon (Vaughan).
Geological horizon.—Lower Claiborne.

The most characteristic feature of this species and varieties seems to be the very low position of the carina, and especially the crescent-shape of the short ribs.

Plate 3, figure 1 is a pen-and-ink sketch we made from the holotype in the National Museum some 25 years ago.

Holotype.—Pl. 3, fig. 1, U. S. Nat. Mus., No. 147039.

Figs. 24 (No. 2392), 26 (No. 2394) Smithville; 25 (No. 2393) Hickory, Miss. Paleontological Research Institution.

Gemmula obsolescens Casey

Plate 2, figure 27

Gemmula obsolescens Csy., St. Louis Acad. Nat. Sci. Tr. vol. 14, 1904, p. 136.

Casey's description.—Crenulations coarse, becoming on the sixth body whorl large, low tumescent rounded elevations, with no distinct principal carinæ, the entire surface having rather close-set and equal spiral carinules; on the upper whorls the crenulations are more abruptly formed and are crossed by about three rather coarser lines, but the periphery nowhere has the abruptly elevated form seen in *rotædens* and allies; the periphery is distinctly below the middle of the whorl and not at the middle as it seems to be in *alternata*, and the crenulations are nearly a fourth as long as the whorl, about 18 in number; upper whorls with a distinct subsutural collar which disappears completely on the larger whorls; body whorl below the posterior end of the aperture having rather coarse lines separated by about three smaller close-set threads. Length of a specimen having 6 body whorls about 19 [17]mm.; width, 5mm. Lower Claiborne Eocene of St. Maurice, La.

This species seems to be closely related to some of the *ludoviciana* varieties.

Holotype.—No. 494, 353, U. S. Nat. Mus.

Gemmula ludoviciana var. **normani**, n. var.

Plate 3, figure 3

Specific characterization.—Long-fusiform as figured; costæ short, crescentic; spiral striæ larger in upper part of each whorl recalling somewhat similarly placed striæ in *alternata;* carina not so basally located as in related forms.

Holotype.—Montgomery, La., Jackson Eocene.

Paleontological Research Institution No. 2396.

Gemmula ludocarola, n. sp.

Plate 3, figure 2

Specific characterization.—Small, fusoid as figured; embryonic whorls increasing rapidly in size, giving the apex a more obtuse appearance than in related species; spiral striation even and fine; subsutural collar faintly shown only in earlier whorls; costæ new-moon-shape but far more open and longer longitudinally than in related forms.

Holotype.—Orangeburg, S. C.; L. Claiborne Eocene.

Paleontological Research Institution. No. 2395.

Gemmula parvidens Casey

Plate 3, figure 4

Gemmula parvidens Csy., St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 135.

Casey's description.—Denticulation of the duplex peripheral carina unusually small and widely spaced, the concave surface, between the periphery and subsutural carinule usually with two fine spiral threads; beak nearly straight, very slender, the aperture and canal combined but little less than half the length of the shell. Length of a specimen having 4 body whorls, 7mm.; width 2.7mm.; Lower Claiborne Eocene of St. Maurice, La.

Holotype.—U. S. Nat. Museum, No. 494, 351.

We are unable to identify this immature specimen with any of our material.

Gemmula wateletella, n. sp.

Plate 3, figure 5

Specific characterization.—General form turrited as figured; whorls 10; 1-3 smooth with 3 beginning to be costate; 4 strongly costate from suture to suture; remaining spiral whorls marked by a central carinal series of nodules marking the retral sinus; above and below the carina the spirals are very conspicuously shown, alternating in size; lines of growth especially apparent on the lower part of the body whorl and just below the suture.

This bears a strong resemblance to Deshayes' *wateleti* from Cuise-la-Motte, Sables Inferieurs. It seems to be a diminutive relative of some Woods Bluff forms described and illustrated in Vol. 3 of Bulletins of American Paleontology, (see Plate 3, figs. 18 and 19).

Holotype figured.— Lower Claiborne Eocene, vicinity of Columbus, western Louisiana.

Paleontological Research Institution. No. 2397.

Gemmula ouachitensis, n. sp.

Plate 3, figures 6-9.

Specific characterization.—Shell narrow fusoid as indicated in the illustrations; apex seemingly bluntly pointed by two or three smooth embryonic whorls; spire showing above, longitudinal costæ broader than their inter-spaces and extending from suture to suture, but below confined to the baso-medial part of each whorl; subsutural collar showing in the smaller spiral whorls, but generally disappearing below; sunken band between the knobby ribbing and the suture above with four or five strong spiral lines decreasing in strength downwards; on ultimate and penultimate whorls two spirals are generally seen below the nodular costation; beak slightly flexed.

This resembles *G. ancilla* Casey, but has a much coarser type of carinal costation and a very different type of apex. (Compare figure 31, Plate 1, with figure 6, Plate 3.).

The apical whorls are very different from those of *G. nucleata* Csy. (See Pl. 1, fig. 29a).

It will be observed by the figures herewith given how the appearance of the costation differs with stages of preservation and erosion.

Holotype.—Figure 6, 14mm. (No. 2398); Danville, La., Jackson Eocene.

Figure 7, 8 and 9 (No. 2399) show variations in sculpture mainly as brought about by age and stages of weathering. All are from Danville, La.

Paleontological Research Institution.

THE MELANIDS

Tripia de Gregorio, 1890

De Gregorio (1890) in his monograph on the Eocene of Alabama seems to have had a specimen quite possibly pathologic, that recalled to his mind certain of Bellardi's Clavatulas with strong body-whorl lirations. Under his generic description he cites as examples of *Tripia* the "*Pl. Clavatula laciniata* Bell., *bicarinata* Bell., *complanata* Bell. etc." His generic characterization reads:

Testa fusiformis, laevigata, crassiuscula, acostata, subcarinata; ultimo anfractu tricarinato; rima in carina contempta vel in peripheria anfractuum, non autem juxta suturam.

The first form (presumably from Claiborne, though not so directly stated) he designated *Pleurotoma* (*Tripia*) *anteatripla* De Greg.

Cossmann in 1896 (p. 85) gives *anteatripla* as genotype but regards *Tripia* as synonymous with *Crassispira.*

We have no specimen corresponding to *anteatripla* as described by De Gregorio. A specimen in the National Museum so labeled we sketched in pen and ink some twenty-five years ago, and the same is herewith reproduced. But the body whorl has none of the strange liration (pathologic?) described by De Gregorio. The spire characteristics however seem to agree.

There are at Claiborne very rare specimens of a general *Spirotropis* aspect, but with a gemmuloid sinus that will probably demand new generic designations in the future when more material is available. One is herewith given the specific name *casteri.*

"Pleurotoma (Tripia) anteatripla" De Gregorio

Plate 3, figures 10, 11, 12?

Pleurotoma (*Tripia*) *anteatripla* De Greg., 1890, Mon. Faun. Eoc. de l'Alabam., p. 38, pl. 2, figs. 43-45.

De Gregorio's description reads:

Testa fusiformis! sublaevigata; anfractibus vix angulatis, unicarinatis; carina costiformi laevigata, obsoleta; ultimo infactu tricarinato; signis accretionis linearibus cosparsis; rima angulosa in carina contempta; apertura angusta lanceolata, postice canaliculata; labro interno notata. L. 18mm., Ang. sp. 28°.

Coquille singulière, conoide, fusiforme, allongée; les tours sont très peu convexes, presque aplatis, très légèrement anguleux et subcarenes; la carène consiste en une côte spirale ressemblant à une petite cordonnet; dans le dernier il y en trois au lieu que une seulement. L'échancrure est anguleuse, peu profonde, elle coincide dans le dernier tour avec la carène postérieure. L'overture est étroite; elle forme postérieurement un petit canalicule, le bord columellaire est remarquable.

Cette pleurotome ressemble à certaines espèces que M. Bellardi référa au gen. *Clavatula;* par examp. à la *Pl. circonfusa* [*circumclusa?*] Bell., *bicarinata* Bell., *complanata* Bell., mais j'ai restrient le sens du gen *Clavatula;* ainsi elle doivent etre placés dans le gen. *Pleurotoma* sensu lato, (Coll. mon Cabinet.)

Time only will tell whether any such specimens are to be found at Claiborne. Fig. 12, U. S. Nat. Museum specimen may be of this species.

This specimen has a marked general appearance like *Turris rara* Gabb as illustrated by Pilsbry, (Phila. Acad. Nat. Sci., Proc., 1921, p. 317, pl. 17, fig. 1,) and also like Dall's *Moniliopsis ophioderma* as shown by fig. 5, pl. 12, of volume 56, Proc. U. S. National Museum.

Gemmula (?) casteri, n. sp.

Plate 3, figure 13

Specific characterization.—Shell turreted, as figured; whorls with noticeably curved sides, covered throughout with strong spiral striæ, the two medial of which bear fine but well marked costæ; above and below these two spirals the longitudinal marking or lines of growth bend sharply to the right and blend in the medial row of costation; embryonic whorls unknown, the type (only) specimen being broken at the apex.

The ornamentation of this species is perhaps most nearly like that of Conrad's *alternata*, but the shape of the shell is wholly different.

The shape, and sinus characteristics of the spire of *casteri* remind one of the old Paleozoic genus *Murchisonia*, but the aperture is not of that genus. It may be related to the foregoing form Fig. 12, described under "*Tripia*," but the shape of the whorls is very different.

Holotype.—Gosport sand at Claiborne, Ala.; Lower Claiborne Eocene. Paleontological Research Institution, No. 2400.

THE TEREBRIDS

Cossmann in working over his Clabornian material in 1893 (See Notes Compl. &c., p. 46) found it impossible to locate generically Meyer's *Pl. terebriformis* (described below) and hence was obliged to create a new genus, *Trypanotoma*. Recognizing its remarkable *Terebra* (Lat. auger) shape he evidently used the Greek *Trypanon* (auger) for its primal root. His Latin diagnosis of the genus is as follows:

> Trypanotoma, testa terebriformis, longispirata, brevicaudata, apice globuloso ac mamillato; apertura vix quartam partem longitudinis aequante, angusta; basi ultimi anfractus subito attenuata; canali lato, brevissimo, profunde emarginato; sinu laterali parum incurvato, alte sito.

His general statements regarding this new genus are as follows:

> Cette forme est caractérisée non seulement par la disposition de la spire qui est aussi allongee que dans le genre *Terbra*, mais encore par la faible échancrure de son sinus labial.
>
> L'embryon resemble à celui des *Homtoma*, quoiyu'il soit un peu plus globuleux, l'overture très courte à de l'analogie avec celle de quelques *Drillia* du groupe *Crassispira*, qui ont aussi une ornementation à peu près semblable, mais le sinus est tout à fait defférent, se rapprochant de celui des *Asthenotoma*, qui ont cependant le canal plus long et la base beaucoup moins subitement attenuée.
>
> Le type de ce genre, *T. terebriformis*, est une petite coquille mesurant 8 mill., de longueur sur 3 mill., de diamètre, ornée sur les primiers tours, de petites crénelures à la partie antérieure et de quatre carènes spirales inéquidistantes, les deux du milieu très rapprochées divisent les crénelures et les rendent bifides; sur les derniers tours, les crénelures tendent a s'effacr t se subdivisent en plis obliques peu sineux; la base est ornénee de carènes écartées qui se serrent d'avantage en s'enroulant sur le dos un peu convexe du canal.
>
> Loc. Claiborne, post type (pl. 2, fig. 18) ma coll.; Newton, donné par M. Meyer.

The specimen he illustrates (*op. cit.* pl. 2, fig. 18) was evidently a rather slender form with a fine central crenulation band obvious even on the last whorl. The diagnosis he gives in '96 (Paleoc. Comp., p. 109, pl. 6, figs. 27-28) is based on a somewhat broader specimen from Newton, still showing fine central crenulation.

Casey, in 1904, having before him considerable material furnished by Aldrich, delimits three Mid-Eocene species of this genus: *Terebriformis* Meyer from the Upper Ferruginous sands at Claiborne, a new species *obtusa* from the "Lower Claiborne Eocene of St. Maurice," and a second new species, *longispira* from the "Lower Claiborne Eocene of Moseley's Ferry, Burleson Co., Texas."

So far as our present knowledge goes the *Trypanotoma* stock was not typically represented before Mid-Eocene times. But we have figured our Woods Bluff *"Pleurotoma carlottæ"* Pl. 3, fig. 14a (See also B. A. Pal., vol. 3, pl. 3, fig. 1.) likewise a highly ornate species, fig. 14a, also from Woods Bluff, that seem to be forerunners of this more typical Claiborne development.

Trypanotoma terebriformis (Meyer)
Plate 3, figures 15, 16

Pleurotoma terebriformis Myer, Bull. Geol. Surv. Ala., No. 1, 1886, p. 75, pl. 2, fig. 8.
Trypanotoma terebriformis Cossm., Ann. de Geol., 12me liv., 1893, p. 46, pl. 2, fig. 18.
Pl. nodo-carinata Heilp., Proc. Phila. Acad. Nat. Sci., 1890, p. 394.

Meyer's original description.—Spire high; aperture and canal small, only about a quarter of the entire length; apex blunt, formed by two and a half smooth embryonic whorls; adult whorls seven or eight—they are flat, having a revolving line above and below, and a carina-like, noduliferous double line in the middle; on the older whorls more spirals appear in the interstices; the striæ of growth indicate a flat sinus, situated on the line in the middle; suture distinct.

Localities.—Claiborne, Ala., rare; (No. 2402) Newton, Miss., Wheelock, Texas. The type specimen is from Claiborne.

Specimens figured.—Claiborne, Ala.; Gosport Sand Horizon. Paleontological Research Institution.

Var. **curta** n. var.
Plate 3, figures 17, 18

This represents a shorter, stouter type of the terebriform development, with coarse costation.

Figure 17 from Newton (No. 2403); Fig. 18, from Hickory, Miss. (No. 2404). Lower Claiborne Eocene.

Paleontological Research Institution.

Var. **cooperi** n. var.
Plate 3, figure 19

This carries breadth as well as coarseness of costation to an extreme. The aperture is proportionally very long.

Figured specimen and holotype.—Cooper's test well, Winnfield, La.; Lower Claiborne Eocene. Paleontological Research Institution No. 2405.

Trypanotoma obtusa Casey
Plate 3, figure 20

Trypanotoma obtusa Csy, St. Louis Acad. Sci., Tr. Vol. 14, 1904, p. 142.

Casey's description.—Spiral carinules fine; spire whorls shorter and more transverse, the second carinule below the suture simple and not nodulose; but one raised line between the periphery and the lower margin and another forming the latter; space between the nodulose peripheral carinæ and subsutural carinules much longer, being twice as long as the width of the peripheral band; lines of growth distinct and uneven but feebler than in *tererbriformis.* Length of a specimen of about 7 body whorls, 10mm.; width 3mm. Lower Claiborne Eocene at St. Maurice, La.

Holotype.—Specimen figured, U. S. Nat. Museum No. 494,357.

Trypanotoma melanella, n. sp.
Plate 3, figures 21, 22

Specific characterization.—General form and characters as figured; whorls with clean-cut bi-nodular peripheral band; spiral liræ strong, numerous and wider than interspaces.

Figure 21 shows how this species or marked variety has representatives not far from *terebriformis.*

Holotype.—Figure 22, length 9mm., Claiborne, Ala.; Gosport Sand Horizon. Paleontological Research Institution No. 2406.

Trypanotoma longispira Casey
Plate 3, figures 23, 24, 33?

Trypanotoma longispira Csy, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 142.

Casey's original description.—Form very slender; subsutural carinæ simple, very coarse and nearly contiguous; peripheral carinæ coarse, separated from the subsutural by a concave space which is subequal in length to the width of the peripheral duplex band and having two fine but strongly elevated and very approximate spiral threads; space below the peripheral nodulose band but little longer than the width of the latter and having one coarse carinule and another forming the lower margin; lines of growth strong and uneven on the body whorl below the convexity. Length of a specimen of 9 whorls, 10.6mm.; width, 2.8mm. Lower Claiborne Eocene of Moseley's Ferry, Burleson Co., Texas. . .

This is a long form with square crenules, not noticeably bipartite.

Holotype.—Fig. 23; Moseley's Ferry, Tex.; U. S. Nat. Mus. No. 494,358. Figure 24, Moseley's Ferry, Tex.; Lower Claiborne Eocene. Paleontological Research Institution No. 2407. Figure 33, Sabine River Section, opposite S. 33. Too immature for specific determination.

THE CATAPHRACTIDS

Since Bellardi's generic designation (*Dolichotoma* type *Murex cataphractus* Br. Plioc.) was already used in Entomology, Harris and Burrows in 1891 proposed to substitute *Bathytoma* for this pleurotomoid. Either term seems appropriate since each refers to the depth or extent of the retral sinus. With considerable variation in form, size, exterior ornamentation and oral plication this stock had persisted from Mid-Eocene time to the present. Though Conrad in describing his *Pl. congesta* from Vicksburg in 1847 notes "It approaches the genus *Brachytoma,* Swainson", its true relationship with foreign forms among the Bathytomas was first brought out by de Gregorio in describing and discussing *refervens* which he regarded as a variety of Conrad's *congesta* though we may infer that the variety was from Claiborne. Solander and Edwards have figured and described the Bartonian *turbidus;* Von Koenen (N. Deutsch. U. Olig., 1890, pl. 29) shows several Oligocene forms; Bellardi (Moll. die Ter. Ter. &c, 1877, p. 230, pl. 7, figs. 20, a, b, c, d,) gives elaborate synonymy and fine illustration of Miocene and Pliocene forms of *cataphracta;* Hoernes describes and illustrates forms of the same from the Miocene of the Vienna Basin; Martin and Thiele, 1904, (Deut. Tiefsee-Expd., 1898-99, pl. 1) gives us good illustrations of *"Genota" atractoides* and others from the Indo-Pacific. Dall's *viabrunnea* from south Cuban waters is a modern representative of this stock.

Oral plication shows up well in Bellardi's fig. 20 a, pl. 7, but we have noticed no foreign species with the stout plication of *crassiplicata*. Specimens so characterized may perhaps be referred to as section *Glyptotoma* Casey, but scarcely as a distinct genus.

Bathytoma nonplicata, n. sp.
Plate 3, figs. 25, 25a

Specific characterization.—Form broad-turrited as figured; first embryonic whorl very minute, remaining three rapidly expanding and showing faint vertical ribbing below; subsutural band with pronounced beading, followed below by two to four crenulated fine spirals; peripheral duplex spiral pronounced, showing below one or two beaded spirals; body whorl anterior to the carination showing about fifteen beaded spirals, coarse at first but becoming finer and less beaded on the beak; lip within, with about eight rather fine but sharply defined spirals; columella entirely smooth.

In general this is between the longer varieties of *crassiplicata* and *fisherana* but in all three well preserved specimens we have, there are no traces of columellar folds.

This at once calls to mind the "*Murex turbidus*" Sol. of the upper Eocene of England.

Holotype.—Fig. 25 (No. 2408).

Specimens figured.—Sabine River section, near Columbus, La.; Lower Claiborne Eocene. Paleontological Research Institution.

Bathytoma (Glyptotoma) crassiplicata (Gabb)
Plate 3, figures 27-30

Scobinella crassiplicata Gabb, Phila. Acad. Nat. Sci., Jour., 1860, vol. 4, p. 380, pl. 67, fig. 19.

Glyptotoma crassiplicata Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 141.

Gabb's original description.—Fusiform, robust; spire straight on the sides; mouth about half the length of the shell, canal straight; umbilicus rudimentary; surface marked by revolving ribs, one narrow nodose rib at the top of the whorl, one wider nodose rib sometimes double on the shoulder, and numerous smaller plain ribs crossing the remainder of the whorl and alterating in size; the nodes on the first two ribs, which are somewhat wider than exhibited on the figure, give this shell a strongly cancellated appearance to the naked eye.

Dimensions.—Length .3 in., length of mouth .16 in., width of whorl .13 in.

Gabb neither gives the type locality nor where the type specimen is deposited. Our figured specimens are from Moseley's Ferry, Tex., Lower Claiborne Eocene. Paleontological Research Institution. Nos. 2410, 2411.

Var. **montgomeryensis** n. var.
Plate 3, fig. 26

Broad; more finely marked than the type species. Jackson Eocene, Montgomery, La. Paleontological Research Institution No. 2409.

Bathytoma (Glyptotoma) conradiana (Aldrich)
Plate 4, figs. 1, 1a
Plate 3, figs. 31, 32. Var?

Borsonia (*Scobinella*) *conradiana* Ald., Bull. Amer., Pal., vol. 1, 1895, p. 60, pl. 2, fig. 13.

Glyptotoma conradiana Csy, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 141.

Aldrich's original description.—Shell small, rather solid, spirally ribbed, ribs beaded; whorls seven to eight; aperture narrow; outer lip crenulate within; pillar lip with four strong plates, the last one oblique to the other three.

Locality.—Wheelock, Texas.

This species has the same ornamentation of *Sc. cœlata* Conrad but the plaits on the pillar lip are different. Gabb's type of *S. crassiplicata* is a very young shell and seems to equal *Sc. cœlata* Conrad. . .

Gabb and Aldrich placed the foregoing and this species under *Scobinella* but the position of the retral sinus is against this assignment. Casey coined a new generic name, *Glyptotoma*, for such forms. They are of a general Bathytoma type as exemplified by *turbidus* Sol. of the Barton beds or short, *catafracta* like forms of the Mediterranean Miocene. *Glyptotoma* shows more apertural plication than do the European representatives.

Figure of type (fig. 1) copied from Aldrich.

Figure 1a, specimen in the Casey type collection in the U. S. National Museum labelled *Glyptotoma aldrichiana*, No. 481,607. This is 9mm. in length, and if it is the type specimen from which fig. 1 was drawn the artist must have taken considerable liberties in its depiction.

Figures 31 and 32, from Moseley's Ferry, Tex., may be referred to *conradiana* but seem to grade directly into *crassiplicata*. These specimens are in the Paleontological Research Institution. No. 2412.

Bathytoma (Glyptotoma) parvula (Casey)

Plate 3, fig. 34

Glyptotoma parvula Casey, St. Louis Acad., Sci., Trans., vol. 14, 1904, p. 141.

Casey's original description.—Smaller species, with numerous very close-set spirals of coarse nodules, the subsutural gradually splitting into two finer spirals on the larger whorls, the concave space below the collar short and with fine irregular thread or threads; spirals below the peripheral alternating in size to the aperture, then equal and almost in mutual contact to the base of the shell; nodules in longitudinal lines from one lyra to the next, giving a closely costulate appearance which does not exist in the preceding species; columella with two large rounded and very approximate folds at the middle, the lower one more oblique than the upper; embryo of about four whorls, higher than wide; aperture and canal relatively longer than in *conradiana*. Length of a specimen of 3 body whorls, 3.9mm.; width, 1.75mm.

Type or types.—Casey remarks: "These species are all well represented in the cabinet of Mr. Aldrich".

Specimen figured.—One of the two specimens in the National Museum, presumably a co-type. No. 494,356.

Bathytoma (Glyptotoma) fisherana n. sp.

Plate 4, fig. 2

Specific characterization.—Stout fusiform as figured; apex not pointed, with two smooth whorls increasing rapidly in size, and passing below through a vertically costate 1/3 whorl, then through a whorl of enlarged median crenulations showing traces of a finely crenulate subsutural spiral; of the two regular spiral whorls the carination is about 1/3 way up from lower to upper suture, centrally incised giving a double beaded appearance; one strong spiral below, many above the carina, finely crenulate and showing traces of incremental lines; body whorl below the carina with a dozen coarse spirals, some of which near the carina are distant and show a few fine interspirals; aperture showing on the columella two strong central plicæ and a faint one anteriorly; lip within with about ten subequal spirals; umbilicus evident.

This is clearly congeneric with *crassiplicata* but the dominance of the central carina, the weakness of the subsutural band and the weakness of the incremental lines at once distinguish this from Gabb's species.

Type and specimen figured.—Fisher, La.; Lower Claiborne Eocene. Paleontological Research Institution No. 2414.

Eucheilodon reticulatus Gabb

Plate 4, figures 3, 3a

E. reticulata Gabb, Jour. Phila. Acad. Nat. Sci., vol. 4, 1860, p. 379, pl. 67, fig. 18.

Gabb gives the generic characters of the genus *Eucheilodon* as follows:

Allied to *Pleurotoma;* fusiform or scalariform; spire high; mouth linear, canal straight, not emarginate anteriorly, posterior sinus shallow and situated a little distance from the suture, outer lip thin on the edge and crenate within, inner lip thin and marked by numerous bead-like teeth, seen only in the adult shell; surface marked like *Pleurotoma.*

Observation.—The most prominent character by far is the peculiar arrangement of the inner lip. The markings are not folds encircling the columella as in the well-known genus *Voluta* . . . but a row of minute beads which are found only in the adult individual. I have before me numerous immature specimens which show no trace of these beads or papillæ.

Gabb's original specific characterization.—Subscalariform, whorls eight, apex acuminate, mouth narrow, linear, outer lip thin on the edge, behind thickened and strongly dentate, inner lip beaded or toothed nearly the whole length, canal straight; surface of first four whorls smooth and polished, of the fifth marked by minute longitudinal ribs, the remainder by revolving lines between which, but not extending over them, are numerous impressed longitudinal lines, giving under the glass a cancellated appearance.

Dimensions.—Length .45 in., length of mouth .22 in., width of body whorl .13 in.

Collection of the Academy and Smithsonian Institution and my Collection . (Wheelock and Caldwell Co., Texas.)

Additional localities for this very well characterized form are as follows: Orrell's Crossing Elm Creek, Lee Co., Hurricane Bayou, near Crockett Houston Co.; Alabama Bluff, Trinity River, Houston, Co., Little Brazos River, Texas.

Specimen figured.—Little Brazos River, Texas; Lower Claiborne Eocene. Paleontological Research Institution No. 2415.

Heilprin described a new species from the collections of the U. S. National Museum in 1880 (Proc. U. S. Nat. Mus., vol. 3, p. 150, pl. 4, fig. 4) as *Eucheilodon creno-carinata* No. 8921, giving as locality, Jackson, Miss. In 1897, Aldrich suggested that this might be conspecific with *reticulatus* Gabb. (See Bull. Amer. Pal., vol. 2, p. 171, pl. 5, fig. 1).

Cossmann somehow overlooked Gabb's work and gives Heilprin as the author of *Eucheilodon* (See Ess. Paleon. Comp., liv. 3, 1899, p. 189) and *creno-carinatus* the species on which the genus was founded. He doubtless did not gather from Aldrich's figures, which he copies, the true character of the columellar "plis" for they in fact are not true folds, but a series of crenulations showing only in some adult specimens. He believes the form "should be regarded as near *Rouaultia* but with a large number of folds on the columella, and with crenulations within the labrum". Had he but seen a figure of either of the above-mentioned species showing the apical featured he doubtless would never have suggested this approachment.

As to Aldrich's suggestion regarding the possible equivalency of these species, it is evident that the clearly twinned carinal crenulation; the strong, crenulated subsutural band, and the general shape of the embryonic whorls of *crenulo-carinatus* distinguish it clearly from *reticulatus*. See figures of *crenulo-carinatus* (pl. 4, fig. 3b.) here introduced for comparison.

"**Pleurotoma (Dolichotoma) congesta** Conr. Var. **refervens** De Greg."

Plate 4, figures 4, 5

Pl. (*Dolichotoma*) *congesta* Conr., var. *refervens* De Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 41, pl. 2, figs. 59-61.

De Gregorio's description.—Testa ovata, fusiformis, potius lente crescens; anfractibus angustis, planiusculis, in medio vix excavatis; funiculis filiformibus, spiralibus, densis, subgranulatis, basi autem ultimi anfractus simplicibus; signis accretionis crispis, funiculos scantibus; rima potius profunda in convexitate antica comtempta; primis tribus anfractibus lævigatis quarto infractu oblique plicato (plicis sinistorsis); plicis relinquorem anfractuum tenuibus, granulosis, dextrorsis, crenuliformibus, in ultimis anfractibus evanescentibus, vel fere; suturis lenearibus; obsoletis; apertura angusta, postice angulata canaliculataque; canali antico brevissimo; labro externo intus plicato. L. 25mm.; Ang. sp. 42°.

The author goes on to say how this form has much resemblance to Conrad's *congesta*, its similarity to Solander's *Pl. turbida* etc., but does not directly state that the specimens were from Claiborne although one must assume that he supposed they were from that locality.

Personally we have always suspected that some specimens described in his Fauna Eocénique de l'Alabama may have come from Vicksburg.

Figure 6 is Conrad's *congesta* from Vicksburg, here introduced for comparison. No. 2417.

THE EOPLEUROTOMIDS

It would seem that de Gregorio had very good reason, in discussing the Clairbornian fauna of Alabama in 1890, for setting apart a pleurotomid group under the name of *Strombina*, including such species as *nuperus, gemmata, et al.* He was unfortunate in choosing a name already preoccupied and including species but distantly related to the more typical *nupera* forms, as later ('96) pointed out by Cossmann. The latter's name for the group, *Eopleurotoma*, seems much less objectionable though in America, at least, this group cannot be literally regarded as the dawning of the pleurotomids.

The stock as a whole is quite prolific in the early Tertiaries of the countries bordering the Atlantic basin. It is chiefly characterized by short peripheral costæ or crenulations, whose upper ends are dragged backward marking the lower margin of the retral sinus, and by a more or less evident crenulation of the subsutural collar. Early whorls may sometimes appear gemmulid, later whorls especially in American forms may appear turriculid. There is at first sight a seeming similarity between these forms and *Pseudomelatoma* of the Pacific, but the more Clavus-like ribbing and sinus band of the latter make the general resemblance but accidental. As a rule it would seem that the European representatives have a sharper geniculation in the lines of growth across the sinus band than the American; in other words the latter are more turriculid.

Eopleurotoma Cossmann, 1889

Cossmann founded his genus on *P. multicostata* Des. (1889) but used as "plesiotype", *Pl. curvicosta* Lam. (Ess. Paléoc. Comp., '96, p. 81, pl. 6, figs. 1-2). He refers some "Paleocene" species to this genus, and certainly *Pl. seelandica* v Kœnen as figured (Abh. der Koen. Gesell. d. Wiss., Goettingen, vol. 32, 1885, p. 25, pl. 2, fig. 6) by v. Kœnen from Copenhagen seems to belong here. The group is well displayed in the Lutetian in France and Cossmann even refers to it some Oligocene forms. As a rule, it appears that the foreign representatives are apt to have a narrower sinus and the same is located nearer the suture than in most American representatives. They seem nearer Dall's *Pseudomelatoma* (U. S. Nat. Museum, vol. 54, p. 317).

Cossmann (*op. cit.* p. 80) defines his genus as follows (Translated).—Form turriculate; spire elongated, apex conical; embryo few whorled, with nucleus obtuse or papillose; costules obliquely bent, subnodulose for a third the height of each whorl, interrupted or decreased in the posterior depression, reappearing again near the suture, along which is formed a beaded band; last whorl a little contracted with base regularly decreasing terminating by a short canal, always bent. Aperture narrow and pyriform; lip curved, cut by a shallow slit but little removed from the suture and coinciding with the nodosities which generally accentuate the angles of the flexed ribs; columella bent at mid-height in a forward direction; columellar lip narrow and callous.

Several species are figured on Plate 4, figures 7-22 seem to represent forms more or less transitional between *Gemmula* and *Eopleurotoma* in that there are still traces of duplex peripheral costation and the sinus is not strictly superhumeral.

Eopleurotoma cainei (Har.)
Plate 4, figures 7-9

Pleurotoma cainei Har., Bull. Amer. Pal. vol. 3, 1899, p. 22, pl. 2, fig. 16.

For description of the typical Woods Bluff form (Upper Sabine Horizon fig. 7.) see publication cited above. A variant form, from Claiborne (sand) is represented by figure 8 (No. 2419); still another from Newton, Miss., (St. Maurice horizon) by figure 9 (No. 2420). Paleontological Research Institution.

Eopleurotoma sabinaria, n. sp.
Plate 4, figures 10, a, b

Specific characterization.—Shell small, fusoid as figured; whorls about 8; 1-2 smooth, blunt at apex; remaining whorls with nearly rectilinear sides, covered with rather strong spiral striæ and very minute lines of growth; spiral whorls showing crescent-shaped ribbing from suture to suture, strongest centrally; body whorl without ribbing; subsutural band indistinct, without crenulation.

Holotype.—Figure 10b, this and 10a and 10c from the lower Claiborne Eocene, Sabine River section, Western La. Paleontological Research Institution. No. 2421.

Eopleurotoma ouachitensis n. sp.
Plate 4, figures 11, a

Specific characterization.—Shell small, short terebriform as illustrated; whorls about 9; whorls marked by rather broad crescent-shaped ribs, varying in strength, subsuturally tending to form an indefinite crenulated zone; spirals inconspicuous save on the anterior of body whorl.

This species appears more or less intermediate between *cainei* and *sabinaria.*

Holotype.—Fig. 11, Danville, La. Jackson Eocene. Paleontological Research Institution. No. 2422.

Eopleurotoma plumbella n. sp.
Plate 4, figures 12, 13, 13a

Specific characterization.—General form and size as indicated by illustrations; whorls about 8; 4 apical smooth, expanding rapidly from 2 to 3; 5 with plicæ extending from suture to suture, practically vertically; remaining whorls with a slight constriction below a rather broad subsutural band, while somewhat oblique ribbing extends to the suture below, all crossed by well defined spirals; body whorl constricted anteriorly giving rise to a rather long, well defined anterior canal.

The generic location of this species is in great doubt. There seems perhaps a possible distant relationship with some *desnoyersi* stock, but the *Clavilithes*-like shape and the faintness of the retral sinus as well as the embryonic characters are very distinctive. A fragment from the Orangeburg district of South Carolina shows quite clearly the apical characters and the ribbing of the earlier whorls.

"Pleurotomella veatchi" Har., from the older Eocene of the Sabine Region, of La., and Texas (Geol. Surv. La., 1899, p. 305, pl. 54, fig. 2) though very much shorter is quite probably of this subgenus.

Holotype.—Figure 13, (No. 2424). This and 13a from Lower Claiborne Eocene Sabine River section near Columbus, La. Fig. 12, (No. 2423) from Orangeburg, S. C. Paleontological Research Institution.

Eopleurotoma politica n. sp.
Plate 4, figure 14

Specific characterization.—Shell small, high-spired as illustrated; whorls 9; 1-3 mooth, 4 and 5 faintly costate nearly vertically; remaining whorls with faint traces of costation especially centrally on each whorl; spiral striation pronounced; humeral sunken zone wider than in the members of this genus heretofore described; spire more tapering; retral sinus rather deep, more or less gemmuloid.

Holotype.—Figure 14. Orangeburg, S. C. No. 2425.

Eopleurotoma adolescens n. sp.
Plate 4, figures 15-18

Specific characterization.—Shell small and fusoid as figured; apex blunt, of two smooth rapidly expanding embryonic whorls and one with the usual crescent shape ribbing; upper row of the twinned carinal band generally dominating, while both rows tend to disappear on larger whorls; retral sinus shallow, geniculated at upper row of crenulæ; subsutural collar but faintly crenulate; sub-carinal liræ on body whorl strongly alternating in size.

This differs from *desnoyersi* Lea by its proportionally longer aperture, its more defined uni- or bi-crenulate carina and its broader embryonic whorls.

Holotype.—Figure 17, (No. 2428), Newton, Miss.

Figures 15 (No. 2426), and 16 (No. 2427) show different aspects of specimens from Newton, Miss. Fig. 18 is an enlargement of a specimen from Hickory, Miss. Lower Claiborne Eocene. Paleontological Research Institution.

Eopleurotoma desnoyersi (Lea)

Plate 4, figures 19-22

Pleurotoma desnoyersii Lea, Cont. to Geol., 1833, p. 135, pl. 4, fig. 128.
Pleurotoma lintea Con., Amer. Jr. Conch., 1865, p. 142.
Pl. (*Coronia*) *desnoyersi* de Greg., Mon. Faun. Eoc., de l'Ala., 1890, p. 25, pl. 1, figs. 77, 78.

Lea's original description.—Shell fusiform, turrited, closely and transversely striate, slightly tuberculate on the superior whorls; substance of the shell rather thick; spire elevated, pointed at the apex; whorls eight; mouth two-fifths the length of the shell. Length, .7, breadth 5-20ths of an inch.

Observations.—The outline somewhat like the last described [*beaumonti*] but differing in the striæ and tubercles. In the *desnoyersii* transverse striæ are disposed to alternate, and are cut by almost imperceptible longitudinal striæ.

The specimen we have numbered 5700 in the Academy's Collection, found glued on the *monilifera* card, seems to answer well for the type of *desnoyersi*. On the *desnoyersi* card are various species, some *desnoyersi*.

Conrad's *lintea* mentioned on p. 18 as from Texas and described on p. 142 of the Amer. Journ. Conchology, as from Claiborne? is practically *desnoyersi*, with more pointed apex.

When specimens are lighted from above there is brought out a faint peripheral carination with a binodular tendency. This shades into a curved series of ribs when lighted from one side. There are three smooth embryonic whorls and a fourth with coarser ribs than appear below.

Specimens figured.—Gosport Sand, Claiborne, Ala.

Lectotype.—No. 5700, Phila. Acad. Coll. Paleontological Research Institution Nos. 2430-2431.

Eopleurotoma nupera (Con.)

Plate 4, figures 23-26

Pleurotoma nupera Con., Foss. Sh. Tert. Form. 1833, p. 46.
P. nupera, idem. 2d ed. 1835, p. 51, pl. 17, fig. 16.
P. (*Strombina*) *nupera* de Greg., *pars;* Mon. Faun. Eoc. de l'Ala. p. 26, pl. 1, fig. 83.

Conrad's original description.—(First edition)—Fusiform, with eight angular volutions, crenulated in the middle, and fine spiral wrinkled striæ; body worl slightly ventricose; shoulder with oblique crenulations, beak somewhat produced.

2nd. edition.—Fusiform; whorls angular, obliquely crenulated on the angle, and with fine revolving wrinkled lines; suture margined beneath by an obtuse carina; beak somewhat produced.

Syn. *P. desnoyersi, P. haeninghausii, P. rugosa* Lea, Con. p. 135, 136, pl. 4, figs. 128, 129, 130.

Locality.—Claiborne, Ala.

The larger pleurotomids at Claiborne are relatively rare, and each specimen of such examples as one finds varies considerablly from all others. It is therefore very difficult to give exact limits to so-called species. Certain specimens have been given specific designations mainly by Lea and Conrad but the proper limitations of such designations is a matter of considerable uncertainty. It will be seen at once from the synonymy given by Conrad just quoted that his idea of the limits of the species *nupera* was extremely vague, and the figure he gives of the species in his "Fossil Shells" is seemingly a composite, as we have never seen a spcimen in the

Academy's collection with its individual characteristics. It represents a form with sides of the spire as a whole concave, and with a far larger number of nodular costæ and subsutural crenulæ, in fact a specimen with strong *sayi* affinities.

Most all the larger specimens have a relatively longer aperture and would perhaps be more naturally classed as varieties of *gemmata*.

We have figured besides the lectotype in the Academy's collection, Fig. 26, a few specimens from our collection that most nearly approach its characteristics (Figs. 23-25).

Lectotype.—Fig. 26, 23.5mm., No. 13356, Phila. Acad. Coll. From the Gosport sand, Claiborne, Ala.

Figure 23, 25mm., Gosport sand, Claib. Ala.; fig. 24, 24mm., Gosport sand, Claib.; fig. 25, 19mm., (No. 2433), Lower Claib. Eoc., Newton, Miss. Paleontological Research Institution. Nos. 2432-2433.

Var. **nuppygis** n. var.
Plate 4, figures 27, 28

This form has longer costæ and far coarser and more deeply incised spiral striation than is shown in typical *nupera*, in fact suggesting some *depygis* characteristics.

Holotype.—Figure 27, mm., Gosport sand, Claib. Ala. Paleontological Research Institution. No. 2434.

Eopleurotoma sayi (Lea)
Plate 5, figure 1 (lectotype)

With various forms heretofore named *monilifera*, *gemmata* &c. Plate 4, figures 29-32, Plate 5, figures 1-4 and 7-9.

In the Gosport sand horizon at Claiborne, Ala., there are turrid forms that vary considerably in size, and ornamentation yet seem to intergrade in such a manner as to render separate specific designations wholly artificial. We notice in fairly well preserved specimens that there are generally about two smooth, rather small apical whorls, then one vertically plicated followed below by one somewhat similarly plicated but showing signs of obliquity and a subsutural row of crenulations, while still lower on the larger spiral whorls the costation becomes oblique, limited to the central part of each whorl, giving this zone a pronounced carinate appearance. Below this central carination the whorls contract to the suture below. These shells therefore have a carinate-fusoid appearance. The contraction of the whorls at the suture lines, the absence of a pronounced subsutural band (though obscure crenulæ may be present) and the elongate character of the costæ on the smaller whorls serve to distinguish this species and its various forms or varieties from other Claibornian turrids.

Eopleurotoma sayi (Lea)
Plate 5, figures 1-5, 7-9
Plate 4, figures 29-31

Pleurotoma sayi Lea, Cont. to Geol., 1833, p. 133, pl. 4, fig. 125.
Pleurotoma monilifera Lea, Cont. to Geol., 1833, p. 133, pl. 4, fig. 126.
Pleurotoma obliqua Lea, Cont. to Geol., 1833, p. 136, pl. 4, fig. 131.

Pleurotoma gemmata Con., Foss. Sh. Tert. Form. 1835, p. 52, pl. 17, fig. 22.
Pl. desnoyersopsis de Greg., Mon. Faun. Eoc., de L'Ala. 1890, p. 31, pl. 2, fig. 21.
Pl. (*Clavatula*) *properugosa* de Greg., *idem*, p. 29, pl. 2, fig. 9.

Lea's description.—Shell fusiform, turrited, longitudinally and thickly folded, transversely and strongly striate; substance of the shell rather thin; spire elevated, pointed at the apex; whorls eight, subcanaliculate above; mouth rather narrow, about one third the length of the shell.

Length .5, breadth .2 of an inch.

Observations.—This species very closely resembles the last described [*lonsdalii*], but may be distinguished by its more numerous folds and stronger striæ, which are disposed to be larger and smaller alternately. It has a strong resemblance to the species figured by Sowerby under the name of *P. comma.*

One can only understand Lea's remarks regarding the resemblance of his species to *lonsdalii* by bearing in mind that while describing the latter he had two specimens before him; a smaller one from which he apparently derived most of the characteristics and a large one serving for measurements. The latter is referable to *rugatina.* The type specimen of *sayi* resembles that of *monilifera* though a little broader, with fewer subsutural crenulæ, and heavier striation over the sinus zone.

Lectotype.—Plate 5, fig. 1.

Other figured specimens: figs. 2, (No. 2436); fig. 3, (No. 2437); fig. 4, (No. 2438), Claiborne, Ala. Paleontological Research Institution.

"Pleurotoma monilifera" Lea

Plate 5, figure 7 (lectotype) figures 8, 9

Lea's original description.—Shell fusiform, turrited, transversely striate, furnished with a larger and smaller row of tubercles; substance of the shell thin; spire elevated, pointed at the apex; whorls nine; mouth two-fifths the length of the shell.

Length .6, breadth .2 [3], of an inch.

Observations.—This species differs from the last described [*sayi*] in having a double row of tubercles, and the mouth being rather longer. It has a very close resemblance to the *P. semicolon* (Sowerby).

The specimen we have numbered in the Philadelphia Academy 5696 is quite probably the type. Regarding it, our notes written with the specimen in hand read: "First two whorls smooth; 3 and 4 plicate; 5-10 with two rows of dots or tubercles. Striation almost gone on shoulder and sinus area."

Lectotype.—Figure 7, 15mm. No. 5696 Acad. Coll., Claiborne.

Figure 8 (No. 2440); 9 (No. 2441), Claiborne; Gosport Sand horizon. Paleontological Research Institution.

"Pleurotoma obliqua" Lea

Plate 5, figure 1a

Pleurotoma obliqua Lea, Cont. to Geol., 1833, p. 136, pl. 4, fig. 131.

Lea's original description.—Shell transversely and alternately striate below, canaliculate above, furnished with a row of oblique folds on the wider part of the whorl; substance of the shell rather thick; whorls subcanaliculate above; mouth long and narrow.

Length . . . breadth .4 of an inch.

Observations.—A single whorl only, being the inferior one, has come under my notice. It is perhaps the largest species here described. The description is of course defective, for want of superior whorls. I have no hesitation, however, from what remains, to consider it distinct; the folds, the striæ and the general form differ from any of the species here described.

This fragmentary specimen has perplexed students for a century. Lea's specimens were mainly small, but this fragment seems to him remarkably large. Conrad had the whole Claiborne bluff to chose from and hence found far larger representatives of the turrids than were contained in the packages sent to Lea. There would seem to be no reason why this fragment should not be referred to *sayi* as it has practically no trace of a subsutural band, its humeral slope is but feebly striate while its anterior portion and back of canal show well defined striæ alternating in strength. There are ten oblique nodules shown on this body whorl.

Holotype.—Figure 1a, Phila. Acad. Mus., No. 5713.

"Pleurotoma gemmata" Conrad

Plate 4, figures 29-31, 32 ?

Pleurotoma gemmata Con., 1835, Foss. Sh. Tert. Form., p. 52, pl. 17, fig. 22; Harris's Reprint, 1893, p. [108], pl. 17, fig. 22.

Conrad's description.—Fusiform; whorls slightly concave above, with prominent tubercles on the angle; an obsolete tuberculated carina beneath the suture; beak produced, rather shorter than the spire. Locality, Claiborne, Alab.

Holotype.—Figure 29, 19.6mm. No. 13,364, Phila. Acad. Coll.

There would seem to be no reasonable doubt that the specimen here illustrated, (fig. 29) is that from which Conrad drew his figure 22 as above quoted.

We have collected no exact replicas of this specimen, but the specimens here shown (30, 31) are probably conspecific with the type. There is a noticeable feature among these forms that seems characteristic, and that is the tendency to obliterate all striation on the upper part of each whorl, but especially the body whorl. There is a tendency also for the carinal nodulation to throw off crescentic extensions across the sinus zone and finally connect up with the subcarinal crenulæ. This is a *hœninghausi* characteristic.

Holotype.—Figure 29, 19.6mm. No. 13,364, Phila. Acad. Coll.

Figures 30, 31, forms showing variation in surface markings.

Figure 32 is unusually smooth (No. 2435) ; probably of this "species".

All from the Gosport sand horizon, Claiborne, Ala. Paleontological Research Institution.

"Pleurotoma (Clavatula) properugosa De Greg."

Plate 5, figure 23

See De Gregorio's Mon. Faun. Eoc., de l'Alabam. 1890, p. 29, pl. 2, figure. 9

There would seem to be nothing gained by retaining this name in our Tertiary literature as the characteristics mentioned and illustrated seem not distinctive. The author himself appears to realize this fact. However, to be sure no injustice is done to our late foreign colleague his description and illustration are herewith copied:

Testa fusiformis, elegans, filis linearibus spiralibus ornata; costis pliciformibus, multo sinuosis, arcuatis, fere cancellatis praesertim in medio.

C'est une espèce douteuse par les nombreuses analogies qu'elle présente. La sinuosité des côtes ressemble beaucoup à celles de la *Pleurotoma* (*Clavatula*) *Hoeninghausii* (Lea) De Greg.; mais les côtes sont beaucoup moins remarquables et dans le milieu des tours elles s'effancent presque du tout, reparaissant près de la suture, où elles ne prennent pas l'aspect de granulations. C'est aussi par l'ornementation qu'elle diffère de la *Pl.* (*Clavatula*) *rugosa* Lea avec laquelle elle a aussi beaucoup d'analogie.

L'échancrure du bord externe est remarquable: elle se trouve près de la suture postérieure; ayant origine de cell-ci et s'enfoncant en avant le long de la dépression postérieure des tours.
Elle a en outre quelque affinité avec certaines variétés de la *Pl. Lonsdali* Lea, de laquele elle diffère par le canal antrieure moins court, l'ornementation defferent etc. (Coll. mon. Cabinet).

"Pleurotoma (Surcula) Desnoyersopsis De Greg."
Plate 5, figure 24

See DeGregorio, as above, p. 31, pl. 2, fig. 21.

The same remarks here apply as under *"properugosa"*.

Testa fusiformis, elegans, spiraliter funiculata; funiculis regularibus linearibus; anfractibus antice tenue plicatis; postice paulo excavatis; plicis circiter 12, brevibus, in ultimo anfractu evanescentibus; L. 10mm.
Coquille très jolie, ornée de filets spiral réguliers; en les regardant sans la loupe ils semblent rapprochés enter eux; tandisque avec l'aide de celle-ci, ils paraissant à une certaine distance l'une de l'autre. Les côtes sont pliformes, courtes et un peu noduleuses, dans le dernier tour elles sont presque effacées. Le contour de la coquille est le meme que celui de *Pl.* (*Surcula*) *Desnoyersi* Lea, avec laquelle je l'avis confondue auparavant; mais ses ornaments sont très différent. Coll. mon Cabinet.

Eopleurotoma cochlea, n. sp.
Plate 5, figure 6

Specific characterization.—Type specimen imperfect but showing six rather large whorls on which the carinal nodules are nearly effaced and obliquely inclined on the three larger whorls; the subsutural band with distinct, oblique and numerous beads, seemingly representing an extreme development in the line shown by *nodocarinata-enstricrina;* columella strong, twisted, slightly umbilicate.

Holotype and specimen figured.—Gosport sand horizon, Claiborne, Ala.

Paleontological Research Institution No. 2439.

This may eventually prove to be but an extreme variation in the modifications begun or shown in Figures 4 and 5.

Eopleurotoma carya, n. sp.
Plate 5, figures 10, 11

Specific characterization.—Shell of moderate size and subfusiform as figured; whorls: 1, 2, and generally 3, smooth; 4 and sometimes part of 3 costate from suture to suture; 5-9 with oblique carinal costules sharply defined; subsutural band consisting of rather large crenulæ; shoulder nearly devoid of spiral striation; sinus broadly surculoid; about a dozen strong spiral liræ on body whorl below carina.

The sharply defined costation and crenulation not hidden by strong spiral or longitudinal striation, and the broad sinus give this species a neat and characteristic appearance.

These Lower Claiborne (or St. Maurice) forms differ from the *sayi* clan by having a comparatively broader body whorl shorter aperture, shorter, more pointed and seemingly more vertically directed costæ and with anterior so strongly striate that as one stria appears above the suture it gives the same a channelled appearance.

Cotypes.—Figures 10 (2442), 11 (No. 2443), Newton, Miss.

Figures 5, 12 and 13, paucicostate variety, var. *fisheriana*, n. var. plate 5; from the Sabine River section near Columbia, La.

Paleontological Research Institution.

Var. **hicoria**, n. var.

Plate 5, figures 14-16

A variety from Newton and Hickory, Miss., has a tendency to submerge the carinal nodulation by heavy spiral striation; ribs or nodules almost too short to show obliquely in trend.

Figures 14 and 15 (No. 2437), cotypes from Hickory; 16 (No. 2438) from Newton; Lower Claiborne Eocene. Paleontogolical Research Institution.

The specimen in the U. S. Nat. Mus. Collection No. 481,553 from St. Maurice, La., with a *nomen nudum* seems to belong here.

Var. **carola**, n. var.

Plate 5, figure 17

Slender forms with ornamentation extremely intensified in strength, lessened in number of units.

Holotype.—Five miles north-west of Orangeburg, S. C., 13mm. Paleontological Research Institution. No. 2439.

Var. from Jackson horizon

Plate 5, figure 18

Striated forms with broad body whorl 13mm.; Montgomery, La. Jackson Eocene, Paleontological Research Inst.

Eopleurotoma nodocarinata (Gabb)

Plate 5, figures 19-22

Plate 6, figures 1-4 vars.

Plate 6, figures 5, 6 var **enstricrina** (Har.)

Turris nodocarinata Gabb, Jr. Phila. Acad. Nat. Sci., vol. 4, 1869, p. 379, pl. 67, fig. 13.
Surcula nodocarinata Con., vol. 1, Amer. Jr. Con., 1865, p. 19.
Pl. (*Drillia*) *nodocarinata* Har., Proc. Phila. Acad. Nat. Sci., 1895, p. 59, pl. 5, fig. 4.
Eopleurotoma nodocarinata Casey, St. Louis Acad. of Sci., Trans., vol. 14, 1904, p. 127.

Gabb's original description.—Turreted; whorls seven, strongly carinated below the middle; suture distinct; mouth linear, columella straight; surface marked by a row of beading, directly below the suture, top of the whorl plain, carina marked by another nodose band larger than the first, rest of the whorl marked by about fifteen heavy revolving ribs, growing smaller on the canal and crossed by much smaller longitudinal lines.

Locality.—Wheelock, Texas, Collection of the Academy.

There are so many different species, and even genera, classed as *Pl. nodocarinata* in the Academy's collections that it is difficult to say just what Gabb had in hand in describing this species. The figure he gives does not resemble closely anything we have obtained from Texas. Judging from the majority of the specimens labelled *nodocarinata* in the Academy's collection it would seem advisable to take such forms as are represented on Plate 5, figs. 19-22 as typical. These are very common at Moseley's Ferry.

Note in this species a considerable increase in the number of costæ as well as prominnce of subsutural band.

Specimen figured.—All from Moseley's Ferry. Paleontological Research Institution. Nos. 2441, 2442.

Variety of **nodocarinata**

Plate 6, figures 1-4

This variety has a tendency to show more fine, yet sharply incised spiral lines, while costæ disappear below. This is the typical Smithville variety. Nos. 2443-2445, Paleont. Resh. Inst.

Variety **enstricrina** Har.

Plate 6, figures 5 and 6

Pleurotoma enstricrina Har., 1895, Phila. Acad. Nat. Sci., Proc., p. 56, pl. 4, fig. 3.

This was described by the author as a distinct species, but by so doing its intimate relationship with *nodocarinata* forms is not properly emphasized. From the figures it will be noticed that here the ribbing is close, vertically directed, and the subsutural crenulate collar is strongly developed.

Type.—Deposited in the State Survey collection at Austin, Texas (Capitol Building). These collections were removed later to the Geological Department, State University.

Specimen herewith figured.—Plate 6, figures 5-6, Smithville, Texas. Lower Claiborne Eocene. Paleontological Research Institution .No. 2446.

Eopleurotoma thyroidifera, n. sp.

Plate 6, figure 7

Specific characterization.—Shell turrited and of medium size as illustrated; costæ on smaller whorls resembling those on *nodocarinata* and varieties, but on larger whorls becoming large and distant; subsutural collar sometimes becoming quite as great in diameter as the central carina, large and heavy, somewhat crenulate; anterior of body whorl four or five heavy liræ strongly resembling the same region in *lisboncola.*

Holotype.—Figure 7, Plate 6; 28mm.; Base of Claiborne Bluff; Lower Claiborne Eocene. Paleontological Research Institution . No. 2447.

Eopleurotoma lisboncola, n. sp.

Plate 6, figures 8, 9

Specific characterization.—Shell long-fusiform as figured; two smooth embryonic whorls, a third somewhat obliquely and distantly plicate; peripheral ribbing short and located near the basal part of each whorl above, but becoming somewhat higher in the latter whorls; whorls constricted just above the ribbing but expanding upwards and forming a well defined and often coarsely crenulated subsutural band; surface of the shell covered by microscopic spirals but with nearly a dozen coarsely raised lines anteriorly on the body whorl and beak.

The general system of fine, even spiral striation, the constriction, the swollen subsutural collar, coarse, sharply defined or pointed costules, and the apex differentiate the species from many somewhat similar forms.

The obliquity and less strength in development of the costæ, as well as the less subsutural collar development distinguished this species from *thyroidifera.*

Holotype.—Plate 6, fig. 8 (No. 2448) ; 29mm. ; Lisbon, Ala. ; Fig. 10 (No. 2450) and 11, (No. 2451) afso from Lisbon. Figure 9 (No. 2449) of Plate 6, is from the base of the bluff at Claiborne but of practically the same horizon. Lower Claiborne Eocene. Paleontological Research Institution.

Eopleurotoma gemmavia, n. sp.

Plate 6, figures 12, 13, 14?

Specific characterization.—Shell comparatively large and long-fusiform as figured; whorls about 11, 1-3, small and smooth; 4-6 with about 10 well defined, basally situated nodules and with some traces of a subsutural beaded band; remaining whorls showing a deeper median constriction and a narrow, deep retral sinus above and below which spiral striæ and nodules are noticeable; somewhat widely spaced and irregularly developed spirals and longitudinals are marked on the body whorl.

This makes perhaps the nearest approach to *Clavatula* of any of our Mid-Eocene material.

Holotype.—Fig. 12 (No. 2452), plate 6; 30mm.; Hickory, Miss. Figure 13 (No. 2453), 26mm.; likewise from Hickory; fig. 14, 19mm., from Newton, Miss., more doubtfully referred to this species. Lower Claiborne Eocene. Paleontological Research Institution.

These specimens may be but local modifications of *carya* but the retral sinus is very sharply defined and deep and the general aspect is Clavatulid.

Eopleurotoma rugatina (Con. museum label only)
Plate 6, figures 15-17

Surcula rugatina Con., List name in Amer. Jour. Conch., vol. 1, 1865, p. 19.
Surcula rugatina Con. Labelled specimen, Acad. Nat. Sci., Phila.

So far as we are aware this species has never been described nor figured. Conrad evidently intended to describe it in 1865, for in the American Journal of Conchology as cited above, he gives as reference, "Acad. Nat. Sci., 1865" without page or reference to plate or figure.

Fig. 15 is a close replica of the Philadelphia "type". The three specimens 5710-5712 of the Lea collection seem to represent three different species. The one drawn by Meyer for Aldrich as the type of "*rugosa* Lea" is a good specimen of *rugatina*. It will be noticed that there is no marked "furrow along the suture" as described by Lea for true *rugosa*.

Specific characterization.—Size and general appearance as herewith illustrated; whorls about 9; apex blunt with one or two smooth whorls; later whorls with from 8 to 10 nearly vertically directed ribs crossing the greater part of the earlier whorls above, but limited to the lower three-fifths below; humeral depression well marked with a Clavatula-like ridge above and below; sinus narrow and deep; spiral striæ very pronounced; beak, semi-umbilicated.

The strong spirals and vertically directed costæ serve to make this a well defined species.

This species (as well as the preceding) has a decided Clavatulid appearance.

Holotype.—Specimen, Phila. Acad. Conrad Coll., 24mm.; Claiborne, Ala.

Specimens figured.—Figs. 15, 16, 17 respectively 23, 13, and 8mm.; Claiborne, Ala.; Gosport Sand Horizon, (Upper Mid-Eocene). Paleontological Research Institution. No. 2455.

Eopleurotoma depygis Conrad

Plate 6, figures 18, 19
Plate 7, figures 1, 2

Pleurotoma depygis Con., Fos. Sh. Tert. Form., 1833, p. 46.
Pleurotoma depygis Con., Fos. Sh. Tert. Form., 1835, p. 52, pl. 17, fig. 20.
Pl. (*Surcula*) *depygis* de Greg., Mon. Faun. Eoc., 1890, p. 29, pl. 2, figs. 10-13.

Conrad's description of 1833.—Subulate, with nine angulated volutions, nodulous in the middle; and with fine revolving spiral striæ; beak very short.

Conrad's description of 1835.— Subulate; whorls angulated in the middle, with obscure oblique nodules on the angle; revolving lines minute, more distinct in the middle of the body whorl, which is slightly ventricose; beak short, straight, truncated.

Syn. P. lonsdalii Lea. Con. p. 132, pl. 4, fig. 124.

Locality.—Claiborne, Ala.

Differs from *P. nuperus* in having a much shorter beak and a more elevated spire.

About 20 specimens representing the larger share of the Clabornian *Eopleurotomæ* are on the "*depygis*" card in the Philadelphia Academy's collection. Among them, perhaps, at one time may have been the type of *depygis* as well as *nuperus.* Their primal classification and nomenclature is now only a matter of conjecture. But from Conrad's publications it is evident he had from Claiborne, besides the goodly sized "*gemmata*" two others, the one *depygis* characterized in part by its "subulate form, fine spiral striæ, obscure, oblique nodules on the angle of the whorls, and with beak short, straight and truncated. The other, *nuperus,* fusiform, with "suture margined beneath by an obtuse obsolete carina".

De Gregorio seems to have grasped the essential features of this species when he wrote (*op. cit.*) :

Gregorio's characterization (Translated).—Shell fusiform, elongated, subcarinated, ornamented with spiral threads; whorls subcarinate, anteriorly they are convex and provided with a series of nodules pinched and oblique; posteriorly they are concave; the sutures simple and linear.

Though the peripheral nodes are pinched and oblique, the much finer series just beneath the suture are short and vertical.

Type material.—Philadelphia Acad. Nat. Sci. collection. Specifically, the Conrad collection.

Specimens figured herewith, all from Claiborne, Ala.; Gosport sand horizon. Paleontological Research Institution. Nos. 2456, 2457, 2458.

Eopleurotoma hœninghausii (Lea)

Plate 7, figures 3-5

Pleurotoma hœninghausii Lea, Cont. to Geol., 1833, p. 135, pl. 4, fig. 129.

Lea's original description.—Shell fusiform, turrited, transversely striate, furnished with two rows of longitudinal folds in zig-zag; substance of the shell rather thin; spire elevated, acute at apex; whorls ten, subcanaliculate above; mouth rather narrow, about one third the length of the shell.

Length .7, breadth .4 of an inch.

Observations.—This species may be distinguished by its double row of folds, which being placed, the superior one obliquely to the right, the other to the left, produce a zig-zag appearance.

Lea evidently intended to include under this name these rather narrow small specimens that carry the markings of the upper whorls of the *sayi*-like forms over the spire and body whorl. On a card marked *Pl. hœninghausi* in the Academy's collection there is one good specimen of *rugosa* Lea and one very small *hœning-*

hausi. This, No. 5708, may be regarded as a co-type. In a tray marked "*P. hœninghausi* Lea, T. A. Conrad, Claiborne, Ala." there are several specimens, some of which might well be Lea's types, though the insertion of "T. A. Conrad" is difficult to explain.

Specimens figured.—From Claiborne; Gosport Sand horizon. Paleontological Research Institution Nos. 2467-2469.

Eopleurotoma rugosa (Lea)

Plate 7, figures 6 and 7

Pleurotoma rugosa Lea, Cont. to Geol., 1833, p. 136, pl. 4, fig. 130.

Lea's original description.—Shell fusiform, turrited, transversely and widely striate on the inferior part, furnished with one row of folds and one of granulations; substance of the shell rather thin; suture sulcate; spire elevated, acute at apex; whorls twelve; mouth narrow, one-third the length of the shell. Length .8, breadth 5-20ths of an inch.

Observations.—The folds and granulations of this species give it a rougher appearance than the others described here. The furrow along the suture is marked, being formed by two superior transverse striæ. On the superior part of the whorl, there are in some specimens minute transverse striæ.

This has fewer, shorter, higher ribs than *hœninghausi*. It is more slender than the latter species and has a more pronounced sutural channel.

Lectotype.—Acad. Phila. Catal. No. 5709.

Specimens figured.—Claiborne, Ala. Paleontological Research Institution. No. 2470.

"Pleurotoma (Clavatula) tupis De Greg."

Plate 7, figure 8

Pl. (Clavatula) tupis De Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 28, pl. 2, fig. 1.

Testa subfusiformis, subconoidea, carinata; anfractibus vix convexis, apud suturam anticam cingulo noduloso cinctis; ultimo cingulis spiralibus granulosis ornato. L 12mm., Ang sp. 35°.

Petite coquille très élégante, subpupoïde, subconique; les tours, presque aplatis, sont pourvus d'une rangée de côtes noduleuses, qui est repprochée de la suture antérieure. Ces côtes forment la carène, qui dans le dernier tour est suivie anterieurement par deux ou trois rangées de granulations decroissantes d'arriere en avant. La surface de la coquille est un peu ridée, le canal très court.—Coll. mon Cabinet.

De Gregorio's illustration and description are scarcely defined enough to allow of placing this species in any particular section of turrids. He doubtless supposed he obtained it from Claiborne.

"Surcula lirata Con."

Plate 7, figure 9

The nearest approach to anything like "*tupis*" we have found is a specimen in the Phila. Academy collection labelled "*Surcula lirata*," said by Conrad (Amer. Jr. Conch., vol. 1, 1865, p. 18) to be described in the Academy's Proceedings for 1965 but I have never been able to verify this reference. I made a pen-and-ink sketch of this specimen while studying at the Academy some 30 years ago and the same is herewith shown as figure 9. This strange and unpublished form was derived from Claiborne, Ala. It is 0.5mm. in length.

Marwick's *Cosmacyrinx* (Geol. Surv. N. Zealand, Pal. Bull. No. 13, 1931, pl. 16, figs. 292-294) though too broad in form has somewhat similar ornamentation.

Eopleurotoma orangeburgensis, n. sp.

Plate 7, figures 10-14

Specific characterization.—Size and general appearance as indicated by the illustrations; whorls in the smaller, common specimens about 8, in the large about 10;

three apical smooth, the fourth finely and longitudinally ribbed; general ornamentation of later whorls consisting of a subsutural collar faint-nodose, a deeply depressed sinus zone, low, nodular carinal ribs or nodes, perhaps 13 on the body whorl. Older shells often with faint or sharply defined spiral channels showing on the back of the body whorl; the same may be in part pathologic. The broadly curved margin of the outer lip, and the sinus slit are well shown in figures 10 and 13.

This species has, in general appearance, much in common with *"Genotia pyrgota"* Edw., (Cossm., Icon. pl. L, fig. 219-2.)

Holotype.—Figure 10 (No. 2471); 11mm.; three miles north-west of Orangeburg, S. C.

Figures 11-14 (Nos. 2472-2475), from the same locality showing variation in size, apical and aperture features. Lower Claiborne Eocene. Paleontological Research Institution. Nos. 2471-2475.

THE TURRICULIDS

Eosurcula, Casey, 1904

Eosurcula beaumonti (Lea)

Plate 7, figure 15

Pleurotoma beaumontii Lea, Cont. to Geol., 1833, p. 134, pl. 4, fig. 127.

Lea's original description.—Shell ovately fusiform, transversely striate, furnished with a single row of compressed tubercles near the middle of the whorl; substance of the shell rather thin; apex pointed; whorls eight, subcanaliculate above; mouth nearly one half the length of the shell.

Length .6, breadth .2 of an inch.

Observations.—A beautiful little species differing somewhat in its form from those above described, as well as in the tubercles and striæ. The tubercules are compressed, and adorn the wider portion of the whorl. The striæ are wide apart, and below the tubercles these are, for four or five rows, alternately smaller. In the canal above the tubercles, flexuous folds of the form of the sinus are visibly and closely set.

The strong subsutural band with its incised central spiral should be mentioned The "row of compressed tubercles" is divided by a spiral line. There are four smooth apical whorls while the fifth shows rather long, oblique costation.

Type.—Phila. Academy Collection, No. 5699. Claiborne, Alabama; Claiborne Eocene.

Specimen figured.—Figure 15, Claiborne, Ala. Paleontological Research Institution. No. 2476.

Eosurcula lesueuri (Lea)

Plate 7, figures 16-20

Pleurotoma lesueuri Lea, Cont. to Geol., 1833, p. 137, pl. 4, fig. 133.

Pleurotoma (*Genota*) *lesseuri* De Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 41, pl. 2, figs. 54-56.

Lea's original description.—Shell fusiform, turrited, covered with closely set transverse striæ, which are cut by indistinct longitudinal ones; substance of the shell rather thick; spire elevated, acute at apex; whorls about nine, subcanaliculate above; mouth long and narrow, about two-fifths the length of the shell. Length 1.1, breadth .4 of an inch.

Lea's description and type specimen refer to the form of this species represented here by figure 16. Body whorls of large specimens, as in figure 19, for example show no signs of costation; others, (see figure 20) are more distinctly costate while the smaller specimens, as in figures 17 and 18 show very marked ribbing as well as strong spiral striation (var. *beta*). (Type *beta*, No. 2479.)

Lectotype.—Phila. Acad. Coll., No. 5717.

Specimens figured.—Claiborne, Alabama; Gosport Sand horizon. Paleontological Research Institution.

Eosurcula sancti-mauritii (Vaughan)
Plate 7, figures 21, 22, and 23?

Pleurotoma sancti-mauritii Vaughan, U. S. Geol. Surv., Bull., 142, 1896, p. 32, pl. 2, fig. 2.

Vaughan's original description.—Form and size indicated by figure. Whorls 11; 1-3 smooth; 4 minutely costate; 5-9 have about 17 rather faint longitudinal folds below the sinus; 10-11 devoid of longitudinal folds; may be subcarinate. Coarse spiral lines may be distinguished on all of the whorls except the embryonic. Lines finer in region of sinus. Below humeral angle revolving striæ alternating in prominence and grouped in systems of five, two coarser on the outside, between which is a median finer one; between the median and each other stria is another still finer. Lines of growth distinct. Sinus moderately deep, situated in the space between humeral angle and suture. Region sinus slightly concave.

Locality.—St. Maurice (Vaughan types); 10 miles northwest of Winnfield (Lerch and Vaughan).

Geological occurrence.—Lower Claiborne.

Type in United States National Museum.

The specimen in the National Museum figured by Vaughan that may be regarded as the lectotype, No. 147,041 is herewith figured (fig. 21).

Figure 22 (No. 2482) is from St. Maurice. Figure 23 (No. 2483) is from a more or less flattened impression about 10 miles north-west of Winnfield, La. Paleontological Research Institution Nos. 2482 and 2483.

Eosurcula pulcherrima (Heilp.)
Plate 7, figures 24, 25
Plate 8, figures 1-5

Conus pulcherrimus Heilp., Proc. Phila. Acad. Nat. Sci., 1879, p. 213, pl. 13, fig. 8.
Pleurot, pulcherrima Ald., Bull. Amer. Pal., vol. 2. 1897, p. 173, pl. 6, fig. 7.
Eosurcula pulcherrima Casey, Trans. Acad. Sci., of St. Louis, vol. 14, 1904, p. 146.

Heilprin's original description.—Shell conical; spire elevated; whorls about seven, slightly concave above, granularly crenulated on the angle, and transversely striated; a prominent simple line below the angle, and one of granulations beneath the suture.

Aperture.—Length about ½ inch. Claiborne, Ala.

Aldrich (*loc. cit.*) says simply: "A much more perfect specimen than the type is here figured. There is no doubt of its being *Pleurotoma.*" A very few small specimens of this species have heretofore been collected and Heilprin and Aldrich have commented on them. Figure 25 of plate 7 shows the more common form. But now we have much larger specimens apparently of the same species as shown by Pl. 7, fig. 24 and pl. 8, figure 1 &c. The slender, smooth apex is very markworthy, likewise the markings on the later whorls and the general fusoid appearance. Another larger shell is shown on plate 8, figure 5, that seems to have a more fulguroid or hemifusus outline and has no trace of the second or sub-medial carination of the first mentioned species. A small specimen in the U. S. National Museum numbered 137,416 may be the young of this fulguroid form (fig. 6, pl. 8). This may be designated as a distinct species under the name *tardereperta*.

Type of pulcherrima.—Pl. 7, fig. 25, Amer., Mus. Nat. Hist.

Specimens figured.—Pl. 7, fig. 24 (No. 2484) Newton, Miss. L. Claib. Eoc. Plate 8, figures 1, 2, Claiborne, Ala.; figs. 3, 4 (Nos. 2485 and 2486), Orangeburg, S. C. Plate 8, fig. 1, Phila. Acad. Nat. Sci. collection, others in Paleontological Research Institution.

Eosurcula tardereperta, n. sp.

Plate 8, figure 5

Specific characterization.—General form and size as indicated by the figure; distinguished from *pulcherrima* by its unicarinate whorls, greater carination or angulation of the whorls centrally with body whorl decreasing in diameter immediately below this carination, or anteriorly.

Holotype.—Pl. 8, fig. 5; Phila. Acad. Nat. Sci. Coll. Pl. 8, fig. 6, U. S. Nat. Mus. No. 137,416. Both from the Gosport Sand at Claiborne, Ala.

Eosurcula moorei (Gabb) and varieties

Plate 8, figures 7-20

Turris moorei Gabb, 1860, Phila. Acad. Nat. Sci., Jr. vol. 4, p. 378, pl. 67, fig. 11 (not 9 as given by Gabb.)

Pleurotoma tuomeyi Ald., 1886, Geol. Surv. Ala., Bull. 1, p. 31, pl. 3, fig. 11.

Pleurotoma (Surcula) moorei Har., 1895, Phila. Acad. Nat. Sci. Proc., p. 57, pl. 4, figs. 6, a, b.

Eosurcula moorei + *tuomeyi* + *concinna* + *helicoidea* Casey, 1904, St. Louis Acad. Sci. Trans., vol. 14, p. 146.

Gabb's original description.—Shell elongated fusiform, whorls nine or ten, strongly carinate; mouth narrow, long, half the length of the shell, inner lip covered with a very delicate coat of enamel, so thin as to be visible only on a very well preserved specimen, outer lip thin, showing internally the marks of the larger ribs; surface marked by about twenty-five revolving lines, smaller on the shoulder of the whorl (except one large one at the upper edge, below the suture) than elsewhere; in the largest specimens, two or three of the principal ribs are compound, the rest are simple; near the apex, on the upper two of the principal revolving lines are small tubercles which disappear in the succeeding whorls.

Dimensions.—Length 1.1 in., length of mouth .55 in., width of body whorl .3 in.

The fine specimen figured, is in my collection from Caldwell Co., Texas.

We are not aware of what became of Gabb's "fine specimen" but another specimen in the Phila. Acad. collection is of medium dimensions, showing, by the way, carinal denticles. As already pointed out (Bull. Amer. Pal., vol. 3, p. 16) the differences between Gabb's *moorei* and Aldrich's *tuomeyi* are but slight. *Tuomeyi* from the Woods Bluff Sabine Eocene horizon sometimes has a pronounced carination. The carinal denticulation on the earlier whorls, hence seeming obviousness of carination, varies in the Texas specimens from locality to locality. Smithville specimens tend to show on their smaller whorls a more obviously curved outline or profile; those from Orrell's Crossing are more carinate (n. var. *gamma* pl. 8, fig. 13).

Specimen figures.—

Figures 7 (No. 2487) 8, 9, 10 (2488) (2489), and 10 (No. 2490) Woods Bluff; upper Sabine Eocene.

Figures 11 (No. 2491), 12 (No. 2492), Smithville, Tex., Lower Claiborne Eocene.

Figure 13, Orell's Crossing, Elm Cr., Tex.; Lower Claib. Eoc.

Figure 16 "*helicoidea*" Csy; St. Maurice, La.; L. Claiborne.

Figures 17, 18, Lisbon, Ala. L. Claiborne. No. 2494.

Figure 13 is in State Survey collection at Austin, Texas; Figures 15 and 16, in National Museum.

All others in the Paleontological Research Institution.

Var. **olssoni**, n. var.
Plate 8, figure 14

Distinguished by suppression of carinæ, but with well defined revolving striæ alternating in size.

Holotype and specimen figured.—Smithville, Texas; Lower Claiborne Eocene. Paleontological Research Institution. No. 2493.

Var. **moorella**, n. var.
Plate 8, figure 19

Distinguished by its extremely long drawn out form, with its main carina not so pronounced as in typical *moorei*.

Holotype and specimen figured.—Vicinity of Columbus, La., L. Claiborne Eocene. No. 2494.

Var. **corpulenta**, n. var.
Plate 8, fig. 20

Distinguished by its broad fusoid form without costules or pronounced carination.

Holotype.—Fig. 20; figured specimen, from Smithville, Texas; Lower Claiborne Eocene.

Paleontological Research Institution. No. 2496.

Eosurcula? superpons, n. sp.
Plate 8, figures 21, 22

Specific characterization.—Shell, large, broad-fusiform as figured; whorls (in most perfect specimen) 7; larger embryonics, costate; spiral whorls characterized by a broad, flat subsutural collar, a broad flat sinus zone, and a narrow subsinus zone with two strong spirals; the upper forming a faint carina; below spiral carina, secondary spirals coarse; above the same, very fine.

What is seen of the apical portion indicates this form may belong to the Protosurculids.

Holotype and additional figure.—Smithville, Texas.

Lower Claiborne, Eocene.

Paleoentological Research Institution. No. 2497.

Var. **subpons**, n. var.
Plate 8, figure 22a

In this variety the second carinal lira becomes very pronounced and juts out forming a sharp carina, while the upper lira is very slightly developed; subsutural collar broad and prominent with a deeply incised line; space between carina and subsutural collar marked with from two spirals on the smaller whorls to six on the larger; anterior of body whorl strongly lirate.

The jutting basal margins of the whorls serve to distinguish this from all other forms of the genus.

Holotype.—Specimen figured. From the base of the bluff, below the bridge at upper Claiborne Landing, practically the Lisbon horizon. Paleontological Research Institution. No. 2498.

Eosurcula quadriplenta, n. sp.
Plate 8, figures 23-26

Specific characterization.—General appearance narrow fusoid as figured; apex pointed; three embryonic whorls smooth, the fourth with strong, vertical costæ; larger spiral whorls marked by a heavy subsutural collar which may have a double appearance on account of a superimposed deep spiral incision, a broad and decidedly concave superhumeral band, the sinus area, and two submedial carinæ, more or less denticulate on the earlier whorls; no signs of plicæ or liration within the aperture, but columella flattened and seemingly eroded concavely instead.

This species has the remarkable characteristic of showing earlier spiral whorls of small dimensions and then at a certain point the whorls begin to increase rapidly in size.

This seems distantly related to some of the varietal forms of *moorei*. The spire, however, is much longer proportionally.

Holotype.—Fig. 23; this with specimens figured as figs. 24, 25 and 26 from 5 miles north of Orangeburg, Old Columbia road; Lower Claiborne Eocene. Paleontological Research Institution No. 2499.

Cochlespirella Casey, 1903

Genotype.—*Fusus nanus* Lea. See Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 279.

Cochlespirella insignifica (Heilp.)

Plate 8, figures 27-29, 31-34

Fusus nanus Lea, Cont. to Geol., 1833, p. 150, pl. 5, fig. 9.
Pleurotoma insignifica Heilp., Phila. Acad. Nat. Sci., Proc., 1879, p. 213, pl. 13, fig. 9.
Not *Pl. nanus* Deshayes, 1824 (Descr, Coq. Foss. des Envir. de Paris, p. 482, of vol. 2, pl. 8, figs. 19-22).

Heilprin's original description.—Shell fusiform, with prominent revolving lines below the middle of the whorl; spire elevated; whorls about five, angular; canal short, obliquely curved; mouth contracted.
Length ¼ inch.
Claiborne, Alabama.

We have given a more complete description of this species in the Proceedings of the Academy of Natural Sciences, 1895, p. 62. Casey (Phila. Acad. Nat. Sci., Proc., 1903, p. 278) is led by Meyer's illustration to believe *nanus* and *insignifica* are distinct species. But when one considers the great variation in this species from place to place the designating of each form by a different name seems an unwarranted procedure.

The pointed apex with its 3 or 4 smooth whorls and the sinus zone with its sharply defined curving growth lines are constant features. But the extent of carination and the number of strong spirals below, or between carina and suture below may vary considerably. Also on the sinus zone there may be one or more spirals.

Holotype.—Figure 27 (enlarged from a print kindly furnished by the American Museum of Natural History) Claiborne, Ala.

Figure 28 (No. 2500) represents a somewhat more adult specimen, also from Claiborne, Ala.

Figure 29 is of a more pointed form from Smithville, Texas.

Figure 31 is a young Woods Bluff specimen, No. 2502.

Figure 32 shows a pointed carinate form from Orangeburg, S. C. This shows well a crenulated spiral on the sinus zone. No. 2503.

Figure 33, a small specimen from near Columbus, La. No. 2504.

Figure 34 is a specimen with more obtuse apex from Moseley's Ferry, Texas.

No. 2505.

Figures 27, 28 are from the Claiborne "sand" horizon, while 29, 32, 33, and 34 are from the Lower Claiborne (St. Maurice) horizon.

Specimens figured as 28, 31, 32, 33, and 34 are in the Paleontological Research Institution.

Var. alabama n. var.
Plate 8, figure 30

One sometimes finds portions of the larger whorls of this type of shell seemingly without a trace of central carination.

Holotype.—Claiborne, Alabama; Gosport Sand horizon.

Paleontological Research Institution No. 2501.

Cochlespira Conrad, 1865; **Ancistrosyrinx** Dall, 1881; **Cochlespiropsis** Casey, 1904

Cochlespira seems never to have been defined by Conrad but several species were grouped by him under this designation, of which a Vicksburgian form *cristata* (Amer. Jr. Conch., vol. 1, 1865, p. 19) appears to be the first. Unfortunately in the same volume, (p. 142) he describes, and on Pl. 21 he figures, a very different type of shell under the name of *Cochlespira engonata*. This together with the very imperfect figures of his *bella* and *cristata* has caused considerable confusion in our Tertiary molluscan nomenclature. De Gregorio for example, overlooking the fact that *cristata* was mentioned before *engonata* on p. 19, *op. cit.*, (see De Greg., Mon. Faun. Eoc. Ala., 1890, p. 37) and relying too much on Conrad's poor drawing concludes that *Cochlespira* is synonymous with *Perrona* Schumacher. Dall doubtless would never have instituted the term *Ancistrosyrinx* (Bull. Mus. Comp. Zool., vol. 9, 1881, p. 54) had he at that date been acquainted with our Tertiary literature. His diagnosis at that time, and his figure of *elegans*, the type species, a modern form off the Florida Reefs as given on Pl. 38, (*op. cit.*) leave no doubt as to the Cochlespiroid characters of this genus. In a late work Dall himself questions the synonymy of these designations (Proc. U. S. Nat. Mus., vol. 54, p. 318). Cossmann misled by de Gregorio's misunderstanding and Conrad's defective figures, in his *Essais de Paléoc. Comp.*, Liv. 2, 1896, p. 68 and 95, inclined to refer *Cochlespira* to *Rouaultia*, Bellardi. This mistake he corrects in his 7th Livr., 1906, p. 221 after having the advantage of Casey's studies on *Pleurotoma* (St. Louis Acad. Sci., vol. 14, 1904, p. 123 *et seq.*) So far as *Ancistrosyrinx* is concerned he remarks: "this shell (*cristata*) is indeed of the same group as *P. terebralis*. Consequently if it is really the genotype which Conrad had in mind when he created *Cochlespira*, *Ancistrosyrinx* Dall is a subsequent synonym and ought to disappear from nomenclature." Cossmann, however, still believed that the term *Cochlespiropsis* created by Casey for the *engonata*-like forms should be referred to *Rouaultia*. This mistake doubtless came about by the imperfection of the specimens he had in hand when investigating *engonata*. (See fig. 13, pl. 14 of his 7th Livr.). Note that the carina is fractured in such a way as to give the impression that the retral sinus is located on the carina. This would correspond with his diagnosis of *Rouaultia* (p. 95, 2d Livr.) when he says of the lip: "marked on the carina by a narrow and deep sinus".

The name *Cochlespira* should be used to designate the *terebralis-cristata* forms of the older Tertiaries, species with the sides of the whorls often nearly vertical and subparallel, and with a strong tendency to become bicarinate at times, and to grow large beads or even spines, and then again to supress such ornamentation. However, there are forms beginning in the middle Eocene as shown on Pl. 9, figs. 18, 19 under the designation of *petropolis* and continued in the Jackson as *columbaria,* in the Miocene of Costa Rica with ornate *elegans* and the smooth *dalli* (?= *miranda* Guppy, *cedo-nulli* Reeves) and in the recent Floridian seas as *elegans* and the Bay of Panama as *cedo-nulli,* that show funnel-shaped whorls, fine subcarinal beading and often one or more spiral beaded lines above, or within the serrate carina that may well be referred to a subgenus *Ancistrosyrinx.* Incidentally it may be noted that some species referred to *Columbarium* (e. g. *C. canaliculatum* Mart.) bear a strong superficial resemblance to *Ancistrosyrinx* (Deutsch. Tiefsee Exp. Pl. 2, fig. 7).

Cochlespira terebralis (Lam.)
Plate 9, figure 17

Among the Eocene gastropods the wide range of variation and distribution of *terebralis*-like Cochlespiras seems the counterpart of *planiscosta*-like Venericardias among the pelecypods. The following notes may be of interest to Cenozoic paleontologists.

In his *Memoirs Sur les Fossiles des Environs de Paris* (Ann. du Mus., vol. 3, 1804, p. 26) Lamarck writes:

20 Pleurotome térébrale Vélin, n. 44, fig. 4.
Pleurotoma (*térébralis*) *fusiformis, subventricosa; striis transversis eleganter granulatis; anfractibus exquisite carinatis; carinis dentatis rotœformis* n. L. n. Parnes. C'est une des espèces de ce genre les plus jolies et les plus remarquables. Elle est fusiforme, un peu ventrue au milieu, se termine inférieurement par un canal rétréci en forme de queue, et offre dans sa moitié supérieure une spire conique taillée en vis de pressoir. Les carènes fort elevées des tours de cette spire sont dentées et ressemblent à de petites roues. Les stries transverses de la coquille sont granulées et imitent des rangées de petites perles. Ce pleurotome a environs 14 millimètres de longeur.
Cabinet de M. deFrance.

Deshayes (Descr. Coq. Foss. des Environs, Paris, vol. 2, 1824, p. 455) gives additional characteristics for this species and separates out a variety with fewer, heavier, smooth lirations from a somewhat lower horizon. In his later work (Descr. An. sans Vert, vol. 3, 1866, p. 359) he remarks: (translated) "This beautiful species is much more variable than we had imagined when we described it in our former work; some varieties exist in the *calcaire grossier,* but the most numerous and the most singular are found in the *sables inférieurs.*"

A distantly related species from Lattorf (Lower Oligocene) has been described by von Koenen (Abh. d. geol. Landesanstalt Bd x, Lief 2, p. 323, pl. pl. 30, fig. 10) under the name of *Surcula persiprata.* This is a large form with very subdued ornamentation. See our Plate 9, figs. 15 and 16. This suggests a trend toward Bellardi's *Clinura* of the Italian Plocene.

So far as we are aware Aldrich was the first to refer (Ala. Geol. Surv. Bull. No. 1, 1886, p. 55) some of our American forms to *terebralis.* Quite probably this is a proper procedure as we have already suggested (Bull. Amer. Pal. vol. 3, 1899, p. 19). But for American usage perhaps local designations will prove the more convenient.

Cochlespira cristata (Con.)

Plate 9, figure 1

Pleurotoma cristata Con., Phila. Acad. Nat. Sci., Proc., 1847, p. 284. *Idem.* Journ., vol. 1, 1848, p. 115, pl. 11, fig. 20.

Cochlespira cristata Con., Amer. Jr. Conch., vol. 1, 1865, p. 19.

Conrad's original description.—Fusiform, whorls ten, angulated in the middle, except the two from the apex, and with a reflected finely dentate carina; revolving lines distinct, fine crenulated; spire scalariform; from the upper end of the aperture runs a prominnt revolving line, much larger than the others; lines on the body whorl below the angle minutely granulated; beak narrow, produced. Length ¾ [in.]. Rare.

Specimen figured.—Vicksburg, Miss., Oligocene. No. 2506.

Var. **greggi**, n. var.
Plate 9, figures 2, 3

Differs mainly from *cristata* by the greater strength of the second or lower carina. The sides of the whorls are more nearly vertical, i. e. do not converge so rapidly anteriorly. Suture bordered above and below by a crenulate spiral.

Holotype.—Figure 2, from Gregg's Landing, Ala. Lower Sabine Eocene. Fig. 3 likewise from Gregg's Landing.

Paleontological Research Institution. No. 2507.

Cochlespira bella Conrad
Plate 9, figures 4, 5

Cochlespira bella Con., Amer. Journ. Conch., vol. 1, 1865, p. 210, plate 21, fig. 6.

Conrad's description.—Fusiform, turrited, whorls ten, with an acute reflexed subspinose carina, and crenulated revolving lines. Differs from *C. cristata* Conr., in having fewer and coarser lines and a more prominent carina. *Locality*.—Texas.

The two carinæ are more distinctly developed, especially the lower than in *cristata*, and the beading is in general much coarser than in *greggi*, subsutural collar well beaded as in typical *terebralis* and the secondary carina shows above the suture. Between the primary and secondary carinæ there is often a heavy beaded spiral.

This is still farther removed from *cristata* or *terebralis* than is *greggi*. The strength of the lower carina is very pronounced. The beaded spiral above and below the suture is noteworthy, likewise the general coarseness of ornamentation.

Specimen figured.—Fig. 4, (No. 2508) 22mm., Smithville, Tex., Lower Claiborne Eocene. Figure 5, (No. 2509) Woods Bluff, Ala., Upper Sabine Eocene. The latter is approaching *greggi*.

Paleontological Research Institution.

Var. **hoplites**, n. var.
Plate 9, figure 6

This variety is characterized by the extreme strength of the dentition on the carination of the whorls, and the lack of finer ornamentation.

Holotype.—Specimen figured, from Orangeburg, S. C. Lower Claibornian.

Paleontological Research Institution. No. 2510.

Var. **polita**, n. var.
Plate 9, figure 12

Varietal characters.—General form like *bella* but without crenulate liræ except on the keel; secondary carina very heavy; anterior liration very coarse.

Holotype.—Ouachita River, La. Jackson Eoc.

Paleontological Research Institution. No. 2513.

Var. **planata**, n. var.
Plate 9, fig. 11

Differs from *bella* by having ornamentation reduced to a sharp, serrate, carina; apex short, approaching *bastropensis*.

Holotype.—Little Brazos River; Lower Claiborne Eocene.

Paleontological Research Institution. No. 2512.

Cochlespira bastropensis, n. sp.
Plate 9, figures 7-10

Specific characterization.—Small and rather broadly fusoid as illustrated; three apical whorls smooth and rapidly expanding, fourth with thick oblique costæ especially basally; remaining apical whorls with coarse denticulation peripherally, and a small spiral anteriorly; subsutural collar coarsely crenulate; sinus slope smooth except for lines of growth; secondary carina not always visible; anterior of body whorl with coarse non-alternating liræ; anterior canal wide, slightly bent anteriorly.

The obtusely pointed apices of these forms are very distinctive. The thickness (vertically considered) of the peripheral dentation, with their oblique orientation, and the weakness in secondary peripheral keel development amply distinguish this from all other species of *Cochlespira*.

Holotype.—Figure 8, 10mm. Moseley's Ferry, Tex. Lower Claiborne Eocene. Figures 7, 9, 10 show various stages of growth.

Paleontological Research Institution. No. 2511.

English "terebralis"
Plate 9, figures 13, 14

Note how the markings of var. "*pulcherrima*" Edw. (fig. 13) resemble those of our *polita*, though the latter is from the Jackson Eocene while *pulcherrima* is from the London Clay, Lower Eocene. Var. "*ditropis*" Edw., (fig. 14) is very close to *bella*, though it too is of a Lower Eocene, London Clay horizon.

"Surcula perspirata" von Koenen
Plate 9, figures 15, 16

From Lattorf (L. Olig.) Germany, shows ornamentation very reduced.

Cochlespira (Ancistrosyrinx) columbaria (Aldrich)
Plate 9, figures 20-22

Pleurotoma (*Ancistrosyrinx*) *columbaria* Ald., 1886, Geol. Surv., Ala., Bull. No. 1, p. 31, pl. 6, fig. 9 .

Aldrich's description.—Shell small, fusiform, whorls ten; the nucleus smooth, composed of three whorls; the remaining seven shouldered, and armed with erect spines rising above the edge of the shoulder, giving to the shell a pagoda form; upper part of whorls smooth, concave, with a faint broken line just below the suture, composed of longitudinal striæ; lower part of the whorls with nine or ten coarse alternate revolving rows of rounded tubercles, which extend over the spines. Slit rather large, semi-circular. *Locality*.—Dry Creek, Jackson, Miss.

Aldrich's figure is herewith reproduced as figure 22.

From the Bunker Hill region along the Ouachita River, La., Veatch collected more perfect examples of this species. See Figures 20 and 21. They are likewise from the Jackson Eocene horizon.

Paleontological Research Institution. No. 2516.

Var. **petropolis**, n. var.
Plate 9, figures 18, 19

Owing to the extent of erosion of the specimens we have so far obtained, it is impossible to tell just how closely this variety comes to the typical *columbaria.* We notice however, that in *petropolis* there is no sign of the alternation or variation in strength of the body crenulate liræ as described by Aldrich and shown in his figures as well as our figure 20; and too there is much doubt as to whether the peripheral dentition of *petropolis* was ever as coarse as that in *columbaria.* More material will make the similarities or differences clear.

Holotype.—Figure 18. 12mm. Little Brazos River, Tex. Figure 19 (No. 2515) from same locality. Lower Claiborne Eocene.

Paleontological Research Institution.

Genus **Turricula** Schumacher, 1817
(*Sensu lato*)

"Genus" **Orthosurcula** Casey, 1904

Type.—*Pleurotoma longiforma* (Ald.) Casey, St. Louis Academy of Science, Trans. vol. 14, 1904, p. 151.

Several types of large surculoids in the Eocene and Oligocene beds of our Southern States have been given distinctive "generic" designations by Casey. The Red Bluff form described by Aldrich as *Pl. longiforma,* Casey uses as the type for the genus *Orthosurcula.* He gives no very distinctive characters by which this "genus" can be recognized except perhaps "completely devoid of ribbing". But during the adolescent stage of specimens from the type locality some show distinctly a mild type of ribbing (See Pl. 9, fig. 25). (No. 2518). These are Oligocene in age. However, *longipersa* from Alabama (fig. 24) (No. 2517), and closely related forms from Texas are from the Midway Eocene. Here then would seem to be a rather general, stabilized form of surculid, from which specialized branches might now and then be given off. (e.g. *Protosurcula*).

"Genus" **Protosurcula** Casey, 1904

Type.—*Surcula gabbi* (Con.) Casey, 1904, St. Louis Acad., Sci., Trans., vol. 14, p. 145.

Casey's definition.—In this genus and *Eosurcula* there is no trace of ribbing, and the moderately large species composing them may be considered allied more closely to the *Cochlespira* group than to any other; the embryo in both is conical or conoidal and multispiral, and, in *Protosurcula* is generally very large and with conspicuous longitudinal riblets on the lower whorls. The collar below the suture is cariniform and the long fasciolar surface between it and the obtuse periphery is broadly concave and with fine spiral lines; below the periphery the spiral lyræ are rather coarse. The columella is straight and generally simple, though sometimes having a strong plica above the middle. The spire tapers evenly to the apex and the beak is slender and frequently very long, the aperture and long, straight canal combined being much longer than the remainder of the shell in *gabbi,* which is assumed as the type.

Limiting this designation to *gabbi* and its near allies and certainly not including *plenta* A. and H., which seems to us of quite different radicle, we have forms with no ribbing in adolescent whorls, the well-developed, vertically ribbed embryo gives way immediately to whorls of adult spiral marking only.

The section or sub-genus *Protosurcula* would seem then to be but a specialized type of *Orthosurcula.*

In our use of the term *Protosurcula* it will be understood that only *gabbi*-like forms are referred to.

Turricula (Protosurcula, emen'd) **gabbi** (Conrad)
Plate 9, figures 26-31

Surcula gabbi Con., Am. Jour. Conch., vol. 1, 1865, p. 142, pl. 11, fig. 5.

Pleurotoma platysoma Heilp., Proc. U. S. Nat. Mus., 1880, p. 150, fig. 3.
Protosurcula gabbi Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 145.
"*Pleurotoma alveata*" Con., in Coll. Acad. Nat. Sci. Phila. (Labelled specimen.)

Conrad's original description.—Fusiform; volutions eight or nine, convex and subangulated beneath and indented above, with fine revolving lines, the indented space angular above, between which angle and the suture the striæ are largest, this indentation has minute, very closely arranged revolving lines, body volution with numerous rugose alternated lines, obsolete on the upper part of the volution; beak long and straight. *Locality,*—Texas.

In adult specimens there are twelve whorls, six of which are embryonic. Of the latter, the earlier two or three increase rapidly in size whereas the fourth and fifth increase less rapidly but appear most as large as the seventh whorl, or the first of the adult form. There is a faint, microscopic, very diagonal ribbing on the third embryonic whorl. Below, the ribbing becomes rapidly more pronounced and vertical, while spiral lines begin to appear, first below, and finally cover the surface of the fifth embryonic. A great change takes place at the junction of the embryonic and adult whorls; the vertical ribbing disappears entirely and the whorls are shaped and striated as described by Conrad. When specimens have been subjected to much erosion their sides appear rectilinear and smooth, and have received from Heilprin the specifiic name "*platysoma.*"

(See plate 9, figure 29.)

In the central Eocene areas of Texas this is a very common species. I have found it as far east as Lisbon, Ala.

Type.—Presumably the specimen in the collection of the Philadelphia Academy labelled in Conrad's hand-writing "*Surcula gabbi,* Texas."

Specimens figured.—Figures 26 (No. 2519), 28 (No. 2521), 30 (No. 2523), Smithville, Tex. 27 (No. 2520), near Columbus, Sabine River Figure 29 (No. 2522), near Columbus, La. Such specimens may be found wherever wave or current action took place.

Lower Claiborne Eocene.

Paleontological Research Institution.

"Protosurcula tenuirostris" Casey

Plate 9, figure 31

Protosurcula tenuirostris Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 145.

Casey's description.—Embryo, large but much narrower, the lower whorls similarly, though more coarsely, costulate, the upper smooth whorls forming a much more acutely elevated apex; subsutural surface broadly, feebly swollen and covered with numerous fine but strong carinules merging gradually into the small threads of the subjacent concavity; remaining characters nearly as in *gabbi*, the beak more rapidly tapering, very slender at the tip, the aperture and canal together but little longer than the remainder of the shell. Length of a specimen of five body whorls, 23.5mm.; width, 6.8mm. Lower Claiborne Eocene of Smithville, Tex.

Holotype.—Figure 31; Smithville, Tex. Lower Claiborne Eocene.

U. S. Nat. Mus. No. 494,360.

Turricula aldreperta, n. sp.

Plate 9, figures 32, 33

Specific characterization.—General appearance, large, fusoid as figured; whorls at least 10, of which the apical are missing in the type specimen; youngest whorls present show fusoid nodulation especially on the lower part of each whorl crossed by two deeply incised spirals; nodulation becomes obliterated on the three larger spiral whorls while at least three heavy spiral lirations become sharply defined; on the body whorl the next to the highest spiral is strongest, giving the medial part of the whorl a suggestion of a carination precisely as in *claibarena.*

This shell so closely resembles the last mentioned species that one naturally hesitates to put them under separate specific designations. But the details of the costæ, especially on the smaller whorls seem totally different.

Holotype.—Specimen figured; 25.5mm.; Claiborne, Ala.; Gosport sand horizon of the Claiborne Eocene.

Paleontological Research Institution. No. 2524.

"Pleurotoma (Clavatula) taltibia" De Greg.

Plate 9, figure 34

This form De Gregorio described and illustrated in his Monogr. Faun. Eocen de l'Alabama, 1890, p. 30, pl. 2, figs. 16-18, and states that it is 25mm. in length. He doubtless supposed it came from Claiborne. It certainly seems closely related to *"Pleurotoma nasuta"* Whitf. from the lower Sabine Eocene of Alabama.

"Subgenus **Pleurofusia**" De Gregorio, 1890

Pleurotoma (*Pleurofusia*) *longirostropsis* De Greg., Mon. Faun. Eoc. de l'Alab., 1890, p. 34, pl. 2, figs. 26, 27.

Characterization.—Testa fusiformis (*Fuso longirostri* Brocc. similis) elongata; costis, crassis, subnodulosis; funiculis spiralibus; spira acuminata; rostro oblongo angusto; rima apud suturam arcuata, insenataque ut in gen. surcula.

Under this heading De Gregorio would place the fusoid resembling Brocchi's *Fusus longirostris,* "These pleurotomas are provided with remarkable ribs, often coarse and heavy, and with spirals which often become veritable cords."

Pleurofusia claibarena, n. sp.

Plate 10, figures 1, 2

Specific characterization.—Form, long-fusoid as illustrated; smaller whorls not preserved in holotype; costæ, six or seven on each whorl, costæ obvious but not sharply defined, visible (except on body whorls) from suture to suture, but fainter across the sinus band; subsutural collar well defined; sinus band broad and sharply defined on body whorl; four strong spirals shown on each whorl, the second from uppermost slightly carinate; upper spirals on body whorl with interspaces showing fine spiral lines; below, an alternation of spirals.

There is a tendency in this species for the two spirals below the sinus zone to suggest a duplex carina as in *servata.* The extending of the nodular ribbing from suture to suture on all but the larger whorls distinguishes this form from *aldereperta.*

Holotype.—Specimen figured; 32mm.; Claiborne Alabama; Gosport sand horizon.

Paleontological Research Institution. No. 2525.

Pleurofusia servata (Con.)

Plate 10, figures 4 and 5

Pleurotoma servata Con., Phila. Acad. Nat. Sci., Proc. 1847, p. 284; Journal, *idem,* vol. 4, 1848, pl. 11, fig. 18.

Pleurofusia servata Casey, St. Louis. Acad. Sci., Trans., vol. 14, 1904, p. 152.

Conrad's original description.—Fusiform; whorls 10, with rounded longitudinal ribs and prominent strong revolving lines, a fine intermediate line on the body whorl; volutions concave above, with a carinated revolving line below the suture; beak narrow, elongated, slightly bent, acuminate; aperture and canal rather more than half the length of the shell. Length 9-10 [of an inch].

The specimens here figured in our collections from Vicksburg show the varying appearance of shells from that locality usually referred to *servata*. The general resemblance, yet difference in costation and striation from *claibarena* is apparent. Casey's "*vicksburgensis*" described below and herewith given as figure 3 unfortunately now lacks the apical characters on which he bases part of his description.

Paleontological Research Institution. No. 2526.

Pleurofusia vicksburgensis Casey

Plate 10, figure 3

Pleurotoma vicksburgensis Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 268.
Pleurofusia vicksburgensis Casey, St. Louis, Acad. Sci., Trs., vol. 14, 1904, p. 152.

Casey's original description.—This species occurs plentifully in the Vicksburgian beds, accompanying *servata* and generally confounded with it. It usually attains a little larger size and stouter form and may be distinguished at once by the fact that the whorl immediately adjoining the nucleus has a strong revolving line below the middle, thickened on the ribs and accompanied by a close-set smaller revolving line immediately above it. The larger whorls usually acquire two other coarse, though much smaller revolving lines, one above and one below the two mentioned, and also finer intermediate threads. Just below the suture the elevated collar is not quite so prominent as in *servata*, and, instead of the abrupt concavity adjoining, the surface is almost evenly concave and rapidly expanded to the system of coarse revolving lines referred to, this surface being also finely, evenly lyrate. The nucleus is much shorter than in *servata*, consisting of between two and three whorls, and is not higher than wide. The aperture and canal are nearly as in *servata*. One of the larger specimens before me measures 17mm. in length by 7 mm. in width. The double carina of the nepionic whorls remains throughout the most conspicuous feature of the revolving sculpture, the lines becoming gradually more nearly equal and more widely spaced, with the dilatations on the ribs much more pronounced than in *servata;* the ribs, also, are much more broadly rounded than in that species and become obsolete in the posterior concave area of the whorls.

The specimen herewith figured (fig. 3) is in the Casey type collection of the U. S. National Museum and hence is presumably the one from which the above diagnosis was mainly drawn. When more material is at hand the true relationship of this and *servata* as well as *claibarena* and *longirostropsis* can be more satisfactorily discussed.

Pleurofusia longirostropis De Greg.

Plate 10, figure 6

Pleurotoma (*Pleurofusia*) *longirostropis* De Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 34, pl. 2, figs. 26, 27.

De Gregorio's original description.—Testa fusiformis! elongata; anfractibus convexis; costis axialibus crassis rotundatis; funiculis spiralibus super costas decurrentibus; ex iis plerumque tribus majoribus quam aliis duobus in medio anfractus, alio prope suturam posticam; canali antico angusto elongatoque. L. 17mm. Ang. sp. 36°.

Coquille fusiforme, alongée, pourvue de 6 ou de 7 côtes lourdes émoussées. Sa surface est couverte de cordonnets et de filets spirals, dont généralement trois sont plus developpés que les autres; deux coïncident à la moitié des tours, formant une espèce de carène, le troisième tout près de la suture postérieure, dans le dernier tour il y en a plusieurs à le base où il arrive souvent qu'entre deux cordonnets il y en a un plus petit interposé. Sur la surface, à l'aide de la loupe, on distingue les marques d'accroissements, qui tout près de la suture sont courbées et arquées comme dans le gen. *Surcula*.

Elle a beaucoup d'analogie avec la *Pl. servata* Con. (1850) Conrad Obs. Eoc. form, and descr. 105 new foss. Vicksburg etc. p. 115, pl. 11, f. 18.) ; elle en diffère par le nombre et la disposition des cordonnets, qui dans la *servata* sont égaux entre eux disposés regulièrement. Je crois qu'en étudiant mieux plusieurs examplaires, de Vicksburg il pourrait arriver qu'on dut retenir la nôtre comme une variété de la même espèce. (Coll. mon Cabinet).

We have found nothing in the Claiborne sand of such exaggerated markings as De Gregorio's drawing indicates. However, whether one regards his *Pleurofusia* as a genus, a subgenus of *Turricula* or a mere section the name is convenient for designating these fusoid turrids with twin spiral carinæ.

Pleurofusia hilgardi Casey
Plate 10, figure 7

Pleurotoma hilgardi Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 270.
Pleurofusia hilgardi Casey, St. Louis Acad. Sci., Trs., 1904, p. 127, and 152.

Casey's original description.—From the Jacksonian of Moody's branch I have two species which appear to have been confounded with *servata,* though differing radically therefrom in the structure of the nucleus. One, named as above, is almost similar to *servata* in size, form and in the number and form of the slightly oblique rounded ribs, but has the raised revolving lines, some eleven or twelve in number, subequal in size among themselves and becoming only silghtly larger on the anterior parts of the whorl. The nucleus differs very radically from that of *servata* or *oblivia,* being small, obtuse and composed of only one and half or two whorls. The canal also is decidedly shorter. Length 16mm.; width 5mm.

The figure herewith given (fig. 7) is of the type specimen by the official photographer of the U. S. Nat. Museum. Museum catalog No. 481,669.

This might well be compared with *huppertzi* of the Lower Claiborne horizon of Texas, and *plutonica* Csy. (Pl. 10, figs. 30, 31).

Pleurofusia collaris Casey
Plate 10, figure 8

Pleurotoma collaris Casey, Phila. Aca. Nat. Sci., Proc., 1903, p. 270.
Pleurofusia collaris Casey, St. Louis Acad. Sci., Trs., vol. 14, pp. 127, and 152.

Casey's original description.—This is the second species from Moody's Branch referred to under the preceding description. It is stouter with a still shorter canal, the aperture and the canal constituting about two-fifths the entire length of the shell. The nucleus is small, obtuse and of about two whorls. Body whorls about seven in number, each with some seven or eight obtuse ribs and a wide and strongly elevated conspicuous collar just below the suture, the upper surface of the collar declivous to the suture and having two close-set revolving striæ, the lower part acutely elevated. The surface below the collar is deeply concave then rapidly expanding to the posterior of the three strong raised lines which occupy about anterior half of the whorl. The concavity is marked with many very fine close-set revolving lines and the spaces between the three larger lyræ referred to also have each about three fine lines. Length 17mm., width 6mm.

The figure herewith represented is by the Museum official photographer, U. S. Nat. Museum Catalog No. 481,668.

Turricula (Pleurofusia?) huppertzi (Har.)
Plate 10, figures 9, 10, 11

Pleurotoma huppertzi Harr., Proc. Phila. Acad. Nat. Sci., 1895, p. 58, pl. 4, fig. 9.

Original description.—Size and general form as indicated in the figure; whorls 11, 1 and 2 smooth, 3-10 somewhat inflated submedially, longitudinal costæ obtuse, most prominent submedially almost vanishing on the subsutural portions of the whorls, becoming short and nodular on the upper whorls, prominently striate spirally, the striæ often irregular and waving on the median portions of the whorls; body whorl costate and spirally striate, striæ becoming of alternate strength on the beak.

Localities.—Bombshell Bluff, Colorado River about 1.5 miles west-northwest of Devil's Eye; Smithville, Bastrop Co., Tex.

Type as shown by fig. 9, deposited in the Texas State Museum from Smithville, Tex. Museum No. 747.

Figure 10 (No. 2527) shows a large specimen with low ribs, from Smithville, Tex., grading towards var. *hammettensis.*

Figure 11 (No. 2529) shows a more typical outline but with *penrosei*-like carination beginning to appear, also from Smithville, and represents Lower Claiborne forms. Paleontological Research Institution. Nos. 2527, 2529.

Var. **hammettensis**, n. var.
Plate 10, figure 10a

This variety carries to an extreme the broad nodulations noted under figure 10. Exact locality in N. W. Louisiana unknown, most probably from Hammett's Branch. Lower Claiborne Eocene.

Paleontological Research Institution. No. 2528.

Surculoma, Casey, 1904
Turricula ("Surculoma") penrosei (Har.)
Plate 10, figure 13

Pleurotoma huppertzi, var. *penrosei* Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 58, pl. 4, fig. 10.
Surculoma penrosei Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 154.

Differentiated from *huppertzi* by Harris, *op. cit.* as follows: "Differs from typical *huppertzi* in having the whorls more acutely carinated, the striation above the carina is evanescent, and the length of the canal is often less in proportion to the height of the spire."

Casey says (*op. cit.*): "*Penrosei* Harr., which was published by its author as a variety of *huppertzi*, is in no way closely related to that species, having a radically different embryo as well as a different position of the anal sinus."

Certainly Casey must never have endeavored to separate these forms when a considerable number of specimens were available.

Type.—Specimen No. 748, Tex. State Museum, Smithville, Tex. Lower Claiborne Eocene.

Specimen herewith figured.—Smithville, Texas. Paleontological Research Institution. No. 2531.

Var. **tabulella**, n. var.
Plate 10, figure 12

Broader, more finely striate, and with more pronounced trace of an umbilicus than is usual in *penrosei*.

Holotype.—Wautubbee, Miss., Lower Claiborne Eocene.

Paleontological Research Institution. No. 2530.

Turricula (Surculoma) stantoni (Vaughan)
Plate 10, figure 14

Pleurotoma stantoni Vn., U. S. Geol. Surv. Bull. No. 142, 1896, p. 34, pl. 2, fig. 5.
Surculoma stantoni Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 154.

Vaughan's original description.—Form and size indicated by figures. Whorls, 9½; 1 and 2 smooth (embryonic), 3-9½ costate. On whorl 3 there are nine costæ; the body whorl has eleven. The last two whorls are distinctly carinate. The area between the carina and the suture is concave, and in it the longitudinal folds are almost obsolete. Surface ornamented with minute crowded spiral striæ, which below the carina are wavy and frequently not continuous. Canal slightly curved.

This species is closely related to *Pleurotoma huppertzi* var. *penrosei* Harris, but it is smaller, the last two whorls are more strongly carinated, the costæ are more numerous, the length of the aperture relatively to the spire shorter, and the canal is curved.

Locality.—St. Maurice (Vaughan).
Geological horizon.—Lower Claiborne.
Type in the United States National Museum.

Figure 14 is a reproduction of a pen-and-ink sketch we made of the type specimen some 30 years ago.

Turricula (Surculoma) leoncola (Harris)
Plate 10, figure 15

Pleurotoma leoncola Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 58, pl. 5, fig. 1.

Harris' original description.—General form and size as indicated by the figure; whorls 9; apical 1½ smooth, rather large, remaining whorls carinated centrally and with evenly arranged rather low but distinct costæ, more prominent below the carina than above it, twelve in number on the body whorl; surface microscopically striate spirally, and with very fine lines of growth; aperture a little over one half the length of the shell; columella long and slightly twisted below.

Locality.—7 miles south of Jewett, Leon Co., Tex.

Geological horizon.—Lower Claiborne Eocene.

Type.—Collection of T. H. Aldrich, Birmingham, Ala.

We have no additional information on this species.

Turricula (Surculoma) dumblei (Har.)

Plate 10, figure 16

Pl. (*Drillia*) *dumblei* Harris, Phila. Acad. Nat. Sci., Proc., 1895, p. 59, pl. 5, fig. 2.
Surculoma dumblei Casey, St. Louis Acad. Sci., Trans., vol. 14, 1905, p. 154.

Harris' original description.—Size and general form as indicated by the figure; whorls about 10, strongly carinated, concave above, convex below, spiral striæ much more noticeable below the carina than above it; beak short, twisted, umbilicated.

Locality.—? Smithville, Tex.

Geological horizon.—Lower Claiborne Eocene.

Type.—Texas State Museum.

No additional material of this species has come to our attention.

Turricula (Surculoma) tabulata Conrad

Plate 10, figure 18, 18a

Pl. tabulata Con., Foss. Sh. Tert. Form., 1833, p. 46, 1835, p. 50, pl. 17, fig. 14.
Pl. cœlata Lea. Cont. to Geol., 1833, p. 132, pl. 4, fig. 123.
Surcula tabulata Con., Amer. Jr. Conch., 1865, p. 19.
Pl. (*Raphitoma*) *cœlata* de Greg., Ann. de Geol., 7e liv., 1890, p. 42, pl. 3, fig. 2.
Amblyacrum tabulatus Cossm., Ann. de Geol., 1893, 12me liv., p. 46, pl. 2, fig. 24.
Amblyacrum tabulatum Cossm., Paléo. Comparée, 1896, 2e liv., p. 138.
Surculoma tabulata Casey, Trans. Acad. Sci., St. Louis, vol. 14, 1904, p. 154.
Surculoma tabulata Cossm., Paléocon., liv. 7, 1906, p. 222, and on Pl. 14, figs. 14 and 15.

Conrad's original description.—Turrited or scalariform volutions eight; cancellated with fine striæ, the spiral ones most distinct; angle of the whorls somewhat carinated; profoundly umbilicated.

On page 50 of Foss. Sh. (1835) &c Conrad puts Lea's *cœlata* in synonymy, gives Claiborne as the locality for the species and remarks: "This species most resembles the *P. dentata* Lam. but is very distinct."

This species is well represented in the Philadelphia Academy's collection (seemingly Conrad's type material) by 6 specimens and there appears to be no reason for regarding Lea's *cœlata* as a distinct species. There is more doubt in the case of de Gregorio's *Pl.* (*Raphitoma*) *rignana* as given in his Annal. de Geol., 1890, p. 42, pl. 3, fig. 1. Cossmann regards it as simply an imperfect form of *tabulata*.

The proper generic name for this species seems difficult to determine, but Casey has taken the easy method of establishing a new name, *Surculoma* for this and three other American species, viz., *penrosei* and *dumblei* of Harris and *stantoni* of Vaughan. The assignment of the species to *Amblyacrum* by Cossmann seems almost wholly on account of embryonic characteristics. The assignment of *dumblei* to this section of turrids is doubtless legitimate, but the *penrosei* forms are too difficult to separate from the *huppertzi* representatives to allow of this assignment.

The umbilical feature becomes extremely developed occasionally as shown by the specimens in the Academy's collections. Meyer in making his type drawings for Aldrich sketched "the only perfect specimen" he found of Lea's *cœlata* (which lacked the smaller spirals, however) and pencils on the card these remarks "type specimen?. I think the type specimen of this species is on the type board of *Pleur. Londalii*". Without knowledge of Meyer's observations, in cataloging the Lea type material I sélected a specimen and gave the number 5684 to the same and added this remark "Found on a card marked *Pl. lonsdalii*".

Holotype.—The well preserved specimen in the Philadelphia Academy's collection illustrated by Conrad in 1835. It is 30mm., in length; Conrad's figure is a slight enlargement (34mm.) Lea's *cœlata* is but 19mm. in length.

Specimens figured.—Fig. 18, 18a, Claiborne, Ala., Gosport sand horizon.

Paleontological Research Institution No. 2532.

Var. rignana De Gregorio

Plate 10, figure 17

Pleurotoma (*Raphitoma*) *rignana* De Greg., Mon. Faun. Eoc. de l'Ala. 1890, p. 42, pl. 3, fig. 1.

With the great variability shown among specimens of *tabulata* there would appear to be no reason why this "species" cannot be placed as perhaps a mere form of Conrad's species. De Gregorio remarks: "C'st une espèce très voisine de la *cœlata* Lea et de la *tabulata* Conr.; elle diffère de la prèmière par les côtes plus développées et moins nombreuses, et de la seconde par l'angle spiral plus grand et par la forme plus accourcie. Coll. mon Cabinet".

We have observed no specimens from Claiborne nor elsewhere quite so broad proportionally as this.

Section **Volutapex**, n. sect.

Perhaps more nearly related to the group of Turriculas called *Surculoma* by Casey than to any other stock are certain following species showing a bluntly mammilate apex, a pronounced subsutural collar, spiral striation most obvious anteriorly and ribbing having typically a vertically pinched appearance thus producing whorls of a more or less carinated aspect. *Surculoma calantica,* n. sp., may be regarded as typical of this section, though *falsabenes, sabinicola, subequalis* and perhaps *kellogi* may likewise be included.

Surculoma calantica, n. sp.

Plate 10, figure 19

Specific characterization.—Size and general appearance as indicated by the figure and explanation; embryonic whorl unusually large and obliquely located; spire and body whorl with four types of ornamentation: first, a strong subsutural collar; second, a carina below the center of the larger whorls, and decidedly below in the smaller volutions; third, low broad ribs, about five on the body whorl and generally about six on the whorls above, where the carina more or less obliterates their individuality; fourth, a few microscopic lines on the humeral zone, more pronounced ones on the lower portion of the body whorl or beak.

A specimen of this species is in the National Museum labelled *Peratotoma dalli* Coss. No. 137,409.

Holotype and specimen figured.—Gosport sand, Claiborne, Ala.

Paleontological Research Institution. No. 2533.

Surculoma sabinicola, n. sp.

Plate 10, figure 20

Specific characterization.—General fusoid form as figured; whorls about 8, 1, 2, large, smooth and not greatly dissimilar in size; remaining spiral whorls with strong, blunt, somewhat obliquely inclined costæ, crossed on lower half by well-defined striæ or lirations; subsutural collar well marked; no sharp medial carination.

The narrow, turrited form makes this species quite different in appearance from its various allies.

Holotype.—Fig. 20; Sabine River section, near Columbus, La. Lower Claiborne Eocene.

Paleontological Research Institution. No. 2534.

Surculoma falsabenes, n. sp.

Plate 10, figure 21

Specific characterization.—Shell of general fusoid appearance as figured; apex of a blunt, volutoid appearance, of about 1½ whorls; smooth; remaining whorls somewhat carinate, costæ broad and vertically pinched at the carination, covered with fine undulating spiral lines; subsutural band light but obvious.

The costation of this species is sharper and more confined to the median portion of the whorls than in *sabinicola* or *kellogi.*

Holotype.—Figure 21, found with the preceding.

Paleontological Research Institution. No. 2535.

Surculoma subequalis (Con.)

Plate 10, figures 22, 23

Pleurotoma subequalis Con., Foss. Sh. Tert. Form., 1835, p. 51, pl. 17, fig. 18.
Surcula subequalis Con., Am. Jr. Conch., vol. 1, 1865, p. 19.
Pleurot. (*Strombina*) de Greg., Mon. Faun. Eocene &c, 1890, p. 27, pl. 1, fig. 80.
Surculoma? subequalis Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 154.

Conrad's original description.—Fusiform; whorls angular, tuberculated on the angle, and with minute revolving striæ; body whorls ventricose; beak rather longer than the spire.

Locality.—Claiborne, Ala.

Found typically only in the Gosport sand horizon at Claiborne, Ala., varietal forms at Hickory, Miss.

Holotype.—Conradian collection, Phila. Acad. Nat. Sci., from Claiborne, Ala. The striation is very faint on the holotype.

Figure 23 (No. 2536) of a varietal form from Newton, Miss.; Lower Claiborne Eocene. Paleontological Research Institution.

Surculoma? kellogi (Gabb)

Plate 10, figure 24, also probably 24a

Turris kellogii Gabb, Jr. Phila. Acad. Sci., vol. 4, 1860, p. 379, pl. 67, fig. 10.
Surcula kellogii Con., Am. Jr. Conch., vol. 1, 1865, p. 18.
Pl. (*Drillia*) *kellogi* Harris, Proc. Phila. Acad. Nat. Sci., 1895, p. 60, pl. 5, fig. 6.

Gabb's original description.—Elongate fusiform, whorls eight; mouth narrow, about two-fifths the length of the shell; inner lip slightly thickened; outer lip simple; posterior sinus wide, rounded, canal straight; surface marked by six or seven large longitudinal ribs crossed by very numerous fine, revolving striæ; suture deep.

Dimensions.—Length .5in.; length of mouth .2 in.; width of body whorl .15 in.

Locality.—Wheelock, Texas.

This species resembles Lea's figure of *P. lonsdalii* in its markings, but is smaller and is both proportionally more narrow and has a larger mouth.

In the Proc. Phila. Acad. Sci., above referred to I have made the following remarks:

The two type specimens in the Philadelphia Academy's collection differ but little from the specimen herewith figured. The only point worthy of note is that in those specimens the length of the aperture is not quite so great in comparison with the whole length of the shell.

This species is characterized mainly by its slim spire, blunt apex and raised line at the suture.

Specimens figured.—Figure 24, copied from Harris, see above reference, from Hurricane Bayou, near Crockett, Houston Co., Tex. Texas State Museum No. 853. Figure 24a is from near Columbus, La.; 24b is the *Pl.* (*Drillia*) *fita* De Greg., Mon. Faun. Eoc. de l'Ala., pl. 2, fig. 39 which though obscurely delimited may belong near here.

Figure 24a is in the Paleontological Research Institution. No. 2537.

Tropisurcula Casey, 1904

Genotype.—*Pl.* (*Drillia*) *caseyi* Ald. The Nautilus, vol. 16, 1903, p. 97, pl. 3, figs. 1, 2.
Tropisurcula caseyi Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 153.

Of the two species Casey refers to this "genus" *caseyi* is the first mentioned, hence may be assumed to be the genotype.

Casey's generic definition.—The shell in this genus is small in size, of slender form, with moderately elongate and slender beak and narrow, closely coiled, multispiral embryo, which is higher than wide, and perfectly smooth and polished throughout. The ribs are about equal in number to those of *Pleurofusia* but culminate in transverse prominences at the summit of an angulate median periphery, and sometimes become gradually feebler on the larger whorls. The spiral lines are subequal among themselves, relatively rather coarse but low, and very close-set throughout.

Tropisurcula caseyi (Aldr.)

Plate 10, figures 25, 26

Pleurotoma (*Drillia*) *caseyi* Aldrich, The Nautilus, vol. 16, 1903, p. 97, pl. 3, figs. 1, 2.
Tropisurcula caseyi Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 153.

Aldrich's original description.—Shell fusiform, whorls ten or eleven, first four smooth, apex pointed, the balance of the whorls nodular with a connecting line situated at the periphery. About nine nodes on each whorl. The balance of the spiral sculpture consists of close-set, rounded lines, which are stronger on the lower part of each whorl; suture nearly concealed by a strong raised and rounded band which is wavy and closely appressed. On the humeral area the spiral lines are cut by fine curved lines formed by the former retral sinus, sinus nearly semicircular. Canal open and slightly spatulate.

Length 11mm., width 3mm.

Localities.—Red Bluff, Miss.; Bryam's Ferry, Pearl Rv., Miss., and Vicksburg, Miss.

Resembles *Drillia texanopsis* Harris, but is carinated at the periphery more strongly striated and with a deeper retral sinus.

Aldrich does not say from which locality he obtained the co-types he figures, but mentions Red Bluff first and as the species is common there we presume this to be the type locality.

Figure 26 (No. 2538) is of a specimen we obtained at Red Bluff, Miss.

All come from an Oligocene horizon. Paleontological Research Institution.

Tropisurcula crenula Casey

Plate 10, figure 27

Tropisurcula crenula Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 153.

Casey's description.—Ribs seven or eight in number, more broadly rounded [than in *caseyi*], very prominent on the angulate periphery, becoming rapidly obsolete below, and usually wholly effaced on the fasciolar surface above the periphery especially on the larger whorls; spirals rather wide but feebly elevated, close-set and subequal throughout but still feebler on the fasciolar surface; embryo acute at tip, of five smooth and highly polished whorls, narrowing more rapidly above the two basal whorls, the apex very small. Length of a specimen of 4 body whorls, 7.5mm.; width, 2.5mm. Lower Claiborne Eocene of St. Maurice, La.

The figure of the type specimen (courtesy U. S. Nat. Museum) scarcely shows the characteristics as described well by Casey but there can be little doubt but that it is close to the varietal form designated below.

Var. **sabines**, n. var.

Plate 10, figure 28

A form with its smooth, many whorled embryo, paucicostate spiral whorls, vertically compressed nodules, evident subsutural band, open and deflected canal and rather thin shell structure from the Sabine River section near Columbus, La., Lower Claiborne Eocene.

Probably but a variety of *crenula* as described above from St. Maurice.

Paleontological Research Institution No. 2539.

Surculoma? floweri, n. sp.

Plate 10, figure 29

Specific characterization.—Whorls 8; 1 and 2 smooth, forming a rather blunt apex; remaining whorls showing more pronounced costation with increase of size of whorls while prominence of subsutural collar decreases in the same direction; costæ, about 10 to 12 on each whorl crossed by spirals deeply incised; a slight obliquity in direction of costæ noted, somewhat as in *sabinicola* while the general spiral expression is that of the Clairbornian *rugatina.*

Holotype and specimen figured.—Smithville, Texas; Lower Claiborne Eocene; Paleontological Research Institution. No. 2540.

Turricula plutonica Casey

Plate 10, figure 31

Pleurotoma plutonica Casey, Philad. Acad. Nat. Sci., Proc., 1903, p. 271.
? Plutonica Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 158.

Casey's original description.—Not rare in the Lower Vicksburg limestones. This species is rather slender, perfectly smooth and polished throughout, with scarcely a trace of revolving sculpture except on the beak, where there are some oblique, widely spaced striæ. The nucleus is smooth, acutely ogival, higher than wide and of about four whorls. The subsequent whorls have each about eight low rounded oblique ribs, which become obsolete in a revolving cavity below the suture. The first three, or thereabouts, of the body whorls have a rather pronounced, though obtusely rounded, swelling adjoining the suture beneath, but this is gradually lost on the larger whorls, these having but feeble traces of a raised band at the suture, the latter being a very fine, slightly sinuous and feebly impressed line. The canal is well differentiated from the aperture, and the two combined constitute about three-sevenths of the total length of the shell. Length 12mm.; width 3.7mm. Another specimen, represented by the spire alone, indicates that the species may attain a length of fully 15mm. or more. There is no trace of this species in the upper marl.

The specimen figured represents the one now deposited in the U. S. National Museum, numbered 481,667.

Var. **weisbordi**, n. var.

Plate 10, figure 30

Much larger specimens and with stronger spiral striation occur in the Jackson Eocene at Danville on the Ouachita, La., which when worn seem very close to *plutonica.* To what extent erosion has polished the surface of the latter remains to be seen when more adequate material is collected.

Paleontological Research Institution. No. 2541.

Turricula prosseri Harris

Plate 10, figure 32

Pleurotoma (Drillia) prosseri Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 60, pl. 5, fig. 5.
? prosseri Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 158.

Harris' original description.—Size and general form as indicated by the figure; whorls about 8; 1, 2, and sometimes 3 smooth; 4, 5, 6, 7, polished, a slightly raised band just below the suture, costæ large, obtuse and somewhat obliquely set; body whorl with subsutural band not well defined, humeral area slightly concave and gently waved by the upper extension of the ribs, which are very large below; beak slightly striate spirally.

Localities.—Near Smithville, Bastrop Co.; Little Brazos River on Moseley's Ferry road, near Crockett, Houston County.

Geological horizon.—Lower Claiborne Eocene.

Type.—Texas State Museum.

This species is distinguished from *huppertzi, kellogi* and varieties by its polished surface, its more pointed apex and length and obliquity of the ribs and its size.

Not having collected in these localities more recently we have no new data regarding this form.

Turricula ( ) danvicola, n. sp.

Plate 10, figure 33

Specific differentiation.—Size and form as indicated by the figure; whorls about 9; two embryonic whorls smooth, remaining whorls with about 8 low, broad ribs extending from suture below to subsutural band above in the lesser spiral whorls but limited to the basal portion of the larger whorls; large whorls noteworthy for the constriction at the sinus zone and for the unusual strength of the spiral lines on this zone and anteriorly on these whorls; body whorl devoid of ribbing but strongly spirally striate throughout.

Holotype and specimen figured.—Jackson Eocene at Danville, La. Paleontological Research Institution. No. 2542.

Turricula ( ) fluctuosa Weisbord's MS

Plate 11, figure 1

Specific characterization.—Rather large and fusoid as figured; whorls 9; 1 and 2 small and smooth; 3, at least partially costate vertically from suture to suture; remaining whorls with but few (generally six) very heavy obtuse, broad ribs extending nearly to the upper suture; sharply defined, alternating spirals cover the whole whorl, except the very narrow sinus band; canal long, open, straight.

The sharply ornamented exterior, the breadth of the somewhat obliquely inclined ribs and the narrow, high-located sinus band distinguish this at once from other Gulf Coast pleurotomids. In general appearance this species resembles rather closely the *Pl. olivacea* Sow., as figured by Reeve, 1843, Icon., pl. 4, fig. 27, from the Pacific Panamic region. The living form is larger and broader however, and with one or two more ribs per whorl. Several of the English forms from the Mid-Eocene as figured by Edwards have a general aspect like *fluctuosa*, but have many more ribs per whorl.

Type and specimen figured.—Bunker Hill, La.; Jackson Eocene; Paleontological Research Institution. No. 2543.

Sub-genus **Plentaria,** n. sub-gen.

Type.—*Pl.* (*Borsonia*) *plenta* Ald. & Har., 1895, Phila. Acad. Sci., Proc., p. 63, pl. 5, fig. 11.

Casey in 1904 (St. Louis Aca. Sci., Tr., p. 144) placed species *plenta* in his newly established genus *Protosurcula* along with *gabbi*, its genotype, regarding columellar plaits as of but little taxonomic importance. This may be a correct view for columellar thickening, granulation, or even folding affecting adult or gerontic stages only; but where the folds are persistent throughout growth it would seem they should receive due consideration.

That this shell belongs to the surculoid branch of our Eocene fauna and not to Bellardi's *Borsonia* (*prima*, genoytpe) is quite obvious on account of general form, and ornamentation; but that it should be classed with *Protosurcula* seems questionable. The latter has a deep, narrow sinus, with large, vertically ribbed protoconch, sharply defined from the later, non-costate whorls. *Plentaria* has a protoconch with early spiral ornamentation and broad sinus closely resembling the same in *Eosurcula* or even *Orthosurcula*. *Eosurcula*, too, has interior labial plications.

The carinal ornamentation consists of vertically pinched crenulations bisected by a spiral incision. Fainter and simpler crenulated spirals occur below the carinal.

Turricula (Plentaria) plenta (Ald. and Har.)

Plate 11, figures 2, 3, 3a

Pl. Borsonia plenta Ald. and Har., Proc. Acad. Nat. Sci., Phila., 1895, p. 63, pl. 5, figs. 11, 11a.

Protosurcula plenta Casey, St. Louis Acad. Sci., vol. 14, 1904, p. 145.

Original description.—General form as indicated by the figure; whorls 13 or 14; 1, 2, 3, smooth, globose; 4 slightly nodular or subcostate submedially and with an elevation just below the suture; 5, 6, 7, subcarinate with nodes on the carinæ; 8, 9, 10, 11, carinate submedially, carina bisected by a depressed spiral line; space between the carina and suture above concave, transversed by about six spiral striæ of equal size, with a slightly elevated band just below the suture; 12 and 13 obtusely carinate with about six fine lines above and four below; body whorl finely striated above the carina and for a short distance below, thence coarsely or alternately striate to the end of the canal; outer lip sharp, liræ within exclusively confined to the inflated portion of the shell and disappearing some distance before reaching the margin of the lip; inner lip very thin showing only on well preserved specimens; columella with one strong plait located three-fourths of the way from the base to the upper terminus of the aperture.

In a few specimens there are traces of a second plait on the columella a short distance below the one referred to above.

Some specimens even show a third plait below the second, though this is very rare. Within the outer lip there are three or four well marked spirals the upper generally the largest.

Holotype.—Specimen No. 856, Univ. of Texas Coll. from Moseley's Ferry, Texas; Fig. 2. Lower Claiborne Eocene.

Figure 3a, (No. 2544) Moseley's Ferry; Lower Claiborne Eocene; Paleontological Research Institution.

Var. **horrida**, n. var.

Plate 11, figures 4, 4a

Varies from the type form in carrying down the bi-partite nodulation nearly to the body whorl and showing stronger spiral ornamentation throughout.

Holotype.—Fig. 4 (No. 2545); near Columbus, La.; Lower Claiborne Eocene. Paleontological Research Institution.

Figure 4a is a copy of our fig. 11a, Phila. Aca. Nat. Sci., Proc., 1895, pl. 5; Moseley's Ferry, Tex.; Lower Claiborne Eocene; Texas State Museum material.

"Pleurotoma (Pleuroliria?) subdeviata" De Gregorio

Plate 11, figure 5

Pleurotoma (*Pleuoliria?*) *subdeveata* De Greg., Mon. Faun. Eoc. de l'Ala., 1890, p. 40, pl. 2, fig. 51.

De Gregorio's original description.—Testa fusiformis, turrita, anfractibus tricarinatis; ex carinis duabus majoribus anticis appropinqunatis, caetera apud suturam posticam; filis spiralibus confertis; labro externo intus plicato, plicis oblongis, rima non distante a sutura, fere ut in gen. surcula.

De Gregorio's remarks (*translated*).—This species by the disposition of the carinas and by the form of the growth lines much resembles *Pl.* (*Pleurofusia*) *titrapa* De Greg.; it differs by the lack of axial ribs, and by the plications of the outer lip.

It is analogous to *Pl. tizis supramirifica,* but differs from it by the slit which does not coincide with the peripheral angle of the whorls nor with the carina, but with the depression interposed between the median carina and the sutural carina. It differs otherwise by the form and disposition of the carinas, of which there are three, as in *tizis,* but differently disposed; that is to say the two anterior approach each other while the posterior is near the suture.

This species is quite analogous to *Pl. helicoides* Edw. (Eoc. Moll. p. 319, pl. 32, fig. 7). It much resembles *Pl. decliva* Con., (Con. 105 new foss. Vicksb., p. 116, pl. 11, fig. 27.), but the description given by Conrad does not correspond with the characters of our shells. At any rate it should be considered as a good variety, on the other hand the limits between this species and *Pl. cochlearis* Conr. may be quite effaced. (Coll. mon Cabinet).

We have found nothing at Claiborne corresponding to this form as described and sketched by De Gregorio.

Cordieria Rouault, 1848

Cordieria biconica (Whitf.)

Plate 11, figures 6, 6a

Mitra biconica Whitfield, Amer. Jour. Conch., vol. 1, 1865, p. 263.

Whitfield's original description.—Shell slender, fusiform; spire elevated; volutions six or seven, slightly convex, with a narrow depression just below the upper margin; suture well marked; body whorl somewhat gradually tapering below its most convex portion; aperture long and narrow; columella strong; with two distinct very oblique folds a little above the middle of its length; surface of the volutions marked by strong longitudinal folds, about nine on the body whorl; entire surface covered with very fine revolving striæ.

Dimensions.—Length of specimen ¾ inch.

Locality.—Six miles below Prairie Bluff, Ala.

Since this species was described without figuring there may seem to be some doubt about its relationships to similar forms in the Gulf Coast Eocene. In my Texas Eocene MS. I find the following note:

It is with some hesitation that the specimens in hand (Texas material, 1893) are referred to *biconica.* The expressions "shell slender" and "very oblique folds" are scarcely applicable to the Texas form. Again, as shown by the figure, this is a pleurotomoid species and not a *Mitra* at all. Specimens submitted to Mr. Whitfield could not be identified by him with certainty owing to the fact that 'the types are no longer accessible,' but he was inclined to regard them as but 'individual variations' of his '*Mitra biconica.*' "

However, during Mrs. Palmer's recent researches for Claiborne and gastropod type material it became evident that Whitfield's monotype might be in the Walker Museum of the University of Chicago. And, through the kindness of Curator A. W. Slocum we were able to borrow and figure this more or less doubtfully-known species (See Pl. 11, figs. 6, 6a). Fragments of this elongate form are not rare at Lisbon, Ala., where Whitfield's specimen was evidently found. They may be also found about Newton, Miss., but as a rule these lower Claibornian forms are shorter (figs. 7, 7a) and sometimes more coarsely striate (fig. 8).

Var. **curta**, n. var.

Plate 11, figures 7, 7a

Specimens varying from the type by slightly more pronounced spiral striation, broader form, and faint suggestion of median carination.

Holotype.—Fig. 7, from Hickory, Miss.; Claibornian.

Paleontological Research Institution. No. 2546.

Var. **newtonensis**, n. var

Plate 11, fig. 8

Specimens varying from type by much coarser spiral striation and broader form; and less from *curta* by stronger striation and more pointed apex.

Holotype.—Fig. 8; from Newton, Miss.; Claibornian.

Paleontological Research Institution. No. 2546a.

Cordieria ludoviciana (Vaughan)

Plate 11, figures 9 and 10

Borsonia ludoviciana (Vn.), U. S. Geol. Surv. Bull. 142, 1896, p. 34, pl. 2, figs. 6, 6a.
Cordiera ludoviciana Casey, St. Louis Acad. Sci., vol. 14, 1904, p. 161.

Vaughan's description.—For size and form consult figures. The specimen represented in fig. 6, pl. 11 has 11 whorls; 1 and 2 are smooth; the remaining are crossed by longitudinal folds which are most prominent submedially and tend to vanish in the sutural region. Suture margined inferiorly by a strong elevated revolving line; surface ornamented by prominent spiral lines, which alternate in size on the older volutions (9-11). Whorl 3 has about nine small costæ; whorl 4, eight costæ; 7-11 have six each. Fig. 6a, Plate II, represents the last whorl of an older specimen, showing that this whorl becomes carinate. In the region of the retral sinus the revolving lines are not so prominent. The columella possesses two strong folds, the upper being the most prominent. On the old specimens, only the last whorl of which is drawn, there is a rudimentary third fold.

This species is closely related to *B. biconica* Whitfield. It is larger and the spiral sculpture much coarser.

Locality.—Montgomery, (Vaughan).

Geological horizon.—Jackson.

Type in the United States National Museum.

By consulting our figure 9, from a specimen obtained from Town Branch, Jackson, Miss., it will be observed that the ornamentation is rather coarse as mentioned by Vaughan. When compared with *biconica* (figs. 7, 8.) the difference between the two species is obvious. Our specimens from Wautubbee and Hickory are clearly of the *ludoviciana* rather than the *biconica* stock though the spiral liræ are scarcely so strong as in the former species.

Specimens figured.—Fig. 9, No. 2547, Jackson, Miss.; Fig. 10, (No. 2548), Wautubbee; fig. 10a, (No. 2549), Newton, Miss.

Geological range.—Lower Claiborne-Jackson Eocene.

Paleontological Research Institution.

Genus **Cochlespiropsis** Casey, 1904

Genotype.—*Cochlespira engonata* Con., Amer. Jr. Conch., vol. 1, 1865, p. 142, pl. 21, fig. 12.
Cochlespiraopsis engonata Csy, St. Louis Acad. Sci., Trans., vol. 14, 1905, p. 143.

Of the two species mentioned *engonata* is the first hence may be assumed as typical for this genus.

Casey's description.—This genus is allied to *Cochlespira*, but differs greatly in having the beak obliquely elevated near the tip, the periphery of the whorls simply angulate in profile and not lamellarly expanded, reflexed or crenulate and the sculpture extremely minute and feeble, close-set and even, wholly differing in character from that prevailing in *Cochlespira*. The genus seems to have become extinct by th middle of the Eocene, not occurring above the Lower Claiborne, and, in fact, so far as known limited to that epoch.

Cochlespiropsis engonata (Con.)

Plate 11, figures 11-15

Turris cristata Gabb (Var. Con.,) Phila. Acad. Nat. Sci., vol. 4, 1860, p. 378, pl. 67, fig. 12.

Cochlespira engonata Con., Amer. Jour. Conch., vol. 1, 1865, p. 142, pl. 21, fig. 12.
Cochlespiropsis engonata Casey, 1904, St. Louis Acad. Sci., Trans., vol. 14, p.143.
Cochlespiropsis blanda Casey, *ibid.*
Rouaultia engonata Cossmann, Pal. Comp., liv. 7, 1906, p. 221, pl. 14, fig. 13.

Conrad's original description.—Fusiform; spire elevated, whorls seven, terebriform, with minute, wrinkled revolving lines, obsolete above the angle, which is carinated and obscurely crenulated; beak produced, reflected at the end.

Length.—1⅛ inch.

Locality.—Claiborne and Texas.

Conrad was somewhat uncertain as to the proper generic nomenclature to be employed in discussing this form. In the Philadelphia Academy the type specimen bears the name *Pl.* (*Cochlespira*) *engonata* in his handwriting.

Casey instituted the new generic name for this shell since he regarded "*cristata*" of the Vicksburg series as the type species of *Cochlespira*. But Cossmann made the statement in 1895 (Pal. Comp., p. 68) that *engonata* is the type species of *Cochlespira*. This he seems later to have doubted (Pal. Comp. '96, p. 221) and regards "*cristata*" as the type. Unfortunately for his studies an imperfect specimen was evidently sent him in which the V-shape break at the periphery gave the appearance of indicating that the retral sinus was located there as in *Rouaultia*. (See his fig. 13, pl. 14.) Again, this imperfect figure probably was at the base of the interpretation given by Grant and Gale (San Diego Soc. Nat. Hist., Mem., vol. 1, 1931, p. 504) when they remarked "This genus looks very much like a small *Surculites*, especially the subgenus *Clinura*, but it is distinguishable by its sharp triangular notch on the periphery".

A glance at the markings of the figures herewith given of *engonata* suffice to rectify this error.

Holotype.—Phil. Acad. of Sci. Coll.

Specimens figured.—Figures 11 (No. 2550), 12 (No. 2551), young forms from Moseley's Ferry; 13 (No. 2552), 14 (No. 2553, adults, Smithville, Tex; 15, the specimen described by Casey as *blanda*, n. sp., a very common form of *engonata*.

Specimens represented by figures 11-14, in the Paleontological Research Institution.

Figure 15, U. S. Nat. Museum specimen, No. 434,359, from Lisbon, Ala.

Surculites Conrad, 1865

Genotype.—*Surcula* (*Surculites*) *annosa* Con., 1865, Amer. Jour., Conch., vol. 1, p. 213, pl. 20, fig. 9.

Conrad's original description of the type.—Turrited; spire elongated; whorls angulated above the middle, with an impressed revolving line above the suture; whole surface marked with fine, revolving wrinkled lines, becoming larger and more distinct towards the base. *Locality.*—Shark River, N. J.

This brief description and Conrad's sketch of the cast, (see figure 20, Pl. 11) herewith given show even more of details than we could observe on the holotype in the museum at Trenton.

Whitfield (U. S. G. S., Mon. 18, pl. 33, fig. 14) gave a somewhat more detailed figure of the type specimen, adding also some seemingly related forms. In 1869 Gabb applied the name of *Surcula* (*Surculites*) *sinuata* to his formerly described "*Conus sinuatus*". In 1876 he renamed his "*Fusus mathewsoni*", *Surcula* (*Surculites*) *mathewsoni*.

Stewart in reviewing Gabb's California Gasteropods (Proc. Acad. Nat. Sci. Phila., vol. 78, 1926, p. 420) refers *mathewsoni* and *sinuatus*, to *Surculites*, as of generic rank.

Quite similar and much better preserved specimens have long been known from our Southern states and Western Europe, and have likewise been referred to various genera. Sowerby calls his *bifaciatus* a *Fusus* though he remarks: "The lip is very imperfect, so that it is not to be positively determined whether it have a sinus towards its upper part, and so be a *Pleurotoma* of LaMarck or not."

Solander's *errans* was put under *Fusus* (*Hemifusus*); likewise von Koenen's "unter-Oligocene" specimen from Helmstadt (N. deut. U. Olig., lief., 1, 1889, p. 233, pl. 17, fig. 5.)

Heilprin described his *engonatus* under *Fusus* and remarks "lines of growth sinuous, and approximating the characteristic lines of the Pleurotomae."

Clark and Martin (Geol. Surv. Md., Eocene, p. 141, pl. 23, fig. 6) put the Maryland form of this species under *Chrysodomus*.

Cossmann would put *errans* in Bellardi's genus *Mayeria* along with the Miocene genotype *acutissima* Bel. (Ess. de Paleoc. Comp., no. 4, p. 92) but the propriety of this assignment is doubtful. Even Cossmann has noted the fact that Bellardi does not refer in his diagnosis to the sinuosity of the lines of growth, and certainly if Bellardi's illustrations are to be trusted there is no indication in them of such a surcula-like characteristic, and, except for the one feature of a very acute carina *Mayeria acutissima* seems to us more fulguroid and remote from *Surculites* than is *Levifusus*. In the last genus the lines do swing back on the shoulder, but their greatest recession is nearer the carina than the suture whereas in *engonata*, at least, it is nearer the suture.

Incidentally, it seems strange that writers since Sowerby's time have misspelled his *bifaciatus*, for Sowerby distinctly says: "the keel like form of the whorls gives them two flat faces from which the name is taken." Clearly Sowerby derived his word from the Latin *facies*, countenance, face &c., and not from *fascia*, fillet, bandage.

Naturally we cannot be sure that all the forms here named belong to one and the same genus, especially to the genus *Surculites*, which is resting on a very unstable foundation.

In America such forms are approximately Mid-Eocene in horizon; in Europe they may be lower, but certainly they occur in the Oligocene. But the Miocene forms should be placed elsewhere.

Surculites engonata (Heilp.)
Plate 11, figures 16-18

Fusus (*Hemifusus?*) *engonatus* Heilprin, Proc. Phila. Acad. Nat. Sci., 1880, p. 372, pl. 20, fig. 8.

Fusus engonata Ald., Geol. Surv. Ala., Bull. 1, 1886, p. 52.

Chrysoodomus engonata Harris, Bull. Amer. Pal., vol. 3, No. 11, 1899, p. 47, pl. 6, fig. 4.

Heilprin's original description.—Shell turrited, of about ten volutions, the first three whorls smooth and convex, the remainder strongly carinated, and traversed by numerous fine revolving lines, which on the median portion of the body-whorl alternate with intermediate finer striæ; body-whorl impressed immediately below the carination (shoulder angulation); lines of growth sinuous, and approximating the characteristic lines of the Pleurotomidæ;

aperture considerably exceeding the spire in length; columella slightly arcuate, and presenting a rudimentary fold at about its central portion.
Length.—1⅓ inch. Woods Bluff, Clark Co., Ala.

We do not understand why Heilprin did not mention the striking tesselated appearance of the surface of this shell caused by the strong spiral and longitudinal lines. However, this characteristic is somewhat less marked in the Woods Bluff specimens than in many of the specimens from Texas.

Type.—Not seen by the present writer. Presumably in the Collection of the Philadelphia Academy.

Specimens figured.—16-18, Smithville, Tex.

Lower Claiborne Eocene; also upper Sabine Eocene. (See Bull. Amer., Pal., vol. III, p. 47.

Paleontological Research Institution. No. 2554-2556.

Var. **exoleta**, n. var.
Plate 11, figure 19

Sinus area concave and comparatively smooth; anterior of body whorl with less coarse, alternating liration.

Type.—Smithville, Texas State Museum. Lower Claiborne Eocene.

Surculites errans Solander
Plate 11, figure 21

Figure of a specimen from the Barton Bluff, Eng., here introduced to show close relationship to American forms.

Beak more pointed, secondary carina more developed than in the American forms.

Surculites annosa Conrad
Plate 11, figure 20

Surcula (*Surculites*) *annosa* Con., 1865, Amer. Jour. Conch., vol. 1, p. 213, pl. 20, fig. 9.

Here introduced to show how very doubtful the characters are on which the genus is founded.

THE MITRIDS

In the American Eocene there are several moderate-sized turrids showing very little or no ornamentation except, naturally, the spiral lines located anteriorly on the body whorl. If we accept *silicata* Ald., with broad sinus and subdued apical costation, from the lower Sabine Eocene, as the radicle from which all were derived, great modifications were brought about in Claiborne and Jackson times in forms, to wit:

(1) No ribs; sinus broad, submedial; smooth.
E. g. *roscoei* Har., *hicoricola* Har.

(2) No ribs; sinus narrow, near suture; smooth.
E. g. *tombigbeensis* Ald.
Upper Sabine Eoc.

(3) No ribs; sinus narrow, near suture; spirally striate.
E. g. *exilloides* Ald., *perexilis* Ald.
Upper Sabine-Jackson.

The relationship of these various categories must await more material and further study. But Casey (St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 150) has classed the smooth *roscoei* with the faintly costate *silicata* (genotype), and hence, if this be allowable, our *hicoricola* and varieties from the Claibornian should be so classed. These all have the broad, open type of sinus. Note that he did not include categories (2) and (3).

Hemisurcula Casey, 1904

Genotype.—Pleurotoma silicata Aldr. Bull. Amer. Pal. vol. 1, 1895, p. 60, pl. 3, fig. 3.

Hemisurcula silicata (Ald.)

Plate 11, figure 22

Pl. silicata Har., Bull. Amer. Pal. vol. 3, 1899, p. 21, pl. 2, fig. 13.
Hemisurcula silicata Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 150.

This is a Gregg's Landing, Lower Sabine species from Alabama, here introduced to show relationship to Claibornian forms. No. 2557.

Hemisurcula hicoricola, n. sp.

Plate 11, figures 23-25

Specific characterization.—General form mitro-fusoid as figured; whorls 10; embryonic whorl smooth, somewhat tilted; smallest spiral whorl showing slight traces of curved ribbing; other whorls nearly smooth, but showing a faint spiral, subsutural band, which in the smaller whorls may show a microscopic medially located incised spiral line; body whorl with very faint spirally incised lines beginning to show at posterior position of aperture, becoming coarser opposite the medial portion of the aperture and again finer anteriorly. The traces of the lines of growth on the whorls indicate that they pass first up and obliquely to the right, and after passing somewhat above the middle of the whorl, swing to the left into the sub-sutural band described above.

Holotype.—Figure 25 (No. 2559), Hickory, Miss.; Fig. 24, tip of same; Figure 23 (No. 2558), shorter specimen, one and one half miles south of Newton, Miss. All Lower Claiborne Eocene; Paleontological Research Institution.

Hemisurcula? fisherensis, n. sp.

Plate 11, figure 26

Specific characterization.—Smooth, moderate-sized, mitriform as illustrated; whorls about 9; slightly shouldered below the suture and there showing about two incised spirals; anterior of body whorl somewhat coarsely striate spirally.

General appearance like the smaller specimens, of *Mitra millingtoni* of the Jackson Eocene.

Holotype.—Fisher, La.; Lower Claiborne Eocene.

Paleontological Research Institution. No. 2560.

Hemisurcula? perexilis (Ald.)

Plate 11, figure 27

Pleurotoma perexilis Aldr., Geol. Surv. Ala., Bull. No. 1, 1886, p. 30, pl. 3, fig. 2.

This Jackson Eocene form is here inserted to show later Eocene developments. From Moody's Branch, Jackson, Miss.

Paleontological Research Institution. No. 2561.

THE SCOBINELLIDS

In the mediterranean seas of the western Hemisphere there existed a pleurotomoid stock, from middle Eocene to Miocene times, that may be spoken of as characteristically beaded. This beading is brought about by deeply incised spiral and transverse lines. The retral sinus is confined to a narrow, depressed band, with from one strongly beaded central spiral, to three or four less strongly beaded. The subsutural collar is well developed, oftentimes showing clearly marked beading. Centrally the whorls sometimes show a tendency toward a carination, bipartite in appearance.

On the one hand there are forms with short aperture, or long spire, with anterior columellar region showing traces of an umbilicus, but without traces of folds. *Hammettensis* and *elaborata* are referred to this Moniliopsis type. They seem confined to the middle Eocene.

On the other hand, the specimens with relatively long aperture, straight, long columella and with from two to a half dozen folds with no umbilical traces, develop a large variety of shapes, sizes, and types of ornamentation. That occurring at Vicksburg was early referred to a new genus by Conrad, 1848, *Scobinella,* and placed in his description between *Caricella* and *Turbinella* though he noted its pleurotomoid affinities. The Jackson horizon brings out the most remarkable variation of forms and ornamentation, while the Vicksburg and Red Bluff beds display an abundance of individuals not equaled elsewhere. The Miocene of the Dominican Republic perhaps furnsihes the largest speceimens (*S. magnifica*). *Vaughanites leptus* Woodr. is a distant relative.

A most remarkable feature of the Vicksburgian *cœlata* is the broadening upwards of the subsutural band so that in some instances the anterior crenulated zone is nearly submerged, showing only the tops of the costules. The whole appearance is quite clavatulid.

Whether the so-called *Moniliopsis* of the recent fauna of our West Coast can properly be referred to this "genus" seems at present uncertain.

Genus **SCOBINELLA** Conrad, 1847

Genotype.—Scobinella cœlata Con., Phila. Acad. Nat. Sci., Proc., 1847, p. 289, 290. — *Idem*, Jour., vol. 1, 1848, p. 120, pl. 12, figs. 8, 9, *Conrad's diagnosis of the genus.*—Shell fusiform with a deep angular sinus in the labrum as in *Pleurotoma;* spire long, turrited; pillar lip wanting; columella with plaits decreasing in size downward, as in *Mitra;* canal short.

With this brief definition of the genus and without access to type material it is no wonder that this rather well defined group of shells should have been placed close to *Borsonia* or *Cordieria.*

The outstanding features of the genus seem to be: (1) ornamentation of series of knobs made by deep growth-lines crossed by deep spirals; (2) a narrow sunken sinus band, generally with a median row of beading; (3) a remarkable inconstancy as regards columellar folding and liration within the outer lip.

Some few species seem to be very generally without columellar folds, as *elaborata,* which, by the way served for Conrad's genotype of a *Moniliopsis* (1865).

Scobinella (Moniliopsis) elaborata Con.

Plate 12, figures 1-4

Pleurotoma elaborata Con., Foss. Sh. Tert. Form, 1833, p. 46 and 2d ed., p. 52, pl. 17, fig. 19.

Moniliopsis elaborata Con., Amer. Jour. Conch., vol. 1, p. 143.
Drillia elaborata Cossm., Notes Compl., 1893, p. 46.

In establishing the genus *Moniliopsis* Conrad remarks:

Turrited, cancellated; fissure of labrum shallow; beak very short.

M. elaborata (*Pleurot.*) nob. This beautiful shell does not agree in generic character with other *Pleurotomidæ*, but it forms a connecting link between the shells with a smooth or entire columella and the plicated genera *Scobinella*, and *Borsonia*.

Conrad's original description.—Subulate, with numerous oblique elliptical nodules, and spiral impressed striæ; beak very short, aperture small; emargination of the labrum profound.

This is a rare and beautiful species found in the "sand" at Claiborne, Ala. Cossmann reports having but a fragment of a specimen and de Gregorio none at all. It is well represented in the Philadelphia Academy's collection, where the type may now be seen. (See tip enlarged, fig. 4.)

Cossmann regarded this as a "*Drilla*" but its remarkable characteristics would seem to call for a different generic designation.

Figured specimens.—Gosport Sand at Claiborne, Ala. Figure 4, Phila. Acad. Coll. Figures 1-3. Paleontological Research Institution. No. 2562.

Scobinella (Moniliopsis) hammettensis, n. sp.
Plate 12, figures 5-7

Specific characterization.—General appearance mitra-form as figured; embryonic whorls not well exhibited though the apex may be classed as "pointed"; below the suture there is a strong spiral cord cut obliquely by lines of growth; retral sinus in a deep, narrow channel ornamented by a line of spiral beading; shoulder and lower portion of the whorls ornamented by a reticulation of strong oblique costation and spiral lines incised more deeply below.

One is instinctively inclined to look for columellar folds on this type of a pleurotomoid, but none seem to be present on our half dozen fairly well preserved specimens.

Holotype.—Figure 5. This and figures 6 and 7, from N. W. Louisiana, probably from Hammett's Branch.

Lower Claiborne Eocene.

Paleontological Research Institution. No. 2563.

Scobinella (Moniliopsis) sculpturata Ald.
Plate 12, figures 8 and 9

S. sculpturata Ald., Bull. Amer. Pal., vol. 5, 1911, p. 6, pl. 2, figs. 4, 5.

For Aldrich's original description consult the above citation.

Length about 8mm.; breadth of body whorl 3mm. Hatchetigbee Bluff, Tombigbee River, Ala.

This is evidently closely related to our *hammettensis* though it lacks characteristic spiral marking, especially the fine beaded line in the sinus concave band. We have no specimen of this species. It evidently lacks all traces of columellar plication.

Note that its horizon is upper Sabine Eocene.

Scobinella newtonensis Aldrich
Plate 12, figures 10-12

S. newtonensis Aldr., Bull. Amer. Pal., vol. 5, 1911, p. 5, pl. 2, fig. 2.

Aldrich's original description.—See citation above.
Length 12; breadth of body-whorl 6mm.
Newton, Miss. Lower Claiborne Eocene.

The somewhat eroded specimen we have from the Jackson Eocene at Montgomery seems to be identical with this Newton form. It is possibly a little more turrited and has at least two columellar plaits. The fine line as shown in Aldrich's figure (fig. 10) below the double row of crenules is too far down, indicating, accordingly, a too narrow subsutural collar. The real suture line is not far below the double row of crenules of each whorl.

Specimen figured.—Figure 10. Newton, Miss.; Lower Claiborne Eocene; Aldr. Coll., Montgomery, La., Jackson Eocene (figs. 11, 12). Paleontological Research Institution. No. 2564.

Scobinella transitionalis, n. sp.
Plate 12, figures 13 and 14

Specific characterization.—Shell of median size, narrow fusoid as illustrated; about three smooth embryonic whorls, of which the first is much the smallest; ribs appearing on the fourth whorl and continue nearly from suture to suture; below, comparatively broad and flat and traversed at first by one incised spiral, but below with no spirals, thus giving a three-beaded appearance; portion of each rib above each spiral not always conformable with portion below; sinus band comparatively wide and showing one or two raised spirals; subsutural collar irregularly beaded; columella with five plaits in most adult forms, though they may be but weakly developed and scarcely visible; outer lip strongly lirate within.

The ornamentation of this species is intermediate between *hammettensis* and *reticulatoides*. The sinus band is broad but not so sharply concave as in *reticulatoides* with its two plain spirals, nor is there the one heavy beaded spiral as in *hammettensis*.

Specimens figured, Montgomery, La.—Fig. 13, holotype, Jackson Eocene.
Paleontological Research Institution. No. 2565.

Scobinella reticulatoides Harris
Plate 12, figure 15

Pl. (*Eucheliodon*) *reticulatoides* Har., Phila. Acad., Nat. Sci., Proc., 1895, p. 63, pl. 5. fig. 12.

Harris's original description.—Size and general form as indicated by the figure; whorls about 10; 1, 2, 3, smooth. tapering rapidly at the point; 4 more or less costate; remaining whorls ornamented as follows: just below the suture a raised line or band, below which a sunken zone is marked in the larger whorls by from one to three spiral incised lines crossed obliquely by lines of growth giving this portion of the whorl a cancellated appearance; on the body whorl, below the three or four cancellated median strong lines there are from 15 to 18 more or less crenulated spiral lines, tending in some instances to alternate in size; labrum within with strong lirations; columella rather long, straight, and with one strong plate located above the middle, below which there are generally several minor folds decreasing in size downwards. In many of its features this species is intermediate between the young of *Borsonia plenta* as here figured and *Eucheilodon reticulata*.

Locality.—Moseley's Ferry, Brazos River, Texas.

Type.—Texas State Museum.

The specimens we have at hand seem to be a little more coarsely cancellate than indicated by the drawing of the type specimen, and the sunken zone appears not quite so broad, but otherwise the figures herewith given seem typical.

Holotype.—Texas Geol. Surv., Coll. (In Univ. Texas Museum).

Specimen figured.—Little Brazos River, Tex.

Lower Claiborne Eocene.

Paleontological Research Institution. No. 2566.

Scobinella pluriplicata Casey

Plate 12, figures 16,17

S. pluriplicata Casey, Phila. Acad., Nat. Sci., Proc., 1903, p. 273.

Casey's original diagnosis.—In the genus *Scobinella,* of Conrad, it should be stated that the species occurring at Red Bluff is distinct from *cœlata* of the upper Vicksburg marls, and I would propose the above name for it. This species is much larger than *cœlata,* with a relatively more elongate and less rapidly acuminate spire, and differs also in sculpture. In *cœlata* there is a broad flattened duplex collar extending from the suture anteriorly for about a fifth the length of the whorl, the surface then concave to well below the middle, generally with about three revolving lines at the bottom of the concavity, the middle one of which is nodulose; the surface from the concavity to the lower limit of the whorl is more prominent, flattended and divided into two coarsely nodose sections by a fine stria. In *pluriplicata* the whorls are relatively much more elongate, and, from the suture for about one-sixth of the length, are flattened; the next sixth of the length is occupied by a small concaviey containing a nodulose line, which is even more prominent than the preceding flattened collar; the surface thence to the anterior limit of the whorl, occupying fully two-thirds the length, is still more elevated but flattened, cylindrical and divided into about four nodose rings by three rather coarse equidistant revolving grooves. The canal is more prolonged and more obconic than in *cœlata,* and the plications of the columella number some four to five. Length of a specimen of about seven body whorls 35mm., width 9.5mm. Length of specimen of *cœlata* of the same number of whorls 21mm., width 6.5mm. *Pluriplicata* occurs also at Byram's Ferry. The Lower Vicksburgian at Vicksburg has not yielded a trace of the genus.

The width and prominence of various bands and relative length of aperture vary greatly, nevertheless, these two species seem quite distinct.

Specimens figured.—Fig. 16, *holotype,* U. S. Nat. Mus. No. 481,663. Fig. 17, Red Bluff; Paleontological Research Institution. No. 2567.

Scobinella cælata Conrad

Plate 12, figure 18

S. caelata Con., Phila. Aca. Nat. Sci., Jr., vol. 1, 1848, p. 120, pl. 12, figs. 8 and 9.

Here introduced to contrast with *pluriplicata.* In the earlier whorls the subsutural band may occupy the greater part of each whorl. Vicksburg Oligocene.

Paleontological Research Institution. No. 2568.

Scobinella macer Casey

Plate 12, figures 19, 20

S. macer Csy., Phila. Acad., Nat., Sci., Proc., 1903, p. 274.

Casey's diagnosis.—Upper Vicksburg. This species resembles the preceding [here succeeding] in general form and sculpture but has only two folds on the columella. These folds are strong, subequal and do not seem to be attended by any adventitious plicæ. This species is elongate and very slender, the nucleus simple and of about three whorls. Each of the subsequent whorls has a broad, moderately elevated double collar subjacent to the suture and a strongly elevated, obtuse and nodose double carina at a third of the length from the anterior margin, the deeply concave intermediate surface having a single strongly beaded line along the middle and a few other very faint and obscurely irregular revolving threads. The low margin is moderately elevated, the surface thence to the large double carina concave. The spire before me consists of seven body whorls and is 10mm. in length and about 3.5mm. in width at base. The remainder of the shell is missing, it being very rare and represented thus far only by fragments.

So far as we can conclude with the material at hand this rather elongate form is best distinguished by the approximate strength of sub-sutural collar and basal carination, with a sharply marked depressed area separating the two. Body and penultimate whorls show the basal portion relatively broader, but on the spire the subsutural collar, as in *cœlata* becomes equally prominent.

Holotype.—Fig. 19, U. S. Nat. Mus. No. 481,661. Figure 20 is from Vicksburg, Oligocene, and shows what the body whorl is probably like. We have no means of determining absolutely the specific identity of such material.
Paleontological Research Institution. No. 2569.

Scobinella louisianæ, n. sp.
Plate 12, figure 21

Specific characterization.—Form and size as indicated by the illustration; three or four apical whorls smooth, while the following ones show a strong vertical ribbing; this ribbing gives place in later whorls to spiral rows of crenulæ, at first arranged definitely vertically, but below showing an oblique or staggered arrangement; subsutural band never very prominent, becoming crenulate on late whorls; sunken band with one finely crenulated spiral; columellar plication scarcely observable.

Though the general character of the markings of this species resembles those of *macer* the lack of development of the subsutural band and plications in *louisianæ* at once distinguishes it.

Holotype.—Fig. 21; Montgomery, La., Jackson Eocene. Another specimen is from a locality one mile above Gibson's Landing on the Ouachita River. Jackson Eocene. Paleontological Research Institution No. 2570.

Scobinella famelica Casey
Plate 12, figures 22 and 23

S. famelica Csy., Phila. Acad. Nat. Sci., Proc., 1903, p. 274.

Casey's description.—Very slender and elongate, the aperture narrow, scarcely at all wider than the canal, from which it is but feebly differentiated, both together constituting but little more than a third of the total length of the shell. The nucleus is rather small, of about three whorls, with its summit obtuse. Subsequent whorls each with a prominent double collar subjacent to the suture and a broad obtuse and strongly elevated revolving keel, fully a third as wide as the length of the whorl and divided into two subequal rings by a revolving groove, situated below the middle of the whorl; this duplex ring is obliquely and coarsely nodose. In the concavity between the collar and the elevated keel there are two or three fine revolving lines, the posterior of which is finely and more or less evenly nodulose. The anterior margin is a fine line on a level with the duplex ring and separated therefrom by a narrow, deep concavity. Columella with six or seven rather unequal, close-set oblique, folds, forming a slightly tumid columellar band as wide as the distance separating it from the posterior angle of the aperture. Length about 25mm., width 4.5mm. It occurs exclusively in the Upper Vicksburg marl and is rare.

This seems to correspond so closely with a specimen in our collection labelled from Montgomery, La., that we wonder if some mistake has not been made in labelling. We have but one specimen, however, (fig. 23) and it may be that more material will show distinctions not now apparent.

Holotype.—Fig. 22; Vicksburg Oligocene; U. S. Nat. Mus. No. 481,662.
Figure 23, Montgomery, La. Jackson Eocene.
Paleontological Research Institution. No. 2571.

Scobinella ferrosilica, n. sp.
Plate 12, figure 26

Specific characterization.—Shell small, fusoid as figured; embryonic whorls 1, 2, 3 smooth, rapidly increasing in size; 4 with vertical ribbing extending from suture to suture; first whorl below embryo, whorl 5, with subsutural beading, a concave space and two rows of beads on the lower half of the whorl the upper the stronger; next whorl below, 6, with similar ornamentation, but showing basally a third row of beading; penultimate whorl, 7, with five rows of lateral beading, the carinal strong, the next weak, and so on alternately to the suture below; body whorl, 8, with six or more beaded spirals, beading strongest near the carinal zone. In the last whorl the subsutural band is surcharged by two spirals so as to give a trebly beaded appearance. The sunken sinus zone is very distinct; beak long and straight. One specimen has its sinus zone so depressed as to give the shell a decidedly pagoda appearance.

This shows finer markings, with more pronounced constriction of whorls at the sutures than in *louisianæ*.

Holotype.—Fig. 26; Old Columbia Road, 5 miles north of Orangeburg, S. C.; Lower Claiborne Eocene.

Paleontological Research Institution No. 2572.

"Borsonia (Zelia) sativa" De Gregorio

Plate 12, figures 24 and 25

Borsonia (*Zelia*) *sativa* De Greg., 1890, Mon. Faun. Eoc. de l'Ala., p. 45, pl. 3, figs. 8-10.

We have nothing to correspond to this species as represented by De Gregorio. But from his description and figures it is evident his *Zelia* is synonymous with *Scobinella*. After giving brief generic and specific descriptions of this form he remarks:

C'est une des espèces plus jolies de la faune de Claiborne. Les sillons sont aussi profonds qu'en se croisant ils donnent naissance à des séries de granulations desposées spiralement et axialment; comme ces sillions à la base du dernier tour sont un peu plus profonds et plus droits que les axials, les granulations semblent disposées spiralement. Le canalicule ou est enfonsée l'échancrure et [est] trés marqué et profond, de sort qu' à regarder la coquille sans l'aide de la loupe, la spire parait étagée, et les sutures des tours semblent coïncider avec les canalicules tandis que les sutures, au contraire, sont tout à fait linéaires et presque invisibles. Dans cet affaissement il y a une ou deux séries de grains sans comparaisons plus fins que ceux de toute la surface. L'overture est étroite; le bord externe est mince, plié en dedans avec la forme d'une aile; le columellaire est pourvu de trois plis decroissant d' arrière en avant; le canal antérieur est extrêmement raccourci.

Cette espèce est analogue de la *lineata* Edwards (Eoc. Moll., p. 330, pl. 33, f. 14), mais elle en est sufficemment distinguée par la forme plus élancée, les granulations plus remarquables, la taille plus développée etc., etc.

Elle ressemble à la *Scobinella cœlata* Conr. (New ter. foss. Vicksburg, p. 120, pl. 12, f. 8, 9.); mais la figure donnée par cet auteur laisse beaucoup à désirer. Quant à la diagnose, Mr. Conrad dit que la suture est bordée par une rangée de petits grains et que la lèvre interne est pourvue, de 4 plis et quelquefois de 5 plis. Est-il possible qu'il eut équivoqué prenant le canalicule des tours pour la suture? Dans se cas son espèce serait très voisine de la nôtre; mais, en jugeant d'après la description qu'il en donne, la *cœlata* doit être bien differente.—Coll. Mon Cabinet).

Scobinella (Moniliopsis) nassiformis, n. sp.

Plate 13, figures 1 and 2

Specific characterization.—Shell small and nassoid as illustrated; apex rather obtuse and smooth; adult whorls showing above a fairly broad subsutural band, tending to be coarsely crenulate, a narrow depressed humeral band followed below by two series of large nodes so arranged as to form oblique costation somewhat as in *hammettensis*.

The upper part of the shell reminds one of some nassoid form, but the body whorl with its offset in costation at the shoulder and its straight, well-developed columella show its pleurotomoid affinities.

Holotype figured.—Orangeburg, S. C.; Lower Claiborne Eoc. Paleontological

Research Institution. No. 2573.

THE AWATERIDS

Nassoid turrids are occasionally common in the Lower Claiborne beds of Texas, especially at Moseley's Ferry. Gabb called the common form *Turris retifera.* Certain small specimens here may be the young of this species, others have a striking resemblance to the immature specimens named by Casey *Glyptotoma parvula.* These seem to correspond in many ways to the genus *Awateria* which is thus described:

Shell compact, buccinoid. The *sculpture* is bold, strong, narrowly convex axial ribs are crossed by more or less spiral strong cords, rendering the axials to a certain extent nodulous. *Protoconch* consisting of 1½ whorls, the nucleus with its initial point erect, but it then suddenly immersed to the extent of one quarter or one half volution, leaving a triangular or semicircular depression. The *suture* is very prominently margined below by a nodulous, somewhat rope-like cord. *Outer lip* with a not deep angular sinus below the suture, the angle lying in the groove below the cord margining the suture. *Aperture* lightly channelled above, with a short, open, and truncated anterior canal.

Genotype.—*Awateria streptophora* Suter, N. Zealand Geol. Surv., Pal. Bull. No. 5, pt. 1, 1917, p. 57.

Of less distinct nassoid markings is the *Pl. jacksonensis* Mr., though showing affinities with this group. (See below).

Awateria retifera (Gabb)

Plate 13, figures 3, 3a. (4, 5 young?)

Turris retifera Gabb, Phila. Acad. Nat. Sci., Jr., vol. 4, 1860, p. 379, pl. 67, fig. 8. (Not 12 as printed)

Gabb's original description.—Thick, fusiform, robust; whorls seven or eight, spire acuminate; mouth narrow, canal short and slightly bent, outer lip thick, simple, inner lip thin; surface coarsely cancellatd by the crossing of longitudinal and revolving lines, the latter about 14 in number, three or four of which are sometimes double.

Dimensions.—Length .28 in., length of mouth .12 in., width of body whorl .11 in.

Locality.—With the above from Wheelock. Easily distinguished by its coarsely cancellate appearance.

This bears considerable resemblance to Deshayes' *Pl. granulata* (Descr. Coq. foss., Envr. Paris, Atlas, pl. 67, figs. 1, 2) designated *Drillia granulata* by Cossmann.

Compare with *Pl. jacksonensis* Mr., 1886, Geol. Surv. Ala., Bull. 1, part 2, p. 75, pl. 2, fig. 10.

Type.—Not found.

Specimens figured.—Moseley's Ferry, Tex.; Lower Claiborne Eoc. Paleontological Research Institution Nos. 2574-2575.

Mitromorpha? jacksonensis Meyer

Plate 13, figure 6

Pleurotoma jacksonensis Mr., Geol. Surv. Ala., Bull. 1, 1886, pt. 2, p. 75, pl. 2, fig. 10.

Meyer's description.—Spire elevated, rather suddenly decreasing near the blunt apex; aperture and canal about one-third of the entire length; whorls covered with elevated, revolving lines and transverse ribs; a distinctly marked depression on the upper part of each whorl indicates the position of the rather deep sinus; columella thickened; outer lip crenate within.

Locality.—Jackson, Miss., rare.

The specimen of *jacksonensis* we here figure is one so labelled in the Philadelphia Academy's collection and is shown by courtesy of the curator in charge. It probably represents Meyer's species though his figure "leaves much to be desired". The Philadelphia Academy specimen (No. 9565) is 9.3mm. in length, while Meyer's is 10.5mm.

The Raphitomids

This is a group of short fusoid forms with sharply defined transverse and longitudinal sculpturing, with embryonic whorls (3d to 5th) often showing pronounced oblique costation and with liration sometimes showing within the outer lip. True Daphnellas form a rather distinct group by their dense nassoid sculpturing Other groups show more fusoid costation. Some show a humeral band more or less defined. The comparatively few spiral whorls and the obviousness of the nuclear whorls distinguish the American Raphitomids from the more typical European Tertiary forms. Casey has proposed (St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 154) a new generic name for certain forms, i. e. *Microsurcula* and though naming no genotype the first species given or described under this name is *nucleola* Casey and the types of this species are herewith shown as figures 20 and 20a, pl. 13.

Genus **Daphnella** Hinds, 1844

Daphnella quindecima, n. sp.

Plate 13, figure 7

Shell fusiform as figured; embryonic whorls 4, increasing rapidly in size, the fourth with fine, oblique transverse ribbing; the three spiral whorls marked by a subsutural beaded line, a depressed zone which shows one spiral in whorl number three; sides of spiral whorls with fine vertical ribbing crossed by spirals as follows: in No. 1, by 3 spirals, No. 2, by 4 spirals, and No. 3 by 5 spirals. Interior of lip with numerous raised lines.

This species is distantly related to *D. imperita*, but is more slender with much finer ornamentation.

Holotype.—Fig. 7; about 2 miles north-east of Newton, Miss., on north end of a deep cut, Route 15. Paleontological Research Institution No. 2576.

Daphnella imperita, n. sp.

Plate 13, figures 8, 9

Specific characterization.—Form and size as figured; whorls about 8; 1 and 2, small and smooth, 3 rapidly expanding; 4 with faint oblique ribbing; 5 or 6 with stronger embryonic ribbing changing suddenly to adult ornamentation with a marked unconformity, adult three whorls with coarse cancellate markings showing but faintly a sinus channel, liration within the lip coarser than in *gregorioi* in accordance with exterior markings.

This shell is much coarser in markings, than *gregorioi* and has a subsutural row of beading. The latter has a much more pronounced sinus band, and is broader generally.

Holotype.—Figure 8 (No. 2577); Hickory, Miss. Figure 9 (No. 2578) is from Orangeburg, S. C. Lower Claiborne Eocene. Paleontological Research Institution.

Daphnella gregorioi Cossm.

Plate 13, figure 10

Pleurotoma cancellata H. C. Lea, Amer. Jr. Sci., 1841, p. 98, pl. 1, fig. 13.
P. gregorioi Cossm., Annuaire Géol., 1892, p. 994; Ann. Géol. et de pal. 12me liv. '93, p. 44.

H. C. Lea's original description.—P. testa sub-fusiformi, subcrassa, cancellata, imperforata, striis longitudinalibus obliquis; spira acuta; sinu magno, prope suturam; anfractibus septenis, convexis; suturis impressis; columella lævi, polita; labro serrato, intus striato; apertura longa; canale brevi.

Shell subfusiform, somewhat thick, cancellate, longitudinal striæ oblique, imperforate; spire acute; sinus large, near to the suture; whorls seven, convex; sutures impressed; columella smooth, polished; outer lip serrate, within striate; mouth long; canal short.
Length .3, breadth .15 of an inch.

Remarks.—This pretty little shell is one of the most fusiform *Pleurotomæ* that I have seen. The mouth is half as long as the shell. The transverse striæ are much more elevated than the longitudinal ones, which on the last whorl become almost obsolete. The channel is shorter than in most *Pleurotomæ*, but is still very evident. The first and second whorls are smooth, the third has only longitudinal striæ, and the rest are cancellate.

De Gregorio is quite justified in his remark that Lea's figure *laisse beaucoup à désirer* and so in copying the same has "touched it up" seemingly in accordance with Lea's description, but even so, little is gained.

Type.—Coll. Phila. Acad. Nat. Sci.

Specimens figured.—(No. 2579) Claiborne sand, Ala. Paleontological Research Institution.

"Genus" **Eoclathurella** Casey, 1904

Genotype.—*Eoclathurella jacksonica* Casey, St. Louis Acad. Sci. Trans., vol. 14, 1904, p. 166; the first species mentioned.

Casey's generic diagnosis.—The shell in this genus is small in size, more or less elongate, having when mature about three convex body whorls, the aperture oblique and rather narrow, oval or sublinear, much less than half as long as the shell, the sinus relatively large, deep, semicircularly rounded, strongly elevated and well separated from the suture, the posterior callous prominences well developed. The inner lip is callous throughout, bearing three or four transverse plicæ at maturity, the canal very short and generally not strongly differentiated. The ribs are numerous, elongated and extend in gradually reduced form to the suture above, the spiral lyræ rather small and widely separated, but abruptly formed and slightly enlarged on the ribs, the fasciolar surface convex, crossed by ribbing but having finer and more close-set spirals. The embryo is relatively large, broadly conical, closely coiled and of between three and four whorls, the lowermost gradually acquiring some longitudinal riblets which merge gradually into the ribs of the subsequent whorls.

Eoclathurella obesula Casey

Plate 13, figure 11

E. obesula Csy, St. Louis Aca. Sci., Trans., vol. 14, 1904, p. 167.

Casey's description.—Form stouter and with thicker walls, [than in *jacksonica*], the periphery of the whorls at about the middle and broadly, faintly angulate in profile, lyræ rather strong and more noticeably dilated on the ribs, almost completely obsolete between the latter and much finer above the periphery; ribs much larger, rounded, longitudinal, about twelve in number; callus of the inner lip almost obliterated for a short distance below the strong prominence at the posterior part of the outer lip; inner surface of the latter prominent with obtuse callus near the sinus and also in a longitudinal sub-basal ridge, and with one or two minute folds between the two larger prominences. Length, 5.0mm.; width, 1.8mm. Jacksonian Eocene of the Montgomery bed, La.

The species described by Meyer, from the Upper Claiborne sand of Alabama, under the name of *Mangelia meridionalis*, undoubtedly belongs to this genus. It differs from the species above described in having two rounded and two carinated smooth embryonic whorls, and five body whorls, and even with this number of whorls, which may be a mistake of the describer, the figured type seems to be immature, as the columellar folds do not appear, and the outer lip is not an adult type; it is materially larger than either of the species described in the table. This genus represents the oldest type of non-operculate Pleurotonidæ known to me at present.

Holotype.—No. 494,370, U. S. National Museum.

Eoclathurella meridionalis (Mr.)

Plate 13, figure 12

Mangelia meridionalis Mr., Geol. Surv. Ala., Bull. 11.; 76, pl. 1, fig. 14.
Eoclathurella meridionalis Csy, St. Louis Acad. Sci., Trans., 1904, p. 167.
Meyer's description.—Fusiform, somewhat inflated; spire turriculated, acuminated; canal

short; nucleus consisting of two rounded and two carinated smooth whorls; adult whorls five, convex, with transverse ribs, about thirteen on each whorl, and with elevated spiral lines; these spirals are small and close together on the uppermost part of each whorl, which is defined by the sinus; sinus broad, near the suture; a curved varix on the outer lip.

Locality.—Claiborne, Ala.; Red Bluff, Miss.

From Claiborne I have only the figured type-specimen, without preserved nucleus.

It would seem from the above statement that Meyer must have drawn his conclusions regarding the character of the nucleus from his Red Bluff specimen. There is therefore reason to doubt whether the specimens were really conspecific.

Specimen in the Phil. Academy's collection, (No. 9525), (see fig. 16); labelled *Mang. meridionalis* is clearly but a slight variant of *venusta,* having the characteristic two or three rapidly expanding smooth embryonic whorls followed by a considerably larger obliquely costate whorl. There would seem to be a reasonable possibility of Meyer's specimen being only a pathologic form of the common Claiborne species.

Eoclathurella jacksonica Casey

Plate 13, figure 13

Eoclathurella jacksonica Casey, S. Louis Acad. Sci., Trans., vol. 14, 1904, p. 167.

Casey's original description.—Form slender; shell substance thinner; obtuse periphery of the whorls well above the middle and broadly rounded, scarcely differentiable from the general convexity; lyræ small in size, finer but scarcely more close set above the periphery; ribs small, somewhat oblique, close-set and numerous, some eighteen in number; callus of inner lip distinct and with a fine free edge throughout; outer lip not distinctly modified within. Length 4.5mm.; width 1.5mm. Jackson Eocene of the Red River Kimbrel bed.

Holotype.—U. S. Nat. Mus.; not numbered.

Genus **Raphitoma** Bellardi, 1948

Sub-gen. **Microsurcula** Casey, 1904

(See below under nucleola)

Raphitoma (Microsurcula) venusta (Lea)

Plate 13, figures 14-16

Fusus venustus Lea, Cont. to Geol., 1833, p. 146, pl. 5, fig. 148.
R. venusta Cossm., Ann de Géol., 12me Liv., 1893, p. 46, pl. 2, fig. 17.
Microsurcula "ventusta" Casey (for *venusta* Lea) St. Louis Acad. Sci., Trans., 1904, vol. 14, No. 4, p. 156.

Lea's original description.—Shell fusiform, furnished with large, longitudinal folds cut by small transverse striæ; substance of the shell rather thin; spire elevated and acute at the apex; whorls six, convex; canal rather short; mouth narrow, one half the length of the shell; outer lip sharp.

Length .4, breadth 3-20ths of an inch.

Observations.—This beautiful little species is more slender than any here described, and its mouth is more contracted. The longitudinal folds being smaller on the superior whorls, and the striæ being there rather large, cause these whorls to be cancellate.

Holotype.—No. 5758, Phila. Acad. Coll.

The type specimen shows whorls 1 and 2 of embryo smooth; 3 microscopically costate; 4 costate, obliquely; 5-7, adult ornamentation.

Specimens figured.—"Claiborne sand", Claiborne, Ala.

Figure 16, No. 9525, Philadelphia Academy. Figures 14 and 15, Paleont. Resh. Inst. No. 2580.

Raphitoma (Microsurcula) carolia, n. sp.

Plate 13, figure 17

Specific characterization.—Shell narrow fusoid as illustrated; whorls about 7; two apical, very small, but the third increasing rapidly in size, smooth; fourth larger with strong, somewhat oblique costation; fifth and sixth as well as body whorl with rather distant and very sharply defined costæ, seven on the penultimate whorl; four or five coarse spirals on two spiral whorls with other distant spirals anteriorly on the body whorl showing alternatelv finer spirals to the end of the canal.

The costation on this species is much sharper than in *veatchi* and the embryo is higher. There is very little trace of a retral sinus, but the costæ on the body whorl do bend forward on approaching the suture.

Holotype and specimen figured.—5 miles N. of Orangeburg, S. C., on Old Columbia road. Lower Claiborne Eocene. Paleontological Research Institution No. 2582.

Raphitoma (Microsurcula) carla, n. sp.
Plate 13, figure 18

Specific characterization.—Size and general appearance as indicated by the figures; whorls about 7; 5 embryonic, of which the earlier are very small, smooth, but later large and with oblique costation; body whorl, and perhaps one spiral with fewer ribs and without indication of carinal carination of *venusta;* spiral lines well marked between ribs.

Holotype figured.—Orangeburg, S. C. Lower Claiborne Eocene.
Paleontological Research Institution. No. 2581.

Raphitoma (Microsurcula) nucleola, var. **veatchi,** n. var.
Plate 13, figure 19

Nearest allied to *nucleola* of which it may prove to be a variety. However, its costæ are less in width than in the interspaces, and its carination higher on the whorls than in *nucleola.*

Holotype and specimen figured.—Sabine River, near Columbus, La.; Lower Claiborne Eocene. Paleontological Research Institution. No. 2583.

Raphitoma (Microsurcula) nucleola Casey
Plate 12, figures 20, 20a
Microsurcula nucleola Csy, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 155.

This is the genotype of Casey's *Microsurcula,* described as follows:

This genus is composed of a considerable number of species, all of which are very small, with the body whorls seldom exceeding four in number at maturity. The embryo is relatively large and complex, conical, multispiral, closely coiled and with about five whorls, the lower one to three of which are covered with fine acute longitudinal riblets. The periphery is more or less obtusely swollen, the ribs small and numerous an dreduced in size and reversd in curvatur on the broad fasciolar surface, generally attaining the suture or small subsutural collar above. The canal is rather tapering in form, straight, moderate in length, and, together with the aperture, about half as long as the shell.

He describes *nucleola* as follows:

Shell very small, with two or three body whorls, moderately stout, the embryo of five whorls which gradually and evenly increase in size, the apical whorl or nucleus very minute, acutely rounded and relatively higher in form, the second to fifth broadly convex and closely covered with an elaborate system of fine riblets becoming more widely spaced on the fifth and gradually merging without break into the ribs of the subsequent whorls; these ribs are some twelve in number, elevated, rounded, extending throughout th convexity of the body whorl below and to the very fine subsutural collar above, becoming reduced and arculately reversed in curvature across the fasciolar surface; spiral lines moderately coarse, even and flat, rather widely spaced and without intermediate lines, bcoming close-set near the base and slightly smaller and more close-set on the fasciolar surface. Length of a specimen of two body whorls, 4.8mm.; width, 1.5mm. Lower Claiborne Eocene of St. Maurice, La.

Of the two specimens in the Casey collection in the National Museum, we judge it is fig. 20a that he regards as the type. The size and pointed chamber of the apical whorls and the coarseness of the ornamentation seem to be the main characteristics of this species. So far as observed the sharp lines of growth so distinctly shown in related forms seem to be absent.

Casey's inclusion of "*Pl. servatoidea* (young)", Pl. 2, fig. 4, Bull. Amer. Pal. vol. 3, cannot be readily explained as the drawing shows clearly the position of the deepest part of th retral sinus exactly on the carina as in *nebulosa* or in *servatoidea.*

We would be inclined to class *Microsurcula bellula* Csy., rather with his *Lyrosurcula,* though the immature character of what would appear to be the genotype, *L. elegans* Csy., renders present discussion somewhat futile. We have collected no material corresponding closely to these immature specimens.

Raphitoma (Microsurcula) pannekoekæ, n. sp.
Plate 13, figure 21

Specific characterization.—Shell small and of short, biconic appearance as figured; whorls 6; 3 embryonic small, increasing rapidly in size, smooth except faint oblique costules on largest whorls; 3 adult whorls having at first very much the appearance of similar whorls in *venusta* but on body whorl extending inter-rib spaces enormously as shown by the figure.

Viewed in front this shell closely resembles any good illustration of *venusta* though its embryonic costules are less pronounced; viewed from the rear, the costation is more like that of *veatchi.*

Holotype and specimen figured.—Claiborne, Ala.; Gosport Sand horizon.

Paleontological Research Institution. No. 2585.

Raphitoma sabinia, n. sp.
Plate 13, figures 22-23

Specific characterization.—Size and general appearance as indicated by the illustrations; whorls 7; embryonic 1 and 2 smooth, increasing rapidly in size; 3 finely vertically costate but not carinate; remaining whorls with 10 to 14 vertical ribs, broad below and narrow above a median carination; shoulder marked spirally with about 4 moderately strong lines; below the carina to the suture there are 4 very heavy spirals.

This is distinguished from *rebeccæ* by its narrower form, more obvious third embryonic whorl, its fainter and larger number of humeral spirals, its weak humeral costation.

Holotype.—Figure 22, near Columbus, La., ditto 22a, Fig. 23a. fig. 23, Sabine River, opp. S. W. ½ S35, 5N. 13W.

Lower Claiborne Eocene. Paleontological Research Institution. No. 2584.

Raphitoma liddlei, n. sp.
Plate 13, figure 24

Specific characterization.—Shell small and short-fusoid as figured; whorls in the small, holotype specimen 7; 1-3 smooth, rapidly expanding, 4, finely and vertically costate; remaining whorls with nine or ten low, broad costæ, fully as wide as interspaces, crossed in whorls 5 and 6 by four heavy raised spiral lirations submedially and below; sinus surculoid, on space between carina and upper suture, traversed by two fine spirals with growth lines clearly marked; inner lip thin, showing clearly oblique spirals; outer lip with raised lines within.

Holotype figured.—Sabine River, vicinity of Columbus.

Lower Claiborne Eocene.

Paleontological Research Institution. No. 2586.

Raphitoma rebecella, n. sp.

Plate 13, figure 25

Specific characterization.—Size and general appearance as figured, whorls about 8; 1-3 smooth, rapidly expanding; 4 with oblique, fine costation; 5-8 adult whorls with rugose, fusoid costation (about 14 costæ on the body whorl); coarse spiral liration passing over ribs and interspaces alike; lirations about 8 on the penultimate whorl, finer on the shoulder, coarser on the humeral angle.

The humeral carination of *rebeccæ* (Pl. 13, fig. 27) is entirely absent on the somewhat allied form.

Holotype and specimen figured.—Sabine River, opposite SW ½ Sect. 35, 5N, 13W. Texas. Lower Claiborne Eocene.

Paleontological Research Institution. No. 2587.

Raphitoma fannæ (Har.)

Plate 13, figure 26

Pl. (*Clathurella?*) *fannæ* Har., Proc. Phila. Acad. Nat. Sci., 1895, p. 64, pl. 5, fig. 14.

Harris' original characterization.—Size and general form as indicated by the figure; whorls 7; 1-3 smooth, 4 finely and obliquely costate; remaining whorls cancellated by narrow costæ and 1 super-humeral and 4 subhumeral raised liræ; columella long, straight and smooth.

Holotype.—Copy of original illustration; Collier's Ferry, Brazos River, Tex. State Survey collection (Transferred to Univ. Tex.) Lower Claiborne Eocene.

"Pl. (Bela) rebeccae" Harris

Plate 13, figure 27

Pl. (*Bela*) *rebeccæ* Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 64, pl. 5, fig. 15.

Harris' original description.—Size and general form as shown by the figure; whorls 7; 1 and 2 small, smooth; 3 finely costate longitudinally; remaining whorls with (a) a subsutural raised line, (2) one or two humeral lines, (e) one prominent line on the humeral angle, (d) many alternating lines below, (e) numerous costæ (15 on the body whorl), most prominent on the humeral angle. *Locality.*—Smithville, Bastrop Co., Texas. *Geological horizon,* Lower Claiborne Eocene. *Type.*—Texas State Univ. Museum.

Specimen figured.—Copy of the original figure.

Not having obtained any more specimens of this little species its adult size, variations and affinities with other turrids cannot at present be determined.

Microsurcula bellula Casey

Plate 13, figure 28

Microsurcula bellula Csy, St. Louis Acad. Sci., Trans., vol. 4, 1904, p. 155.

Casey's description.—Shell slightly larger and rather more slender [than *nucleola*], with more elevated and less obtusely rounded periphery, the aperture and canal combined noticeably shorter than the remainder; embryo relatively larger, higher than wide, of about five whorls, the four uppermost smooth; forming a large even cone, the two lower whorls of which are relatively more inflated toward base, the fourth acquiring coarse feeble riblets which grow stronger on the fifth, where they are broadly arcuate and widely spaced; the fifth whorl is large, and more evenly convex and gradually acquires spiral sculpture but no definite peripheral swelling; subsequent whorls with about eighteen small but distinct ribs, gradually becoming obsolete at the lower margin, attenuated and arcuate in reverse on the fasciolar surface but not quite attaining the rather distinct cariniform subsutural collar; on the second body whorl the ribs form acute nodules on the peripheral ridge but do not extend materially below the latter, and while still distinct on the fasciolar surface, come still further from attaining the subsutural collar; spiral liræ on and below the periphery moderately coarse, even, well spaced and without intermediate threads, becoming close-set on the beak; on the fasciolar surface they are finer and close-set. Length of a specimen of 2 body whorls, 6.4mm.; wideth, 2.0. Lower Claiborne Eocene (from a well seven miles south of Jewett, Texas)—Mr. T. H. Aldrich.

Unfortunately it may be some time before additional material is obtained to help locate systematically this odd specimen. So far as general appearance is concerned it might equally well be referred to "*Lyrosurcula*" or perhaps even with "*Leptosurcula*".

Holotype.—Fig. 28; U. S. Nat. Mus. No. 494,366.

Raphitoma (Microsurcula?) intacta (Casey)

Plate 13, figure 29

Casey in 1903 (*op. cit.*) defines this species as follows:

Pleurotoma intacta Csy., 1903, Phila. Acad. Nat. Sci., Proc., p. 271.
Microsurcula intacta Csy., 1904, St. Louis Acad. Sci., Trans., vol. 14, p. 156.

It is small, moderately stout, fusiform, the aperture and canal, which are not very strongly differentiated, together constituting nearly half the entire length of the shell. The nucleus is as wide as high, consisting of about three whorls, smooth but gradually acquiring the fine riblets which become the eight or nine rather narrow and subacutely elevated oblique ribs of the subsequent whorls, the latter short, about four in number in the largest specimen before me, the ribs angular in profile from base to apex of the whorl with point of maximum elevation just below the middle of the length and becoming obsolete just below the pronounced ly uneven and closely duplex collar margining the suture beneath. Each whorl has six or seven coarse, subequal and closely approximate flattened or slightly convex lyræ, those in the lower half slightly coarser than the posterior three, and that at the middle slightly thickened at the summits of the ribs.

Length of the largest in an extended series 7mm.; width 2.5mm.

This species occurs only in the upper marls at Vicksburg and is common.

U. S. Nat. Museum No. 481,666.

Genus **Leptosurcula** Casey, 1904

Genotype.—Pleurotoma beadata Har., 1895, Phila. Acad. Nat. Sci., Proc., p. 57, pl. 4, fig. 7.

This beautiful pleurotomid is given as the sole representative of this genus the characteristics of which are summed up by its author as follows: (St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 157):

In this genus the form is very slender, fusiform, the canal very long, the aperture and canal together being about half as long as the entire shell. The embryo is relatively very large, higher than wide, conical and composed of five or six polished whorls, the lower whorls gradually acquiring close-set longitudinal riblets, and then, equally gradually, the spiral lyræ*. The type is the very isolated *P. beadata* Harris, of the Texas Eocene, a slender and much elongated species, with a long slender and tapering beak. The series of small rounded close-set nodules forming the sub-sutural collar, are completely independent of the relatively large and oblique costæ, which are less than half as numerous The strong, even spiral lyræ are also a peculiar feature.

Leptosurcula beadata (Harris)

Plate 13, figure 30, 31

Pleurotoma beadata, Har., Proc. Acad. Nat. Sci., Phila., 1895, p. 57, pl. 4, fig. 7.
Leptosurcula beadata Casey, Tr. Acad. Sci. of St. Louis, vol. 14, No. 5, 1904, p. 157.

Harris's original description.—General form as shown in the figure; whorls 9; 1, 2, 3, smooth, 4, 5, transversely costate, 6, 7, 8, obliquely costate, the costæ most pronounced not far

*In copying Casey's descriptions we are not changing his spelling "lyræ"—evidently a mistake for liræ.

below the suture and dying out below, evenly and coarsely striate spirally; suture bordered below by a raised crenulated line; body whorl either costate on its humeral portion, or plain; evenly striate spirally; retral sinus shallow, canal long, straight.

Holotype.—Texas State Survey collection transferred to the Geol. Dept., State Univ., Austin, Tex.

Paleontological Research Institution No. 2588.

Pseudotoma heilprini (Ald.)

Plate 13, figures 32, a, b

Pleurotoma heilprini Ald., Soc. Nat. Hist. Cinn., Jour., 1885, p. pl. 3, fig. 15; Geol. Surv. Ala., Bull. No. 1, 1886, p. 29, pl. 1, fig. 15.

Aldrich's description.—Shell short, broadly fusiform, decussated; whorls eight; surface covered with revolving lines crossed by prominent nodes upon the spire, sculpture rather fine; suture impressed, bordered by a raised band which is cut by the longiturinal lines; apex pointed, the first two whorls smooth; upper part of the volutions concave; body whorl angulated at the shoulder, cancellated; the angulation and depressed margins giving the shell a twisted appearance; aperture narrow; canal short, rather wide and twisted; sinus deep, rather wide, trigonal; a slight callosity on the upper part of the columellar lip, which is smooth below; outer lip thin, wavy from the striations, smooth inside; lines of growth prominent on the body whorl, and the raised lines very numerous. Length 7/10 of an inch; breadth, 4/10.

Locality.—Moody's Branch, Jackson, Miss.

Since the early illustration of this species is not very clear, and the species is represented in various aspects in Louisiana it has seemed worth while to supplement its illustrations with our figures 32 and 33.

Holotype.—Aldrich Collection (Johns Hopkins Univ.)

Specimen figured.—Fig. 32, a, b, Montgomery, La.; Jackson Eocene.

Paleontological Research Institution. No. 2589.

Var. **gibsoni**, n. var.

Plate 13, figure 33

Higher spire and with few broad ribs.

Holotype.—Gibson's Landing, Ouachita River, La.; Jackson Eocene.

Paleontological Research Institution. No. 2590.

THE LYROSURCULIDS

Lyrosurcula Casey, 1904

Certain minute and seemingly immature specimens in Casey's material from St. Maurice, La., he names specifically as *elegans, acuta* and *obsoleta* and refers them to his new genus *Lyrosurcula*. The *L. elegans* was the only species found by the writer in the National Museum collections in 1936. However Casey says that *vaughani* and *sylvaerupis* Harris are also referable to this genus; likewise *beaumonti* Lea may be included. The *elegans* is first mentioned and is 4.3mm. in length while *acuta* is but 2.7, and *obsoleta* 1.9mm. and hence the *elegans* here figured and described may be taken to well represent the genus.

Lyrosurcula elegans Casey

Plate 13, figure 34

L. elegans Csy., St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 156.

Casey's description.—Embryo acutely conical higher than wide, of 6 whorls, the apex or nucleus more swollen and slightly eccentric, the first three smooth, the lower three covered with very regular riblets which are at first very fine, close-set and feeble, becoming gradually coarser and more widely spaced, the sixth whorl gradually acquiring the spiral lyræ, these appearing distinctly between the riblets; fasciolar surface beginning abruptly at the end of the sixth whorl; next two whorls—the first two body whorls—having strongly rounded outline, about eleven feebly elevated and transversely rounded subcylindric ribs, three strong but narrow, well separated spiral lines in rather more than basal half and a declivous, broadly concave fasciolar surface, with distinct acute lines of growth and two fine spiral threads and not entirely crossed by the rapidly obsolete ribs; subsutural collar very small and feebly carinulate; canal short, slender and twisted. Length of a specimen having a complete embryo and 2 body whorls, 4.3mm.; width 1.6mm. Lower Claiborne Eocene of St. Maurice, La.

Holotype and genotype species here figured.—U. S. Nat. Museum.

Lyrosurcula gibbera, n. sp.

Plate 13, figures 35-37

Specific characterization.—Size and general appearance as figured; whorls about 10, of which two embryonic are small and smooth; spiral whorls quickly showing a tendency towards coarse nodular costation crossed by spiral lirations of various dimentions, small on the sinus zone, very large centrally and alternating in size below; upper of carinal lirations becomes predominant on body whorl; low varices often present on larger whorls; beak short but gently curved; labial callosity faintly shown; labrum lirate within.

Some specimens have the general aspect of Miocene forms referred by Woodring to *Carinodrillia* but their anterior canals and ornamention are different.

Holotype.—Fig. 36, this and other figured specimens are from Smithville, Texas; Lower Claiborne Eocene.

Paleontological Research Institution. Nos. 2591-2593.

Lyrosurcula vaughani (Har.)

Plate 13, figures 38, 39

Pleurotoma vaughani Harris, Phila. Acad. Nat. Sci., Proc., 1895, p. 57, pl. 4, fig. 8.

Lyrosurcula vaughani Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 157.

Harris' original description.—Size and general form as indicated by the figure; whorls about 11; 1, 2, 3, smooth and very small, 4 nodular, 5 nodular and with a sutural line or band; 6, 7, 8, as 5 but also striate spirally; 9, 10 nodular costate, costæ showing a slight tendency to become oblique, mainly confined to the lower moiety of the whorls, strongly striate below, and with two noticeably large striæ on the carina, faintly striate above; body whorl rather coarse spiral lines alternating in size from the carinal region to the end of the beak, subcarinal region faintly striate, costæ obscure, labrum striate within.

Localities.—Smithville, Bastrop Co.; Hurricane Bayou, Marster's Survey, Houston Co., Texas.

Geological Horizon.—Lower Claiborne Eocene.

Type.—Texas State Museum.

Figure 39 is a copy of the figure of the type specimen; Figure 38 is of a specimen from Smithville, Tex.

Paleontological Research Institute. No. 2594.

Lyrosurcula funiculigera (Cossm.)

Plate 13, figures 40, 41

Peratotoma funiculigera Cossm., Ann. de geol. et de Paleont., 12me Liv., 1893, p. 47, pl. 2, fig. 16.

Cossmann's original description.—Testa angusta, sublata, apice obtuse ac papilloso, anfractibus 8 obtuse nodoscostatis, spiraliter quinquefuniculatis, postice paululum canaliculatis et supra suturam marginatis; apertura tertiam partem longitudinis æquans, rhomboidalis, canali brevissimo, subintorto, columella incrassata; sinus mediocriter emarginatus supra suturam.

Cossmann's French description, translated.—Shell rather small and narrow, sublate, with apex obtuse largely papillate, composed of eight whorls a little convex except posteriorly where there occurs a shoulder, narrow and canaliculate above [below] the sutural band. The ornamentation is composed of: in an axial sense, pustulose swellings, obtuse, sometimes similar to broad oblique, scarcely salient ribs, again most entirely effaced on the latter whorls; spirally, with five cords regularly spaced on the convexity of the whorls, two or three lines nearer together on the shoulder, and finally, a heavy sutural band; besides, fine lines of growth, oblique and sinuous, especially on the shoulder, cross in an elegant manner the spiral ornamentation.

Aperture equalling one-third the total length, fairly wide, is terminated by a canal very short, a little twisted; labrum obscurely plicated interiorly, columella callous and a little excavated; sinus broadly excavated on the shoulder below the sutural band.

Dimensions.—Length 7.5mill., diameter 2.5mill.

Like the preceding species, this has been confounded with others, probably with *P. insignifica,* although this is distinguished from it by its ornamentation, by the absence of a carina, by its aperture less abbreviated and its canal less twisted; on the other hand, its ornamentation and its form more slender does not permit of confounding with *P. dalli.* It possesses some analogy to *P. fragilis* of the Paris Basin, but the broadly flattened out, obtuse ribs separate it completely from the latter. Claiborne. My collection.

This is indeed a rare species at Claiborne. I think there can be no doubt as to the form referred to by Cossmann, but it would seem that the lines of growth are exceedingly fine and obscure.

Type.—Cossmann Coll., Paris.

Specimens figured.—Gosport sands, Claiborne, Ala.

Paleontological Research Institution. No. 2595.

Lyrosurcula dalli (Cossm.)
Plate 13, figures 42-43

Per. dalli Cossm., Ann. de Geol. et Pal., 12 livr., 1893, p. 47, pl. 2, fig. 15.

Cossmann's original description.—Testa turrita conica, apice obtuso ac papilloso, anfractibus 9, obliquiter nodocostatis, antice bi vel tricarinatis postice paulo excavatis et tenue liratis, ad suturam funiculatis; apertura tertiam partem longitudinis superans, pyriformis, canali fere recto, haud emarginato ac mediocriter elongato; sinus lateralis super suturam profonde resectus.

Read Cossmann's characterization (translated):

Shell conic, turriculate, with obtuse spire, smooth and papillose, composed of about nine whorls, a little convex anteriorly and concave posteriorly, ornamented with thick ribs, oblique and projecting but slightly, not extending to the suture below; spiral ornamentation consists of two or three carinæ equally spaced on the convex part of each whorl, of two or three threads on the posterior slope and of one cord often bifid below the suture; the whole surface as finely striate spirally, and with lines of growth very oblique and sinuous. Aperture equal to four-elevenths of the total length, pyriform or enlarged posteriorly, narrower anteriorly, in the region of the canal which is moderately long, not excavated and scarcely curved; retral sinus deeply cut on the concave shoulder below the sutural cord.

Dimensions.—Length 11 mill., diameter 4 mill. Claiborne, Ala.

All the little worn fusoid forms we have from Claiborne, seemingly of this species, have two very pronounced spiral carinules on each whorl.

Type.—Cossmann Collection,, Paris.

Specimens figured.—Gosport sand at Claiborne, Ala.

Paleontological Research Institution. No. 2596.

Var. **quadrivaricata** n. var.
Plate 13, figures 44-46

Varietal characters.—Shell small, subfusiform as figured; whorls about 8; 1, 2, smooth; remaining whorls show a tendency toward a quadrilateral distribution of varices on each whorl crossed by two spiral liræ heaviest on the varices and often showing vertical undulations; fine wavy lines on humeral sinus region; lines of growth appearing between coarse spirals showing clearly the broad sinus notch.

This is clearly of the *dalli* type of pleurotomid and may be regarded as the St. Maurice representative of that Gosport species.

This seems to be the same form for which Casey had evidently proposed a new generic and specific name. See No. 481, 551, St. Maurice, La. (U. S. Nat. Mus.) Nat. Mus.)

Locality.—Columbus, La.; and Cooper's Well, Winnfield, La.

Specimens figured.—Vicinity of Columbus, La.

Fig. 44 may be taken for the *holotype.*

Paleontological Research Institution. No. 2597.

Lyrosurcula sexvaricosa, n. sp.
Plate 14, figures 1, 2

Specific characterization.—Shell roughly fusiform; whorls 9 or 10; apex blunt, of 1 or 2 whorls; 3 multicostate; remaining whorls at first distinctly nodular costate but with costæ becoming subdued or almost disappearing on the body whorl; spiral lirations generally wavy above, rectilinear on the body whorl; sinus shallow, greatest recession not far above the greatest diameter of the whorls; about three spiral lirations near the middle of each whorl somewhat larger than those above and below; columella somewhat twisted but scarcely showing an umbilication.

This lacks the pointed apex of *vaughani* as well as the rather smooth shoulder zone of that species. It has characteristics resembling *quadrivaricata, texana* and *shaleri.*

Localities.—Claiborne, Ala., Gosport Sand horizon; Newton, Miss. Lower Claiborne horizon.

The figured specimens are from Claiborne.

Figure 1 may be regarded as the holotype.

Paleontological Research Institution. No. 2598.

Lyrosurcula shaleri (Vaughan)
Plate 14, figure 3, 3a

Pleurotoma shaleri Vaughan, U. S. Geol. Surv. Bull. 142, 1896, p. 33, pl. 2, fig. 4.
Asthenotoma shaleri Casey, St. Louis Acad. Sci., Tr., vol. 14, 1904, p. 149.

Original description.—Size and form indicated by the figure. Whorls 6+. The embryonic whorls are broken off the type. On each of the post-embryonic whorls above the body whorl there are seven gentle longitudinal folds, which decrease in prominnce with the increasing age of the shell. On the body whorl the folds have vanished. Suture appressed. Surface coarsely striate spirally. Below the suture is a space, on the body whorl 1 mm. wide, in which there is a single elevated revolving line. Between this space to the suture below there are five coarse striæ; just above the uppermost of these there is a smaller stria. The lowest of the above-mentioned striæ borders the suture superiorly. On the back of the rostrum the striæ are finer, crowded and wavy. Lines of growth rather distinct. Retral sinus situated medially in the whorls of the spire.

This species apparently is most nearly related to *Pleurotoma vaughani* Harris but is smaller and more robust, and the longitudinal folds are obsolete in the body whorl.

Locality.—Ten miles west of Liberty Hill, on the road to Vernon (Lerch and Vaughan). Lower Claiborne. Type in the collection of the Louisiana Geological Survey.

Vaughan's specimen was somewhat larger than the one herewith figured from Hickory, Miss. The latter shows nearly two smooth embryonic whorls, then a small portion of a whorl with costæ extending nearly from suture to suture, but quickly giving way to centrally located nodules which finally disappear as described by Vaughan.

Localities.—Ten miles west of Liberty Hill, La.; Hickory, Miss. Claiborne, Ala.

Specimens figured.—Fig. 3 (No. 2599), Hickory, Miss.; 3a (No. 2600), Claiborne, Ala.

Paleontological Research Institution.

Lyrosurcula columbiana, n. sp.
Plate 14, figure 4

Specific characterization.—Shell of moderate size and resembling in outline a full spindle, as illustrated; whorls about 8; first, smooth and low naticoid giving the spire a blunt appearance; second showing a few fine slightly curved, nearly vertical ribs, but quickly passing into centrally arranged knobs; third and fourth showing sharply defined nodular ribs crossed by two spiral liræ, also showing well defined subsutural collar; fifth showing less well defined ribs, but carinal spirals becoming strongly developed, subsutural collar becoming wavy and bipartite while the sinus zone shows one well defined spiral; remaining spiral whorls showing, besides the two carinal spirals, another just above and another just below, with costal nodulation dying out anteriorly and vanishing entirely on the body whorl.

This seems in every respect intermediate between *shaleri* and *eximia.*

Holotype.—Vicinity of Columbus, Sabine River, La.; 10½mm.

Paleontological Research Institution. No. 2602.

THE ASTHENOTOMIDS

Certain forms that may at least temporarily be referred to *Asthenotoma* have regular, strong spirals anteriorly on the whorls while the nodulations are confined to the earlier whorls.

Asthenotoma strigosa (Casey)
Plate 14, figures 5, 5a

Asthenotoma strigosa Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 149, 150.

Casey's original description.—Form very much elongated, the spire apparently more than twice as long as the aperture and canal combined, gradually, evenly acuminate; columella somewhat obliquely tumid; spire whorls each with a very coarse subsutural lyra, two others similar to the subsutural and moderately approximate at the middle and another similar lyra between the lower-most of the median and the lyra forming the lower margin; spiral space between the subsutural lyra exactly equal to the space between the lower-most of the median lyræ and the one next below the latter. Length of a specimen of about 9 body whorls, 15.5mm.; width 3.9mm. Lisbon bed Alabama. Mr. Aldrich.

The *Holotype* is herewith shown as Fig. 5; Courtesy of the Nat. Mus. No. 494,364; a specimen from the vicinity of Columbus, La. is shown by fig. 5a (No. 2601). Lower Claiborne Eocene.

Paleontological Research Institution.

Asthenotoma eximia Casey
Plate 14, figures 6, 7

Asthenotoma eximia Casey, St. Louis Acad. Sci., Trans., vol. 14, 1904, p. 149.

Casey's original description.—Form somewhat as in the preceding species [*shaleri*], the spire rapidly tapering and not more than one half longer than the aperture and canal combined the inner outline of the columella broadly, evenly arcuate; spire whorls with a strong flattened subsutural lyra, bordered beneath by a feeble concavity not longer than a seventh or eighth of the total length of the whorl, succeeded by two smaller and more approximate carinules and these by four strong lyræ occupying the entire space thence to the lower margin; on the larger whorls there is a single small raised line alternating with the last mentioned lyræ. The obtuse ribs of the nepionic whorls are few in number and become completely obsolete on the fourth and fifth whorl. Length of a specimen of seven body whorls, 12mm.; width, 3.4mm. Texas, (6 miles west of Wheelock)—Mr. T. H. Aldrich.

Figured *Holotype* (fig. 6) U. S. Nat. Mus. No. 494,363.

Figure 7 (No. 2603) is from the Columbus region, Sabine River section, N. W. Louisiana.; Paleontological Research Institution.

Asthenotoma texana (Gabb)

Plate 14, figures 8, 9

Turris texana Gabb, Phila. Acad. Nat. Sci., Proc., vol. 4, 1860, p. 379, pl. 67, fig. 9 (not 11 as printed.)
Surcula texana Con., Amer. Jr. Conch., vol. 1, 1865, p. 19.
Asthenotoma texana Casey, Acad. Sci., St. Louis., Tr., vol. 14, 1904, p. 149.
A texana Casey, Proc. Phila. Acad. Nat. Sci., 1903, p. 276.

Gabb's original description.—Narrow fusiform, whorls eleven or twelve; mouth narrow, canal short, straight, outer lip simple, inner lip slightly thickened; surface marked by about twenty revolving lines, two small ones on the shoulder of the whorl and the remainder larger and decreasing from the shoulder towards the end of the canal; traces of longitudinal ribs exist obscurely on the first half dozen whorls

Dimensions.—Length .7 in., length of mouth .3 in., width of body whorl .2 in.

This diagnosis is scarcely satisfactory for a description of the form we are referring to *texana* as will be seen by consulting the illustrations. Casey has given a far more accurate description (*op. cit.* p. 149):

Concavity below the subsutural carina large, extending very nearly to the middle of the whorl, the surface thence to the lower margin having three to four equal and widely spaced spiral lines; spire almost twice as long as the aperture and canal combined. Length of a specimen of 9 body whorls, 18mm. Texas.

Two specimens in the Philadelphia Academy of Nat. Science may be Gabb's types.

Localities.—Alabama Bluff, Trinity River; Hurricane Bayou, Houston Co.; Collier's Farm, Town Branch, Brazos Co. Little Brazos River, Texas.

Specimen figured.—Little Brazos River, Texas; Lower Claiborne Eocene. Paleontological Research Institution. No. 2604.

THE DRILLIDS

Whorls nearly devoid of spiral sculpturing save anteriorly on the body whorl; embryo smooth, acute subsutural collar pronounced; costæ nodulous on all whorls. For the *lonsdalei*-like forms Casey has proposed a new generic name *Eodrillia* (St. Louis Acad. Sci., vol. 14, 1904, p. 159.)

Eodrillia lonsdalei (Lea)

Plate 14, figures 10-14

Pleurotoma lonsdalii Lea, Cont. to Geol., 1833, p. 132, pl. 4, fig. 124.
Pl. callifera Con. Foss. Sh. Tert., Form., 1835, p. 52.
Pl. lonsdali de Greg., Mon. Faun. Eoc. l'Ala., 1890, p. 35, pl. 2, figs. 33, 34.
Pl. (*Drillia*) *Pinaculina* de Greg., *ibid.*, p. 36, pl. 2, fig. 36, 37, 38.
Pl. (*Pleurofusia*) *tiprapa* de Greg., *ibid.*, p. 34, pl. 2, fig. 28.
Drillia lonsdalei Cossmann, Ann. de Geol. et de Paléont., 12me Liv., 1893, p. 45.
Drillia levis Con., Labeled specimen in Phila. Acad. and name only. Amer. Jour. Conch., 1865, p. 19.
Eodrillia lonsdali Casey, St. Louis, Acad. Sci., Tr., vol. 14, 1904, p. 160.

Lea's original description.—Shell fusiform, turrited, longitudinally folded, transversely and finely striated, substance of the shell thin; spire elevated and acute at apex; whorls ten, with an elevated band below the suture; mouth rather narrow, about one third the length of the shell.

Length .5, Breadth .2 of an inch.

Observations.—A pretty little species, and may be distinguished by its elevated spire, and the band which surrounds the whorls below the suture.

There appear to be two species represented on the type card in the Academy's collection. The larger, (No. 5691) corresponding to Lea's measurements, is fairly strongly striate and scarcely can be regarded as belonging to the species as described. But the smaller (5692) is clearly such. It is also the form designated *levis* by Conrad. It is quite abundant at Claiborne and shows considerable variation as to ornamentation, but generally there is a lack of macroscopic spiral striation, the sub-sutural band is pronounced, while the plications are fewer above, per whorl, more numerous below, and in a few instances the body-whorl shows a number of finer plications, and a strong varix some distance behind the aperture. A few specimens, especially if a little weathered, show fairly well defined spiral lines.

Occurrence.—Gosport sand at Claiborne, Ala.

Figured specimens.—Gosport sand, Claiborne, Ala.

Paleontological Research Institution. No. 2605-2606.

Eodrillia texana (Conrad)

Plate 14, figures 15-17

Drillia texana Con., Amer. Jour. Conch., vol. 1, 1865, p. 143.
not *Turris texana* Gabb. Phila. Acad. Nat. Sci., Jr., vol. 4, p. 379, pl. 67, fig. 9.
not *Surcula texana* (Gabb) Con., Amer. Jr. Conch., vol. 1, 1865, p. 19.
Pl. (*Drillia*) *texacona* Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 61, pl. 5, fig. 7.

Conrad's original description.—Turrited, whorls seven, polished, longitudinally costate; ribs prominent, rather distant; suture profoundly carinated; deposit on labium thick and broad; beak very short.

Locality.—Wheelock, Texas.

The type is probably the specimen now in the Philadelphia Academy.

The *lonsdalei* as here understood including *lævis* of Conrad is somewhat larger, generally, than the Texas relatives, with more attenuate apex, the body whorl proportionally wider, and the ribs more angular and oblique; but so far as can be determined all have the same general type of apex, subsutural band, and want of spiral striation and hence might well be considered one species *sensu lato*.

This small form is common on Little Brazos River, near Iron Bridge on Moseley's Ferry road; Cedar Creek, Wheelock League; Orrell's Crossing, Elm Creek, Texas, Fisher, La. It is displayed in various forms in western Louisiana.

I formerly used a different designation for this Conradian *texana* to distinguish it from Gabb's *texana*. But if different generic designations are used for these species there will be no confusion in using the specific term *texana* for both species.

Of our figured specimens, Fig. 15 (No. 2607), is from Columbus, La.; 16 (No. 2608), is from Little Brazos River, and 17 (No. 2609), is from Moseley's Ferry, Texas; Lower Claiborne Eocene; Paleontological Research Institution.

Var. **educata**, n. var.

Plate 14, figures 18-20

This variety is quite as remarkable in length of spire in comparison to mouth, as *texana* is in length of mouth in comparison with length of spire.

Holotype.—Fig. 20, near Columbus, La.; Lower Claiborne Eocene.

Paleontological Research Institution. No. 2610.

Eodrillia texanopsis (Harris)

Plate 14, figures 21, 22

Pl. (*Drillia*) *texanopsis* Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 61, pl. 5, fig. 8.

Harris' original description.—Form in general as figured, though the specimen drawn was young; whorls about 12; 1-5 smooth, tapering to a sharp point; other spiral whorls scarcely distinguishable from those of *texacona*, body whorl with faint revolving striæ, becoming stronger below; beak long, straight.

On the last or body whorl the costæ often become obsolete and a more or less distinct carina is developed; above which, or between which and the suture, the shoulder is slightly concave.

Localities.—Smithville, Bastrop Co.; Bombshell Bluff, Colorado River, Texas.

Type.—Texas Univ. Museum.

The outstanding features of this species are: the long, sharp, smooth apex; the smooth, almost shining surface; the long, straight beak; ribs few, vertical.

Specimens illustrated.—Smithville, Tex.; Lower Claiborne Eocene. Paleontological Research Institution. No. 2611.

"Drillia harmonica" Casey

Plate 14, figure 23

Drillia harmonica Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 273.

Casey's original description.—A well defined species, quite rare in the Lower Vicksburg, and not found yet in the upper marls. It is rather stout, the spire apparently narrowing somewhat more paridly towards the apex. Nucleus simple and composed of three or four whorls. The subsequent whorls are rather short, each with some eight or nine strongly marked rounded ribs, longitudinal in direction or nearly so, and generally in line from one whorl to the next; they extend nearly throughout the length of the whorl, becoming obsolete only in the narrow revolving concavity below the ante-sutural elevated collar, which is rather thick and conspicuous and marked posteriorly with one or two striæ. Each whorl has some seven or eight nearly equal revolving lyræ those near the middle maturally separated as a rule by a finer line. The apeurture is rather wide, the canal very short, the two together but little more than a third of the total length, the callus near the posterior angle of the aperture tumid and conspicuous. Length 11mm., width 3.7mm. I had confounded this species with *mississippiensis*, of Conrad, until a recent inspection of the type of the latter showed that is is very different; *mississippiensis* is very stout, much larger, with the revolving concavity below the sutural collar very wide, constituting about half the entire length of the whorl; the short, broad rounded ribs are confined to anterior half of the whorls and are obsolete on the posterior concavity. The specimen is somewhat water-worn, so that the sculpture is not distinct, but there are apparently revolving raised lines which distinguish the species at once from the smooth and otherwise very different *ebordies*. The type seems to be unique.

Type specimen figured, U. S. Nat. Mus. No. 481,665.

"Pleurotoma (Drillia) Pinaculina" De Greg.

Plate 14, figure 24, a

Pleurotoma (*Drillia*) *Pinaculina* De Gregorio, Mon. Faun. Eoc. de l'Ala., 1890, p. 36, pl. 2, figs. 36-38.

De Gregorio's original description.—Testa minuta, angusta, elongata, turrita, fusiformis; spiraliter minute striata; anfractibus in medio subangulatis, antice convexiusculus, plicatis, poste concavis; plicis tenuibus obliquis subcancellates; striis confertis, maxime minutis; sutures marginatis. L. 8mm. Ang. sp. 20°.

Remarks translated: This species is very near to the *Pl.* (*Drillia*) *Lonsdali* Lea; it differs from it by its lesser spiral angle, the ribs much less developed and by the spiral striæ. These are extremely fine, it requires a microscope to see them. The sinus is about the same as in *Lonsdali*, that is, as in the genus *Surcula*. Coll. My Cabinet.

We have nothing to add regarding this species.

"Drillia dipta" (Harr.)

Plate 14, figure 25

Pl. (*Drillia*) *dipta* Harr., Phila. Acad. Nat. Sci., Proc., 1895, p. 59, pl. 5, fig. 3.

Harris' original description.—Size and general form as shown in the figure; whorls 9; 1, 2, smooth, 3 longitudinally costate, 4-8 medially carinate, carina ornamented by oblique nodules, just below the suture there is a raised line or band; body whorl with less prominent carinal nodules, but with a few well-defined raised spiral lines; canal short, slightly curved.

Locality.—Baptizing Creek, Kimble headright, Cherokee Co., Tex.

Geological Horizon.—Lower Claiborne Eocene.

Type.—Univ. Texas, Austin, Tex.

We have had no more material from this locality and hence can only give a copy of the original figure. Regarding the same Casey says (Acad. Sci. of St. Louis Trans. 1904 p. 144): "It is probable that the species described by Harris under the name of *Drillia dipta,* will constitute the type of a distinct genus near *Cochlespira* Casey."

Until more material is obtained its generic assignment is in doubt.

Phandella Casey

Genotype.—*Phandella nepionica* Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 272.

Casey's generic diagnosis.—This genus occurs in the Upper Vicksburg marls, and appears to have no closely allied living descendant, although related perhaps to *Daphnella.* The shell is minute and the animal apparently existed the greater part of its life in the nuclear stage, there being no example which I have seen, out of a considerable series collected, possessing more than between one and two body whorls. The nucleus is relatively large though evenly conical, pointed, consisting of from five to six whorls which are exquisitely sculptured in two systems of very minute lines crossing each other at an angle of about 45°, producing an appearance very much like the engine-turning frequently engraved upon a watch.

There are before me three species, distinguishable among themselves by very clearly marked characters, but at the present time I will briefly outline the most abundant of the three, which may be regarded as the type of the genus.

Phandella nepionica Casey

Plate 14, figure 26

Casey's specific characterization—This species has about one and a half body whorls, which are together about twice as long as the nucleus, polished and completely devoid of revolving sculpture, having, however, about ten sharply elevated longitudinal or slightly oblique ribs, which become abruptly declivous posteriorly and obsolescent near the suture. The nuclus has about five whorls; the canal is rather short and there is a fine raised collar margining the suture beneath, which line may also be observed to mutually separate the larger of the nuclear whorls. Length 2.25mm., width 1.2mm. Many specimens.

This type specimen (Fig. 26) is in the Coll. U. S. Nat. Mus., but is un-numbered. (1936)

Genus **Microdrillia** Casey, 1903

Casey remarks (Phila. Acad. Nat. Sci., Proc., 1903, p. 276, regarding the species of this new genus:

"They are very small and characterized by a well-developed, multispiral closely coiled embryo, having one to three of its basal whorls costulate, few body whorls which are wholly devoid of costæ but spirally carinate, the retral sinus relatively large, circularly rounded and close to the suture, the aperture oblique, columella callous, with or without plications, and the canal short or subobsolete."

This author lists and describes ten species, seven of which are new. He believes the genus "to have become wholly extinct in the Oligiocene of lower Miocene" and says "The species were numerous and individually abundant, especially in the Mid-Eocene of the Lower Claiborne."

Cossman subsequently designated *Pleurotoma cossmanni* Meyer as the genotype (See Ess. de Paléoconch. Comp., No. 7, p. 223) and renamed the species *meyeri* as a form belonging to a similar group of turrids was already named *cossmanni* by de Raincourt. *Cossmanni* (or *meyeri*) is the first species listed or discussed by Casey, *op. cit.*, hence it may well be considered the genotype.

Otto Meyer's discussion of *cossmanni* is given in his *Beitrag zur Kenntnis der Fauna des Altertiärs von Mississippi und Alabama* (See Sonder- Abdruck aus Bericht über die Senckenbergische naturforschende Gesellschaft in Frankfurt a. M. 1887, p. 9, t. I fig. 5,) and reads as follows (translated) :

The nucleus consists of three smooth and ribbed whorls. These whorls increase regularly in size. Adult whorls have a strong raised spiral near the suture. Another strong spiral lower down gives the whorls a keeled appearance. Between these two "Longitudilalen" (?) the sinus occurs as evidenced by well defined growth-lines. Remainder of the whorls likewise covered with a few spirals. The mouth is narrow. The outer lip is sharp, within with two strong spiral folds.

The species, named after M. Cossmann of Paris, is similar to *Pleurotoma infans* Mr. The most outstanding distinctions of *P. cossmanni* are the depressed form, the flattened sides not really keeled, and the two spiral folds of the outer lip. *Pleurotoma infans* is not, as I formerly supposed, identical with *Pleurotoma nana* Lea sp. which is narrower and with a different nucleus.

Of this ilk we therefore have three species.

Pleurotoma nana Lea sp. *(Pl. insignifica)*	Claiborne Ala.
Pleurotoma infans Mr.	Red Bluff, Miss. Vicksburg, Miss. Newton, Miss.
Pleurotoma cossmanni Mr.	Jackson, Miss.

We have copied Meyer's original figure of *cossmanni* (See pl. 14, fig. 42) and have had photographed the specimen labelled *cossmanni* in the U. S. Nat. Mus, from Moody's Branch, Miss. (Length 4.5mm.) Pl. 14, fig. 43, Casey Collection not numbered. Fig. 46 shows a specimen so labelled in the collection of the Phila. Academy, No. 6514. (Length 8mm.)

In spite of the considerable attention already given to this section or genus of turrids the so-called species rest on very doubtful foundations. Casey, while apparently shedding some light on certain forms, has injected many uncertainties for future students by naming and not figuring what appear to be young stages of indeterminate forms.

The oldest form with which we are acquainted is that shown as figure 49, plate 14 which may be a variety of *infans* or a distinct species according to one's viewpoint. It is from the Upper Sabine or Woods Bluff horizon of Alabama. This seems to have is one specimen characters that appear exaggerated or effaced is subsequent forms. The apex is but moderately pointed; the embryonic costate whorls are three in number and show fairly clean cut ribbing; the spiral whorls are slightly carinate medially; a slight tendency to carinal crenulation is shown; apertural dentation or plication is weak; signs of umbilication are not obvious; typical lines of growth on the sinus band are well shown. Variations are brought about by widening or narrowing the form, sharpening or blunting the apex, increasing or decreasing the strength of the usual second or submedial carina, raising the same to show a third carina or lowering it and producing a unicarinate whorl, and so forth. A form differing but slightly from *aldrichella* or *harrisi* from the Bowden Miocene is named *tersa* by Woodring (Carn. Inst. Wash., Publ. no. 385, 1928, pl. 197, pl. 8, fig. 14).

Plate 14, figures 36-49 show various forms that have received specific designations.

"Scobinella læviplicata Gabb"

Scobinella læviplicata Gabb. Phila. Acad. Nat. Sci., Jour., vol. 4, 1860, p. 380, pl. 67, fig. 20.

Gabb's original description.—Thick, fusiform; whorls eight or nine, carinate; apex acuminate; mouth narrow, canal short, outer lip striate within, corresponding to the external ribs, inner lip thickened, the folds on the columella smaller than in the preceding species [*crassiplicata*]; surface marked by twelve or fifteen angular revolving striæ, no trace of longitudinal ribs or nodes, but obsolete lines of growth.

Dimensions.—Length .22 in., length of mouth .08 in., width of body whorl .08 in. Collection of the Smithsonian Institution.

Note that here Gabb states that his specimen is in the Smithsonian Institution. But a fragmentary small specimen is in the collection of the Philadelphia Academy labelled *"Scobinella læviplicata* Gabb, type" which is nothing more or less than a fragment of a specimen of *Eucheilodon reticulata* Gabb. This is very similar to our fig. 3, pl. 4. Gabb's fig. 20 certainly looks quite different from this, and it seems quite possible that it was drawn from some *Microdrillia,* perhaps the *aldrichiella* of Casey, or a specimen like Cossmann's *læviplicata* (See pl. 14, fig. 45).

Microdrillia harrisi (Aldr.)

Plate 14, figures 27-30, 44

Glyphostoma harrisi Aldrich, Bull. Amer. Pal., vol. 1, 1895, p. 61, pl. 1, fig. 11.

Microdrillia aldrichiella Casey, *Ibid.*, p. 278.

Microdrillia harrisi Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 278.

? *Pleurotoma infans* Meyer, Geol. Surv. Ala., No. 1, 1886, p. 75, pl. 2, fig. 9.

Aldrich's original description.—Shell small, whorls nine, spire acuminate, suture deeply impressed; the first four whorls smooth, the next two with longitudinal beads, balance with strongly raised spirals; suture bounded by a cord above and below, followed by a broad excavated space corresponding to the fasciolar space; lines on the last half of the body whorl with as intercalary thread, aperture narrow, outer lip slightly incurved, striate within; pillar lip thickened and bearing two (in the type) to six plaits; umbilicus rudimentary.

Locality.—Wheelock, Texas, also in Lee and Burleson Co. The figure is a little too broad. This species is placed by Mr. Harris under *P. infans* Meyer, but is seems to me to be a very different species as the latter has no plaits on the columella, is narrower, has fewer whorls and a twisted canal.

Figure 44 is a copy of Aldrich's figure of this species, of which he says "The figure is a little too broad."

Figures 27 and 28 from Little Brazos River, Tex., appear to be of this species. Figures 29 and 30 are the types (U .S. Nat. Mus. Coll., not numbered.) of Casey's *aldrichiella,* from Moseley's Ferry.

Casey describes his *aldrichiella* as follows:

Spire more rapidly narrowed towards the apex, the embryo very small, of three or four whorls, the lowermost apparently costulate; body whorls five or six in number, each with subsutural and submedian coarse equal carinæ and a third, finer and less conspicuous, between the later and the base; concave fasciolar surface between the coarse carinæ with a fine, median revolving thread; lines of growth well marked as usual; columella subumbilicate as a rule. Length 6.5mm., width 2.3mm. Lower Claiborne Eocene. Moseley's Ferry, Burleson Co., Texas.

From the above statement it would appear that *aldrichiella* should have a little more pointed spire and more apparent umbilication than *harrisi.* Had the U. S. Nat. Museum specimens been slightly coated with ammonium chloride their characters would have appeared far more clearly. See figures 29 and 30.

All figures of specimens from Texas, Lower Claiborne Eocene.

Figures 27, 28, Paleontological Research Institution. No. 2612.

Figures 29, 30, U. S. National Museum.

Figure 44, Aldrich Coll., Johns Hopkins Univ. Coll.

Microdrillia ouachitæ, n. sp.

Plate 14, figures 31, 32

Specific characterization.—Small and somewhat terebriform as indicated by the figures; whorls 8 or 9; apex obtusely pointed, with three rapidly expanding smooth embryonic whorls followed by one early whorl with vertical ribbing; earliest spirals below the embryo of two equally defined thick liræ, one corresponding to the subsutural collar and the other to the carina; soon a second though smaller lira appears below the carinal, then a third and in the last whorl a fourth may be appearing; subsutural collar unusually prominent, with deeply concave sinus belt below; between heavy liræ fine, sharp, lines of growth are beautifully exhibited; sinus belt may show a microscopic spiral about centrally located; aperture with two, sometimes three columellar folds corresponding to the heavy spiral liræ without, and with four strong liræ within the outer lip.

This is with our Danville, Jackson material, though specimens are not so individually labelled.

Cossmann's "*Scobinella læviplicata* (Gabb)" (Ann. de Geol. et de Pal., 12th liv., 1893, p. 43, pl. 2, fig. 19) sent him by Meyer from *l'Eocène du gisement de Jackson*, has, it would seem from his description, practically the same elemental character as *ouachitæ* but in different proportions. Since they are from the same horizon one may expect connecting links. Casey notes the similarity of *læviplicata* as figured by Cossmann to *harrisi* and remarks, "It is said to have been found at Jackson, Miss., by Meyer, but I have seen no plicate species from that horizon."

Cotypes, specimens figured.—Ouachita River, La., Jackson Eocene; Paleontological Research Institution. No. 2613.

Microdrillia infans (Meyer)

Plate 14, figure 33

Pleurotoma infans, Meyer, Geol. Surv. Ala., Bull. 1, 1886, p. 75, pl. 2, fig. 9.

Meyer's original description.—Small; aperture and canal about one third of the entire length; the pointed apex is formed by two and a half small, smooth, embryonic whorls; three rather large, transversely ribbed embryonic whorls complete the nucleus; the largest specimen has three adult whorls—they are strongly carinated in the middle; upper part has only one revolving line near the suture, the lower part three elevated spirals; the upper part indicates the position of the large, regularly rounded sinus; the lines of growth are almost riblike.

Localities.—Red Bluff, Miss., Newton, Miss., Claiborne, Ala., Vicksburg, Miss. (Var.)

Meyer further remarks: "The type-specimen is from Red Bluff, where the species is not rare; it is much larger than the others of this locality, which have only two adult whorls."

Fig. 33 is a copy of Meyer's type figure.

Var. **bicincta**, n. var.

Plate 14, figure 47

Pl. (Mangilia) infans Har., Phila. Acad. Nat. Sci., Proc., 1895, p. 62, pl. 5, fig. 10, *pars*.

The two carinal liræ are nearly equal in strength and are separated from sutures above and below by broad smooth bands; the form is perhaps the most slender of all species of this genus; the embryonic whorls with vertical ribbing are conspicuous.

Figure 47 is a copy, somewhat reduced from Phila. Acad. publication given above. Specimen obtained at Smithville, Tex. Lower Claiborne Eocene. Texas State Museum (moved to the Univ.)

Microdrillia robustula Casey

Plate 14, figures 38, 39

Microdrillia robustula Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 277.

Casey's original description.—Embryo as wide as high, obtusely oval at tip, with three smooth and two costulate whorls; subsequent whorls four in number, each with one subsutural and three other equal carinæ; fasciolar surface without a revolving thread. Length 5.6mm., width 2.25mm. Lower Claiborne Eocene. St. Maurice, La.

The type specimens herewith figured (Figures 38, 39) and in the U. S. National Museum collection, No. 481, 559.

It seems quite probable that this blunt spired form with three strong carinal spirals showing on the larger whorls is the same as that shown by figs. 48, 48a from Columbus, La., though the latter are a little more carinate.

Type material.—U. S. National Museum.

Figs. 48, 48a.—Paleontological Research Institution. No. 2615.

Microdilla biplicatula Casey

Plate 14, figure 36

Microdrillia biplicatula Casey, Phila. Acad. U. S. Proc., 1903, p. 278.

Casey's original description.—Revolving carinæ fine as in *elongatula*, the shell similarly slender, differing in having two costulate revolving whorls, a fine revolving thread in the fasciolar surface and but two columellar folds; body whorls but two in number in the type. Length 2.3mm., width 1mm. Red Bluff Eocene (Oligocene).

Holotype.—Not numbered; U. S. Nat. Museum.

We have no means of determining with which of the more adult species figured this may be associated. Its apex seem to ally it with *"robustula."*

Microdrillia vicksburgella Casey

Plate 14, figure 37

Microdrillia vicksburgella Casey, Phila. Acad. Nat. Sci., Proc., 1903 p. 277.

Casey's original description.—Embryo nearly one-half higher than wide, subcylindrical, rapidly pointed at tip, with three smooth and nearly three coarsely costulate whorls, the latter strongly and more medially convex, subsequent whorls not exceeding four in number, the fasciolar surface with a fine revolving thread, shell much more slender and longate than in *infans*. Length of embryo alone, 1.4mm., width .8mm. Upper Vicksburg Oligocene.

The pointed apex and "fasciolar surface with fine revolving thread" seem to be the characters relied upon to distinguish this from *robustula* and *infans*.

Holoytpe.—U. S. Nat. Mus. No. 481,645.

Microdrilla citrona

Plate 14, figure 34, 35

Specific description.—Shell of rather short, solid appearance as figured; whorls 8; 1-3 smooth, increasing rapidly in size, 4 or 4½ vertically ribbed, remaining whorls with two comparatively strong central spirals with a third finer spiral just above the suture and a fourth just below the suture; fasciolar band broad and slightly concave; body whorl showing comparatively fine spiral raised lines between which finer ones appear; aperture truncate anteriorly; somewhat umbilicate.

The rather blunt apex, truncation anteriorly, wide sinus band and comparatively fine and alternating spiral striation on the body whorl give this form a rather distinct aspect. Its nearest ally is doubtless *robustula*.

Holotype.—Fig. 34, found 3 miles N. W. of Orangeburg, S. C. Lower Claiborne Eocene.

Microdrillia minutissima Casey

Plate 14, figures 40, 41

Microdrillia minutissima Casey, Phila. Acad. Nat. Sci., Proc., 1903, p. 277.

Casey's original description.—Embryo acutely conical, scarcely higher than wide, with three smooth and one costulate whorls; subsequent whorls not more than two in number in any of the three specimens at hand, similar to those of *robustula*, but much more slender. Length 2.3mm., width 1mm. Lower Claiborne Eocene, St. Maurice, La.

Doubtless a large amount of material must be collected before these young forms can be correctly placed.

Types.—U. S. Nat. Mus., No. 481,557 (See figs. 40, 41).

Microdrillia meyeri (Cossm.)

Plate 14, figures 42, 43

Pleurotoma cossmanni Meyer, Senckenbergische Naturf. Gesell., in Frankt, a M., 1887, p. 9, pl. 1, fig. 5.

Pleurotoma meyeri Cossm. (not *cossmanni* de Raine.) Ess. de. Paléonc. Compar., 7th liv., 1906, p. 223.

This species has already been discussed. See p. 89.

Figure 42 is a copy of Meyer's illustration; fig. 43 illustrates the specimen in the Casey collection at the U. S. Nat. Museum, from Moody's Branch, Jackson Eocene; not numbered.

Paleontological Research Institution. No. 2614.

Genus **Conorbis** Swainson, 1840

Conorbis conradi De Gregorio

Plate 14, figure 50

Pleurotoma conoides Con., Foss. Sh. Tert. Form. 2d ed., 1835, p. 51, pl. 17, fig. 17.

Conorbis (*Cryptoconus?*) *conradi* de Greg., Mon. Faun. Eoc., p. 23, pl. 1, fig. 69.

Conrad's original description.—Fusiform; spire conical acute; apex obtuse; whorls convex, with a few revolving lines, distinct near the suture, obsolete on the wider part of the body whorl and distinct at base; aperture contracted; beak short, straight, slightly grooved longitudinally.

Locality.—Claiborne, Ala.

Specimen herewith figured.—Claiborne, Ala.

PLATES

(Plates furnished, gratis, ready for insertion, by the author)

PLATE 1
(Vol. Pl. 2)

20. *Gemmula childreni*, var. *novoppidi*, n. var., 10mm. 12
Newton, Miss.; Lower Claiborne Eocene

21. *"Pleurotoma denticula"* Heilp., (enlarger) 12

22. *Gemmula childreni*, var. *acutirostra* (Con.), 14mm. 12
Claiborne; Gosport sand horizon

23. *Gemmula conjuncta* Casey, 9.5mm. 12
"Jackson Eocene of the Kimbrel Beds". Holotype, 494,349

24. *Gemmula conjuncta* ? Casey, 10mm.
Danville; Jackson Eocene

24,a. *Gemmula conjuncta* ? Casey, 8½mm.
Danville; Jackson Eocene

25. *Gemmula* var. *childreni? montgomeryensis*, n. var., 18mm. 12
Danville; Jackson Eocene

26. *Gemmula amica* Casey, 14mm. Holotype 13
Red Bluff; Oligocene; U. S. N. M. No. 494,346

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Red Bluff; Oligocene

28. *Gemmula amica* Casey, 12mm.
Red Bluff; Oligocene

29, a. *Gemmula nucleata* Casey, 8.9mm. Holotype 13
St. Maurice; L. Claiborne Eoc.; U. S. Nat. Mus. No. 494,350

30. *Gemmula ancilla* Casey, 13mm. Holotype 13
Red Bluff; Oligocene; U. S. Nat. Mus. No. 494,354

31. *Gemmula ancilla* Casey, 17mm.
Red Bluff; Oligocene

32. *Gemmula nodulina* Casey, 9.5mm. 14
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33, a. *Gemmula gemmata* Hinds, 22mm. 5
Figures of Hinds' specimen, British Museum of Nat. History; Photographs prepared by Keeper L. R. Cox; Recent

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15.	*Gemmula margaritosa* Casey, 30mm. Smithville; Lower Claiborne Eocene	
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17.	*Gemmula margaritosa* Casey, 13mm. Smithville; Lower Claiborne Eocene	
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19.	*Gemmula alternata* (Conrad), 26mm. Claiborne; Gosport Sand Horizon	16
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PLATE 3
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21. *Trypanotoma melanella*, n. sp. 8mm. 22
Claiborne; Gosport Sand horizon

22. *Trypanotoma melanella*, n. sp., 9mm. (Holotype)

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Moseley's Ferry, Tex.; Lower Claiborne Eocene
U. S. Nat. Mus. No. 494,358

24. *Trypanotoma longispira* Casey, 10mm.
Moseley's Ferry, Tex.; Lower Claiborne Eocene

25. *Bathytoma nonplicata*, n. sp., 10mm. (Holotype) 23
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25,a. The same species, etc., but 11mm in length.

26. *Bathytoma crassiplicata*, var. *montgomeryensis*, n. var., 6.5mm. 23
Montgomery, La.; Jackson Eocene

27. *Bathytoma crassiplicata* (Gabb), 5mm. 23
Moseley's Ferry; Lower Claiborne Eocene

28. The same species, etc., but 7mm in length

29. A broader var. of the same species, from near Columbus, La.

30. A small variety of the same, Sabine River
Opposite sect. 35; Lower Claiborne Eocene

31. *Bathytoma conradiana?* Aldr., 8mm. 23
Moseley's Ferry; Lower Claiborne Eocene

33. *Trypanotoma* sp. Sabine River, opposite sect. 35

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"Lower Claiborne Eocene of Texas"; U. S. Nat. Mus. No. 494,356

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2. *Gemmula ludocarola,* n. sp., 12mm. (Holotype) — 17
Orangeburg, S. C.; Lower Claiborne Eocene

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Montgomery, La.; Jackson Eocene

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Columbus; Lower Claiborne Eocene

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14. *Trypanotoma carlottæ* (Har)., 9mm. (Holotype) — 21
Woods Bluff, Ala.; Upper Sabine Eocene

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Woods Bluff, Ala.; Upper Sabine

15. *Trypanotoma terebriformis* (Meyer), 8mm. (Copy of type figure) — 21

15,a. *Trypanotoma terebriformis* (Meyer)
Claiborne; Gosport sand horizon

16. *Trypanotoma terebriformis* (Meyer), 9mm.
Claiborne; Gosport sand horizon

17. *Trypanotoma terebriformis* var. *curta,* n. var., 8mm. — 21
Newton; Lower Claiborne Eocene

18. *Trypanotoma tereberiformis,* var. *curta,* n. var., 9mm. (Holotype)

18. *Trypanotoma tereberiformis,* var. *curta,* n var., 9mm. (Holotype)
Hickory, Miss.; Lower Claiborne Eocene

19. *Trypanotoma cooperi,* n. sp., 9mm. (Holotype) — 21
Cooper's test well, Winnfield, La.; Lower Claiborne Eocene

20. *Trypanotoma obtusa* (Casey), 10mm., (Holotype) — 21
St. Maurice; L. Claiborne Eocene. U. S. Nat. Mus. No. 494,357

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PLATE 4
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19. *Eopleurotoma desnoyersi* (Lea) 11mm. 29
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21. The same, 8mm.
22. The same, 8mm.
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24. The same, 24mm.
25. The same, 19mm. Newton; Lower Claiborne Eocene
26. The same, 23.5mm. (Lectotype) Claiborne; Phila. Ac. Mus. No. 13356
27. *Eop. nupera*, var. *nuppygis*, n. var., 17mm. (Holotype) 30
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28. The same, 9mm.
29. *Eopleurotoma "gemmata"* (Conrad), 19.6mm. (Monotype) 32
    Claiborne; Gosport Sand Horizon; Phila. Acad. No. 13365.
30. The same, 26mm.; paucicostate var.
31. The same, 22mm.
32. Probably the same species, unusually smooth, var. 17mm.
    All *"gemmata"*-like forms from Claiborne; Gosport sand horizon

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16.	The same, 10.5mm.	
17.	The same, 10.5mm. (Holotype)	
18.	The same, enlarged, Hickory; Lower Claiborne Eocene	

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4.	The same, 19mm.	
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21.	The same species, 13mm.	
22.	The same species 12mm.	
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1.	*Eopleurotoma nodocarinata* (Gabb), 17mm.	35
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2.	*Eopleurotoma nodocarinata* (Gabb), var., 17mm.	
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4.	The same, 18mm.	
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	Claiborne; Gosport Sand horizon	
16.	The same, 13mm.	
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18.	*Eopleurotoma depygis* (Con.), 14mm.	37
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PLATE 7
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9.	*"Surcula lirata"* Conrad, 10.5mm. (Holotype)	38
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10.	*Eopleurotoma ? orangeburgensis*, n. sp., 11mm. (Holotype	38
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11.	The same, 11mm.	
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13.	The same, 8mm.	
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16.	*Eosurcula lesueuri* (Lea), 21.5mm. (Typical)	39
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	Claiborne; Gosport sand horizon	
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	St. Maurice; Lower Claiborne Eocene. Ribs short, numerous	
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	About 10 miles N. W. of Winnfield, La.; Lower Claiborne Eocene. Ribs long, distant	
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	Newton, Miss.; L. Claib. Eoc.	
25.	*Eosurcula pulcherrima* (Heilp.) Holotype	
	Claiborne, Amer. Mus. Nat. Hist.	


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PLATE 8
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24. The same 11mm.; showing apical characters and fine denticulation on larger whorls
25. The same, 7mm. (young)
26. The same, apex enlarged
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    Claiborne; Gosport Sand horizon; Amer. Mus. Nat. Hist.; Photo. by the Museum artist
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30. *Cochlespirella insignifica* var. *alabama*, n. var., 8mm. 44
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    Woods Bluff, Ala.
32. *Cochlespirella insignifica* (Heilp.), 5mm., showing crenulated spiral on sinus zone; Orangeburg; Lower Claiborne Eoc. 43
33. *Cochlespirella insignifica* (Heilp.), 4mm.
    Near Columbus, La.; Lower Claiborne Eocene
34. *Cochlespirella insignifica* (Heilp.), 5.5mm.
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	Claiborne; Gosport sand horizon. Phila. Acad. specimen	
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6.	Probably young of same, 10mm. U. S. N. M. No. 137,416	
	Gosport sand at Claiborne	
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	Moseley's Ferry; Lower Claiborne Eocene	
8.	*Eosurcula moorei* (Gabb) 17mm.	
	Woods Bluff; Upper Sabine Eocene	
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10.	The same, 33mm., canal long, dentation of carina obsolescent	
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12.	The same, 19mm., smooth apical whorls	
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	Elm Cr., Lee Co., Tex.; Lower Claiborne Eocene	
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	Smithville; Lower Claiborne Eocene	
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	St. Maurice; Lower Claiborne Eocene	
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	Lisbon; Lower Claiborne Eocene	
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	Vicinity of Columbus, Sabine River; Lower Claiborne Eocene	
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	Claiborne; below bridge; Claiborne	
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	Orangeburg; Lower Claiborne Eocene	

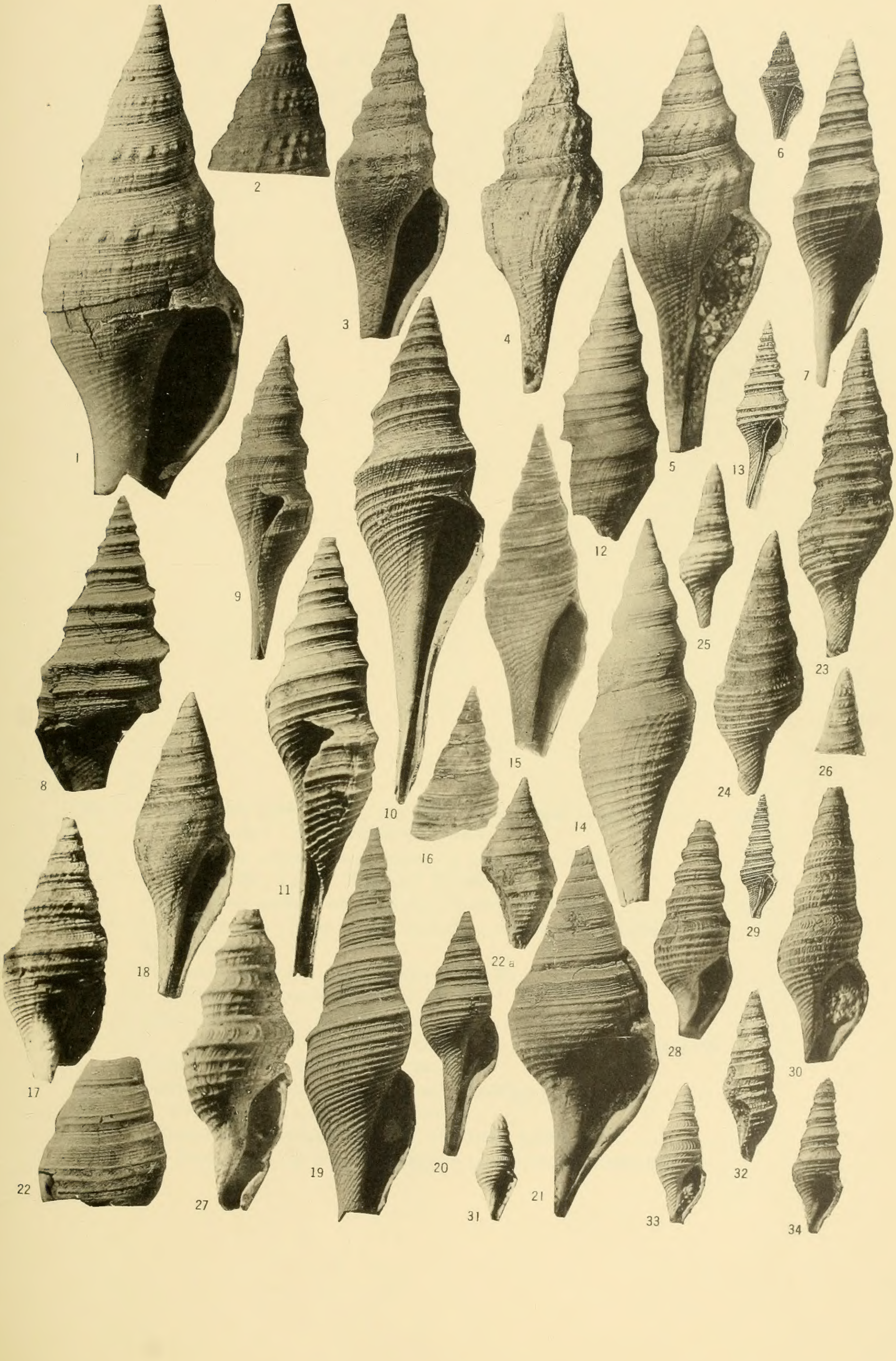
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PLATE 9
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26, 27. *Protosurcula gabbi* (Con.), 7.5 and 4.5mm. respectively 48
Smithville; Lower Claiborne Eocene.

28. *Protosurcula gabbi* (Con.), 45mm., a typical specimen.
Smithville; Lower Claiborne Eocene.

29. *Protosurcula gabbi* (Con.), 33mm. (eroded specimen) 49
"*platysoma*" Heilp.; near Columbus, Sabine Riv.; Lower Claiborne Eocene.

30. *Protosurcula gabbi* (Con.), 43mm. (typical)
Smithville; Lower Claiborne Eocene.

31. *Protosurcula gabbi*, var., 23.5mm. 49
Smithville; Lower Claiborne Eocene. Type of *tenuirostris* Casey, N. S. Nat. Mus. No. 494,360.

32, 33. *Turricula aldreperta*, n. sp., 25.5mm. (Holotype) 49
Claiborne; Gosport sand horizon

34. "*Pleurotoma* (*Clavatula*) *taltibia*" De Greg., 25mm. 50
Presumed to be from the Gosport sand horizon, Claiborne, Ala.

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	Orangeburg.	
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	Moseley's Ferry; Lower Claiborne Eocene	
8.	*Cochlespira bastropensis*, n. sp. 12mm. (Holotype)	
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	Little Brazos River, Tex.; Lower Claiborne Eocene.	
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	Ouachita R.; Jackson Eocene.	
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	London Clay, Engl.	
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	Paris Basin; Mid-Eocene.	
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19.	The same, 5mm.	
20.	*Ancistrosyrinx columbaria* (Ald.), 13mm.	47
	Bunker Hill, Ouachita Riv., La.; Jackson Eocene.	
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23.	*Ancistrosyrinx elegans* Dall, 27mm. (Copy, type)	44
	West Indies; Recent.	
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	Red Bluff; Oligocene. Showing apical features. Compare with 26, 27.	

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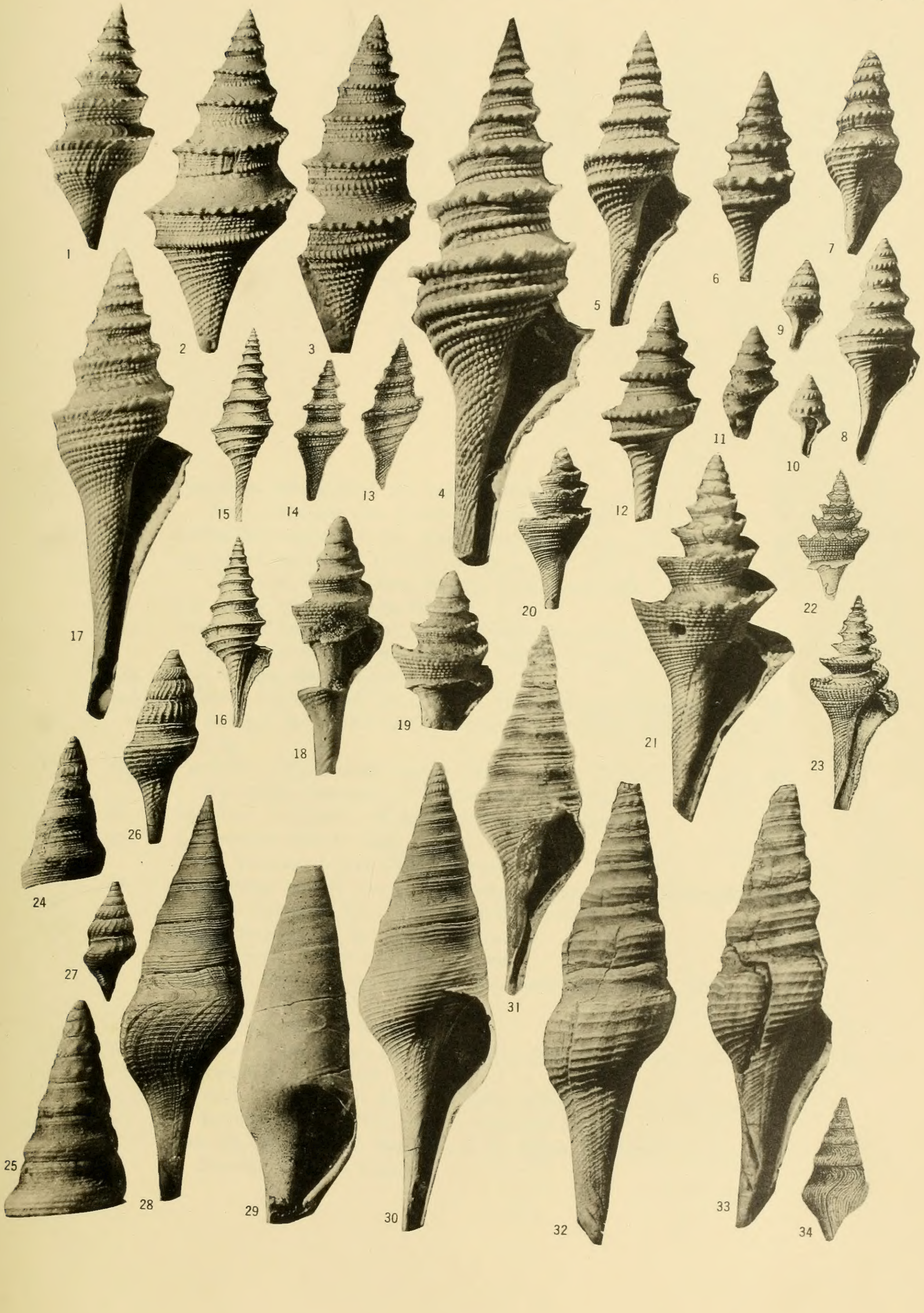
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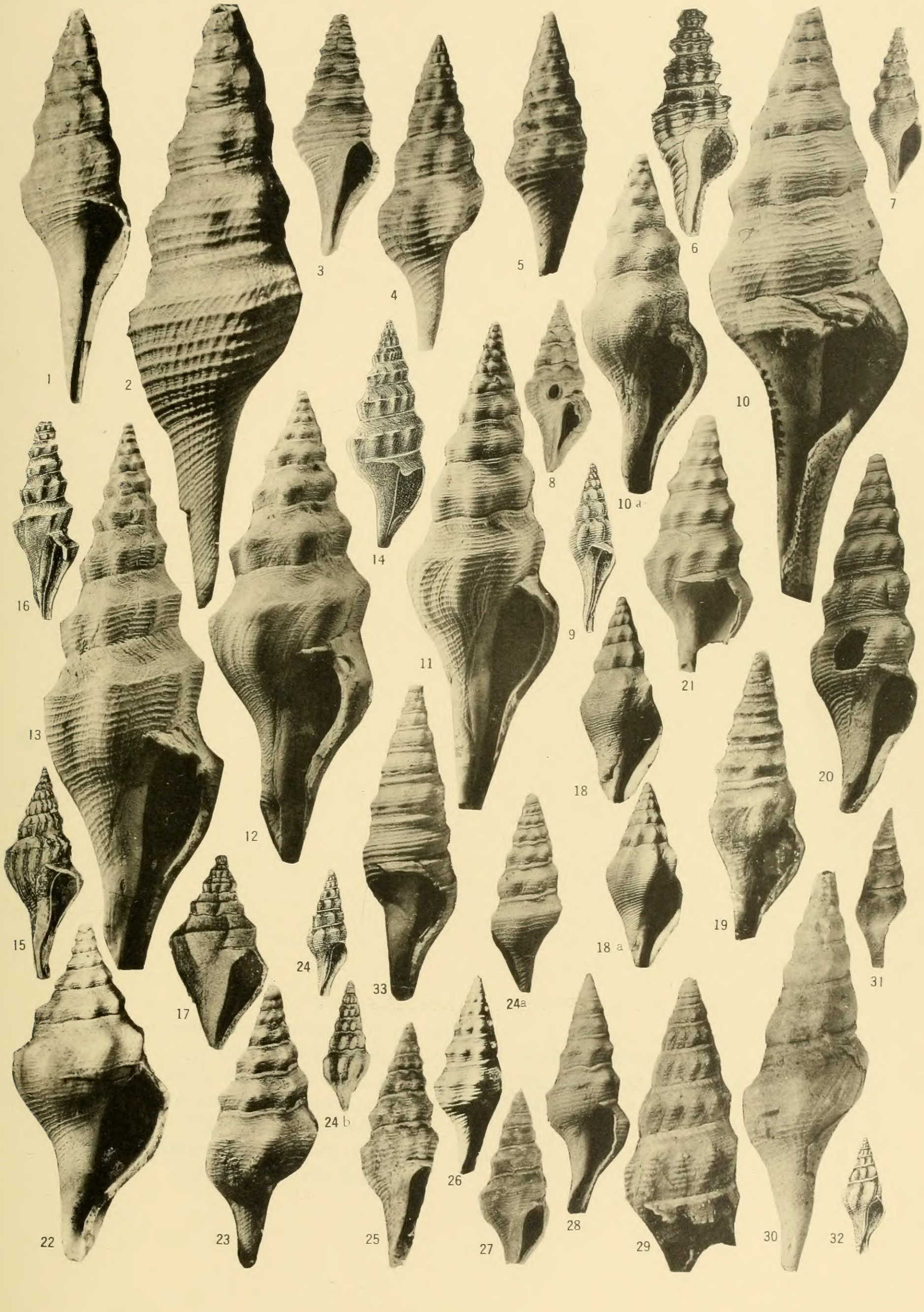
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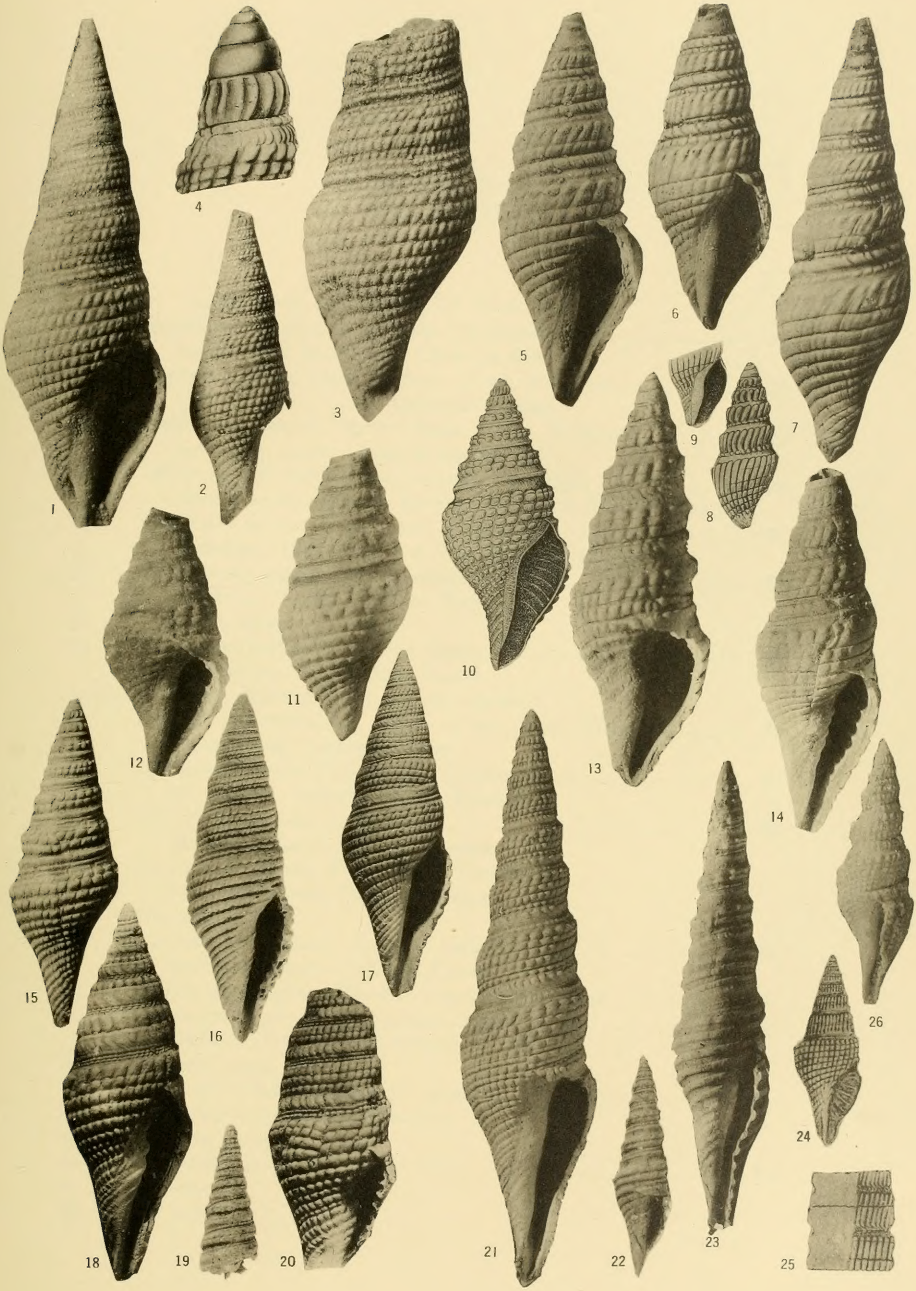
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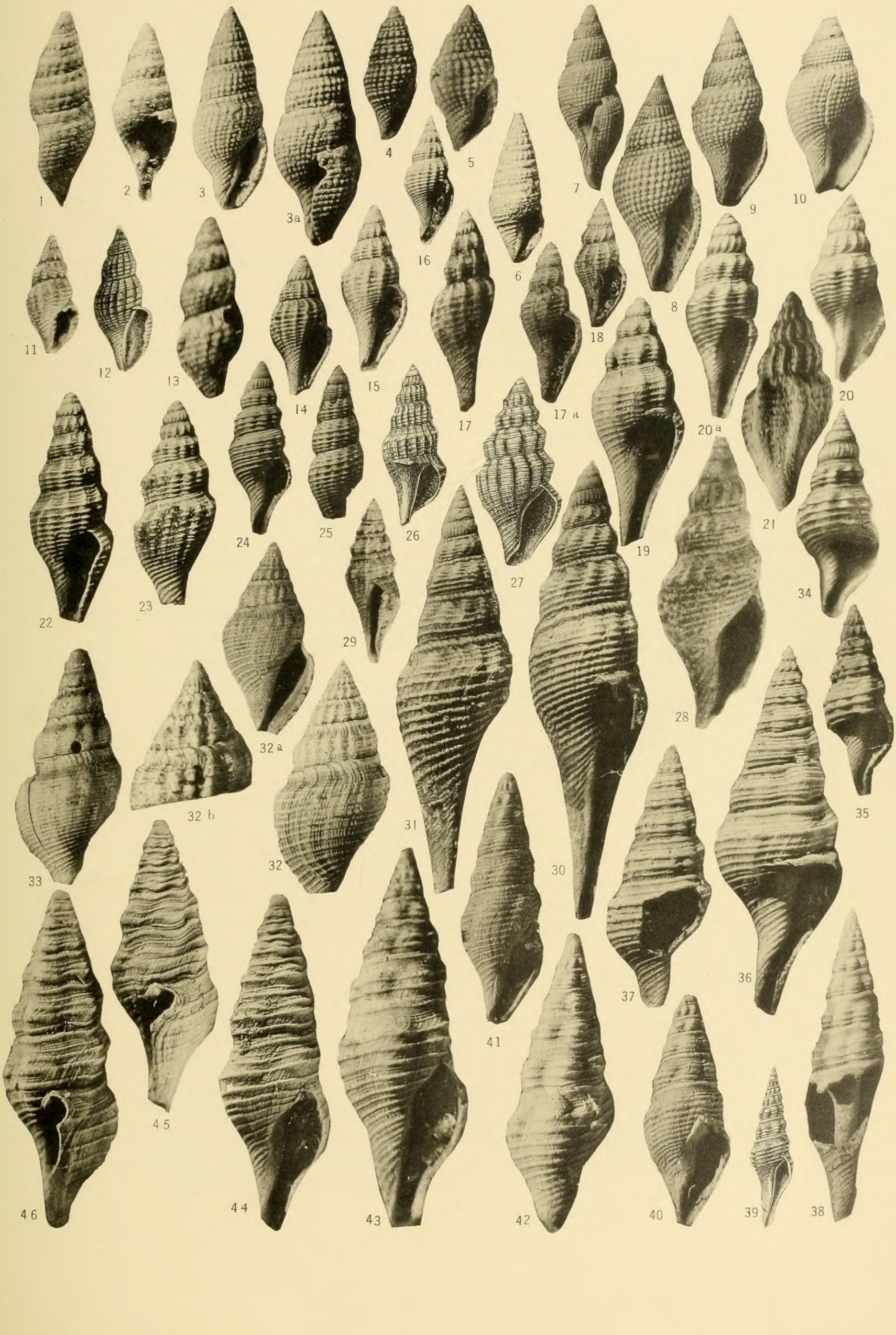
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PALAEONTOGRAPHICA AMERICANA

Volume 2, No. 8

PALAEONTOGRAPHICA AMERICANA

ILLUSTRATED CONTRIBUTIONS

TO THE

INVERTEBRATE PALEONTOLOGY

OF

AMERICA

VOL. II

NO. 8: NEOCENE SPONDYLI FROM THE SOUTHERN UNITED STATES AND TROPICAL AMERICA

By

KATHERINE VAN WINKLE PALMER

October 29, 1938

Palaeontological Research Institution
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NEOCENE SPONDYLI FROM THE SOUTHERN UNITED STATES AND TROPICAL AMERICA

By

Katherine Van Winkle Palmer

INTRODUCTION

During a visit to the type locality[1] of the middle Miocene, Bowden formation at Bowden, Port Morant, St. Thomas-in-the-East Parish, Jamaica, B. W. I. on December 8, 1934 a large, right valve of a *Spondylus* was found in this formation by the writer.

No perfect, large valves of *Spondylus* have heretofore been recorded from the Bowden beds at Bowden. The small shells in the collections studied by W. P. Woodring[2] were referred by him to *S. bostrychites* Guppy.

Spondylus bostrychites Guppy[3] was described originally by Sowerby[4] as *S. bifrons* from the Miocene of Santo Domingo. The species has been reported by authors from Anguilla,[5] Jamaica,[5] Florida,[6] Antigua[7] and Porto Rico.[8] Woodring doubted that the specimens from Florida, Porto Rico, Anguilla and Antigua were *S. bostrychites* but did include small shells from the Bowden under the Dominican species. Mansfield[9] recently excluded the Floridian form from *S. bostrychites* Guppy.

Gabb[10] found in the Miocene of Santo Domingo, in the same formation in which *S. bostrychites* occurred, a *Spondylus* which he identified as the common, eastern, American, Recent species, *S. americanus* Hermann. Gabb's specimens were described and named *S. gumanomocon* by Brown and Pilsbry[11] and later figured by Pilsbry.[12]

[1]Sawkins, J. G. and others, Reports on the Geology of Jamaica, West Indian Survey pt. II, [Mem. Geol. Sur.], pp. 44, 46, 1869; Hill R. T., Bull. Mus. Comp. Zool. Harvard College, vol. 34, (Geol. ser. vol. 4), pp. 82-84, 145-152, 1899; Woodring, W. P., Carnegie Inst. Wash., Pub. No. 366, p. 7, 1925.

[2]Woodring, W. P., ibid, p. 76, pl. 9, figs. 5-7, 1925.

[3]Guppy, R. J. L., Proc. Sci. Assoc. Trinidad, pt. 3, p. 176, 1867; Harris Reprint, Bull. Amer. Pal., vol. 8, No. 35, p. 55. 1921.

[4]Sowerby, G. B., Quart. Jour. Geol. Soc. London, vol. 6, p. 53, 1850 name preoccupied.

[5]Guppy, R. J. L., ibid, pp. 164, 176, 1867; Guppy, R. J. L., Proc. Sci. Assoc. Trinidad, vol. 2, p. 87, 1873, Harris Reprint, ibid, pp. 43, 55, 71, 1921; Woodring, W. P., ibid, p. 77, 1925.

[6]Dall, W. H., Trans. Wag. Free Inst. Sci., vol. III, pt. IV, p. 758, 1898; Dall, W. H., U. S. Nat. Mus., Bull. No. 90, p. 124, 1915; Gardner, J., U. S. Geol. Sur., Prof. Paper No. 142-A, p. 51, 1926.

[7]Cooke, C. W., Carnegie Inst. Wash., Pub. No. 291, p. 144, pl. 11, figs. 11a, 11b, 1919.

[8]Maury, C. J., N. Y. Acad. Sci., Sci. Sur. Porto Rico and the Virgin Islands, vol. III, pt. 1, p. 22, 1920; Hubbard, B., N. Y. Acad. Sci., Sci. Sur. Porto Rico and the Virgin Islands, vol. III, pt. 2, p. 97, 1920.

[9]Mansfield, W. C., Florida Depart. Conservation, Geol. Bull. No. 15, p. 215, 1937.

[10]Gabb, W. M., Trans. Amer. Philos, Soc., n. s. vol. 15, p. 257, 1873.

[11]Brown, A. P. and Pilsbry, H. A., Acad. Nat. Sci. Phila., Proc. vol. 64, p. 514 footnote, 1912 [1913].

[12]Pilsbry, H. A., Acad. Nat. Sci. Phila., Proc. vol. 73, p. 413, pl. XLIII, figs. 4, 5, 1922.

Additional, new species of *Spondylus* were reported from the Caribbean Neocene and the two, original species were listed from other places than the type locality.

A study of the available Spondyli of the Neocene of the Caribbean area revealed that the type specimens of Sowerby's *S. bifrons* (=*S. bostrychites* Guppy) have never been figured. So far as the specific differentiation of the American Neocene Spondyli is concerned basic illustrations have been lacking. Photographs of the holotypes of the Dominican species were acquired by the author. It seemed expedient to publish those pictures and comparative notes and to record the discovery of a large specimen of *S. bostrychites* from the Bowden Miocene of Jamaica.

The research on the species of *Spondylus* as discussed herein is not complete. The collections of Spondyli from the Neocene of Porto Rico, Antigua, Anguilla, Florida and the Gabb Dominican collection in the Academy of Natural Sciences, Philadelphia have not been examined by the writer. Certain points introduced in the paper have not been checked by a study of the specimens from those localities. Data given in this work will probably permit more definite conclusions in regard to the material from those areas.

Through the courtesy of Dr. L. R. Cox, Department of Geology, British Museum, Natural History, a photograph of the lectotype of *S. bifrons* Sowerby and the collection of five paratypes were sent to the author.

Miss Helen Winchester graciously photographed the syntypes of *S. gumanomocon* Brown and Pilsbry at the Academy of Natural Sciences, Philadelphia, Pa., and William T. Clarke, Jr., of that Institution sent the measurements of the specimens.

Dr. Chas. W. Merriam permitted the writer to study the Santo Domingo Gabb and Maury duplicate Spondyli material which is in the Paleontological Laboratory, Cornell University, Ithaca, N. Y.

The holotypes of the species described by Olsson, Weisbord, Hodson and Harris are in the Paleontological Research Institution where they have been examined by the author.

Appreciation is expressed to the persons mentioned and to the Institutions which have been responsible for the preservation of the type material.

To the Paleontological Research Institution and particularly to G. D. Harris, thanks are due for study and photographic facilities combined with an inestimable amount of cooperation.

Paleontological Research Institution,
Ithaca, N. Y.
Aug. 6, 1938

SYSTEMATIC DESCRIPTION

Family Pectenidæ

Subfamily Spondylinæ

Genus Spondylus Linnæus, 1758.[13]

Genotype by subsequent designation, Gray, 1847,[14] *S. gæderopus* Linnæus. Recent. Mediterranean.

The shells are usually heavy, inequivalved with one valve projecting dorsally. The mollusc is attached to foreign objects by the right valve. The right valve in the type species[15] is flat while commonly that valve is convex. Such is true of the American Neocene species. In many forms both valves are convex, with the right valve more inflated. Where the right valve is large and projects dorsally, the cardinal area of the right valve is larger. The chrondophore is triangular and median. The hinge in both valves consists of 2, heavy teeth, one on either side of the chrondophore with corresponding sockets. The adductor muscular impression is orbicular and situated posteriorly. The adductor muscle is composed of two parts. The posterior portion is larger and the fibres are opaque. The anterior fibres are semi-translucent. The impression of the two parts of the muscle is clearly shown in the figures of the Miocene fossil, pl. 3, figs. 1, 2 and 5, this report. Dakin pointed out that the adductor muscle in its "bipartite" division is like *Pecten* and therein *Spondylus* reveals its ancestry. The two genera differ in the volume of each type of adductor muscle fibres. The translucent fibres are responsible for the contractions which close the valves and cause the process of swimming. In *Pecten* the amount of translucent fibres is greater than in *Spondylus*. *Spondylus* lost the power of swimming when it acquired the habit of adherence. Hence the number of translucent fibres decreased and the opaque fibre area enlarged. The pallial line is entire. The exterior surface is usually ornamented with coarse, unequal, radiating ribs. The larger, radiating ribs bear spines. The spines in many species become numerous and long. Concentric, foliated lamellæ occur over the attached valve in varying extent. The living species are often highly colored with orange, yellow, red, purple and brown.

The prodissoconch and first nepionic stage is pectiniform.[16] A byssal notch is formed in the first nepionic stage of growth but is lost when the young animal at the close of the pectiniform growth fastens the shell to some object or becomes embedded in coral.

[13]Linnæus, C., Systema Naturæ, 10th ed., p. 690, 1758.

[14]Gray, J. E., Proc. Zool. Soc. London, pt. XV, p. 201, 1847.

[15]Dakin, W. J., The Anatomy and Phylogeny of Spondylus, with a particular reference to the Lamellibranch Nervous System, Roy. Soc. London, Biol. Sci. ser. B, vol. 103, No. B 725, pp. 337-354, 1928.

[16]Jackson, R. T., The Phylogeny of the Pelecypoda. The Aviculidæ and their allies., Mem. Boston Soc. Nat. Hist., n. s. vol. IV, p. 351, 1890.

Jackson through a study of the ontogeny of the shell and Dakin from an examination of the soft anatomy of *Spondylus* deduced that the genus evolved from *Pecten*. Watson[17] although not agreeing with Dakin as to the interpretation of the relation of the central nervous system of *Spondylus* believed that the classification of *Spondylus* and *Plicatula* in one family distinct from *Pecten* should be discontinued. He would place the two genera in the Pectenidæ, dividing that family into the Amusiinæ, Plicatulinæ, Pectininæ and Spondylinæ. Such is the classification given by Thiele.[18]

After *Spondylus* becomes fastened it loses its ancestral, pectiniform character and the shell and anatomy are modified accordingly. The distortions in the shape of the shell, greatest in the right valve of *Spondylus* make difficult specific determination of fossil forms. Dall[19] emphasized this factor when he included over twenty, specific names under one for the common, living, eastern, American *S. americanus* Hermann.[20]

Spondylus is found today in the warm waters of the world. Typical *Spondylus* appeared in the Cretaceous.[21] Formally its range was thought to extend to the Trias.

Spondylus bostrychites (Guppy)

Plate I, figs. 1, 2; plate II, figs. 1, 3, 5; plate III, figs. 1-5

Spondylus bifrons Sowerby, 1850, Quart. Jour. Geol. Soc. London, vol. 6, p. 53. *Non S. bifrons* Goldfuss, 1835, Petref. II, p. 99.

Spondylus bostrychites Guppy, 1867, Proc. Sci. Assoc. Trinidad, pt. 3, p. 176, Harris Reprint, 1921, Bull. Amer. Pal., vol. 8, No. 35, p. 55; Guppy, 1873, Proc. Sci. Assoc. Trinidad, vol. 2, p. 87, Harris Reprint, ibid, p. 71; Gabb, 1873, Trans. Amer. Phil. Soc., vol. 15, p. 257; Guppy, 1874, Geol. Mag. decade II, vol. 1, p. 443 *partim;* Dall, 1898, Trans. Wag. Free Inst. Sci., vol. III, pt. IV, p. 158, *partim*; Dall, 1903, ibid, vol. III, pt. 6, p. 1586; Maury, 1917, Bull. Amer. Pal., vol. 5, No. 29, p. 190, pl. 32, fig. 4; *cf.* Cooke, 1919, Carnegie Inst. Wash., Pub. 291, p. 144, pl. 11, figs. 11a, b; Maury, 1920, New York Acad. Sci., Sci. Sur. Porto Rico and Virgin Islands vol. III, pt. I, p. 22 *partim;* Hubbard, 1920, New York Acad. Sci., Sci. Sur. Porto Rico and Virgin Islands vol. III, pt. II, p. 97 *partim;* Pilsbry, 1922, Acad. Nat. Sci. Phila., Proc. vol. 73, p. 413; Woodring, 1925, Carnegie Inst. Wash. Pub., No. 366, p. 76, pl. 9, figs. 5-7; *cf.* Trechmann, 1930, Geol. Mag., vol. LXVII, No. 791, p. 211.

Testa subregularis, rotundata, ventricosa, margine latiusculo, valide denticulato; extus radiatim costata, costis 5 ad 6 spiniferis; areâ cardinali alterius valvæ angustissimâ, alterius latiori.

Nearest to *S. imperialis*, easily distinguished by the area of one valve being very narrow, and that of the other being rather broader, though still narrow.—[Sowerby, 1850].

Following are the description and measurements made by the author from the paratypes which were loaned from the British Museum. The term holotype was applied to the specimen of which a photograph was sent. The selection of the

17Watson, H., On the Central Nervous System of *Spondylus* and what happens to a Headless Mollusc's Brain, Proc. Mal. Soc. London, vol. 19, pp. 31-36, 1930; Watson, H., On the Anatomy and Affinities of *Plicatula*, l. c., pp. 25-31, 1930.

18Thiele, J., Handbuch der Systematischen Weichtierkunde, pt. 3, pp. 804-809, 1931.

19Dall, W. H., ibid, p. 760, 1898.

20Hermann, J., Der Naturforscher, vol. XVI, p. 51, 1781; Hedley, C. and Pilsbry, H. A., The Nautilus, vol. XXVI, No. 4, pp. 45, 46, 1912; Cox, L. R., Proc. Mal. Soc. London, vol. XVIII, pt. V, pp. 253, 254, 1929.

21Dacqué, E., Leitfossilien, 7 lief. Wirbellose des Jura. Teil I, p. 214. 1933.

22Blake, J. F., List of the types and figured specimens recognized by C. D. Sherborn, F. G. S. in the collection of the Geological Society of London, verified and arranged, with additions, p. 65, London, 1902.

type was made by Sherborn and Blake[22] when the types and figured specimens in the collection of the Geological Society of London were arranged. Since Sowerby's description does not indicate that a holotype had been selected by him, the author prefers to employ the term lectotype and has so used that appellation in this discussion. The paratype material consists of 5 specimens: one, large individual which consists of right and left valves together; right and left, large valves; right and left, small valves. The 5 co-types would be strictly speaking paralectotypes but according to common usage they will be designated as paratypes. The numbers 1-5 as used herein are designated for convenience and have nothing to do with original numbers of the specimens.

The shell is large, suborbicular with the right valve more inflated than the left. The umbo of the right valve is arched above the left. The cardinal area of the right valve is wide, high and coarsely striated. The cardinal area of the left valve is narrow, vertical and coarsely striated. The auricles are large, sculptured with coarse lines of growth crossed by fine, radiating ribs. The valves are ornamented with large, radiating ribs which are arranged in a series of primary and secondary ridges. The number of such ribs is given in detail in the following paragraphs:

Paratype No. 1, left valve, has 11 primary, radiating ribs with 1-3 secondary ribs between the primaries; 55 mm., length; 55 mm., height; 17 mm., width.

Paratype No. 2, right valve, has 7 primary, radiating ribs with 3-6 secondaries between the primaries; some secondaries are split ventrally; 58 mm., length; 62 mm., height; 20 mm., width.

Paratype No. 3, left valve, has 7 primary, radiating ribs with 2-7 irregular secondaries between the primaries; 90 mm., length; 95 mm., height; 26 mm. width.

Paratype No. 4, right valve, has 9, primary, radiating ribs with 2-7 secondaries between the primaries; some of the secondaries are split ventrally; 90 mm., length; 95 mm., height; 30 mm., width.

Paratype No. 5, two valves together, has 8 primary, radiating ribs on the right valve and 6 primary, radiating ribs on the left valve; 3-6 secondaries on the right valve and 4-6 secondaries on the left valve; 80 mm., length; 90 mm., height; 35 mm., width (right valve); 80 mm., length; 85 mm., height; 30 mm., width (left valve).

Specimens of *S. bostrychites* Guppy in the Cornell Gabb and Maury collections from the Miocene of the Dominican Republic consist of the following:

1. A right valve, 85 mm. in height, has typical sculpture with additional, concentric ribs or flutes on 7 mm. of the umbonal tip.

2. A broken specimen has 10 mm. of the umbonal area with concentric ribs.

3. A left valve, 13 mm. in height, from Rio Gurabo, Zone F, Maury collection, lacks concentric sculpture.

4. A typical, left valve, 32 mm. in height, lacks concentric flutes.

5. A left valve, 49 mm. in height, has large, spinose, secondary ribs and has 5 or 6, finer, tertiary, radiating ribs.

The specimens in the above collections show that *S. bostrychites* may have concentric ribs over the umbonal portion of the right valve. One of the right valve paratypes has conspicuous, concentric ribs on the attached area. The factor of concentric lamellæ is taken up in detail because authors have used the presence or absence of concentric ribs in specific determination. When concentric foliations do not occur below the point of adherence they may be present or absent and are not of specific value in such species as *S. bostrychites* Guppy. The material studied so far in this report has the concentric lamellæ limited to the right or attached valve. An exception in material elsewhere is *S. striatus* (Sowerby) from the Cretaceous of England. Both valves of that species are described by Woods[23] as having concentric ribs.

That the presence of numerous, concentric lamellæ is governed more by attachment than by specific differentia is suggested by the many, complete illustrations of D'Orbigny.[24] Several species have numerous, concentric lamellæ and in those cases the concentric foliations occur over the valve which has been fastened to an object.

The three specimens of *S. bostrychites* from Bowden, Jamaica, figured by Woodring show the forms to be typical, young shells of that species.

The figure given herein, pl. 1, fig. 1 is of a large, right valve collected by the writer from Bowden. The specimen came from an exposure at Port Morant, about half way up the hill, in the side of the road leading to the old Capt. Baker house. This road turns off the bayside road near Bowden P. O. and the United Fruit Company wharf. The locality is therefore higher in the formation than the gravels at the base from which the large collections of Bowden fossils have been obtained.

The shell measures 150 mm. in height, 122 mm. in length and 60 mm. in width, exceeding the largest paratype of *S. bostrychites* by 60 mm. in height. The umbones of this valve are elevated and arched so that unless in photographing the shell is tilted forward the auricles may not be seen to their full extent. The dorsal area is narrowed and the shape of the valve is less orbicular than that of typical *S. bostrychites*. The change in shape is probably due to the greater size and shell age of the Bowden form. There are about 9, primary, radiating ribs bearing large spines with 3-6, irregularly sized, secondary, radiating ribs. Much of the surface of the shell reveals conspicuous, fine, radiating and concentric threads similar to those on paratype No. 5, pl. I, fig. 2. The striking feature of the Bowden shell is the concentric, fluted ribs over the umbonal region. One of the paratypes, No. 2, pl. III, fig. 3, has such ribs. Further discussion of this character has been given in connection with the Maury-Gabb collection of *S. bostrychites*. One young Bowden specimen (right valve) figured by Woodring shows well de-

[23] Woods, H., Pal. Soc. London, vol. LV, p. 120, 1901.

[24] d'Orbigny, A., Paléontologie Française, Terrains Crétacés, t. 3, pp. 652-677, pls. 450-461, 1843-47.

veloped, concentric flutes. Because of the likeness in sculpture of the large, Bowden shell with that of the paratype material of *S. bostrychites* Guppy and in spite of the difference in shape, the specimen is determined as a gerontic individual of that species.

Large spines project from the radiating ribs of *S. bostrychites.* The spines are common on the primary ribs but by no means limited to the primary ribs as has usually been described by writers. Numerous spines may be seen on secondary ribs on paratypes 3 and 4, plate 2, figs. 1 and 3. The lectotype has incipient spines on secondary ribs. The whole surface of the shell is sculptured with scaly, concentric lines giving the radiating ribs a lamelliform appearance. Specimens Nos. 3 and 4 have the posterior end produced in both valves. Specimen No. 5 shows a slight posterior production. Specimen No. 2 has conspicuous, concentric ribs on the umbonal region.

The specimens figured by Cooke[25] from the Oligocene of Antigua exhibit the same relationship between primary and secondary, radiating ribs. Because this observation is made only from a comparison by illustration and lacks an examination of specimens one hesitates to assign the forms to *S. bostrychites.*

Trechmann[26] referred to *S. bifrons* Sowerby as distinct from *S. bostrychites* Guppy. Guppy stated in 1867 and 1873 that the name of Sowerby was preoccupied and gave the name *bostrychites* to replace *bifrons.* The two names apply to the same species.

Lectotype and paratypes.—No. R 12833, (Geol. Soc. London) in British Museum (Natural History).

Occurrence.—Dominican Republic (type) ; Gurabo formation, middle Miocene, Dominican Republic (Maury) ; Bowden formation, middle Miocene, Bowden, Jamaica (Woodring, Palmer).

Spondylus gumanomocon Brown and Pilsbry

Plate I, figs. 3, 4; Plate II, figs. 2, 4

Spondylus americanus Gabb, 1873, Trans. Amer. Phil. Soc., vol. 15, p. 257 *non* Hermann, 1781 *non* Lamarck, 1819.

Spondylus gumanomocon Brown and Pilsbry, 1912, [1913] Acad. Nat. Sci. Phila., Proc. vol. 64, p. 514 footnote; Maury, 1917, Bull. Amer. Pal., vol. 5, No. 29, p. 191; Pilsbry, 1922, Acad. Nat. Sci. Phila., vol. 73, p. 413, pl. XLIII, figs. 4, 5; Olsson, 1922, Bull. Amer. Pal., vol. 9, No. 39, pt. 2, p. 207, pl. 21, fig. 1.

Spondylus carmenensis F. Hodson, 1927, Bull. Amer. Pal., vol. 13, No. 49, p. 41, pl. 25, figs. 1, 2, 3.

A species resembling *S. varians* Sowb. (*S. delessertii* Chenu). The upper valve is Pectiniform, orbicular, of moderate thickness, with low radial ribs, the principal ones irregularly spinose, spines short; cardinal area small and short, as in *S. americanus.* Lower valve very ponderous, with a long, level, (not receding) cardinal area, and a very long, straight (or sometimes laterally curved) beak, the cavity of which is deeply excavated in young shells, nearly solidly filled in old ones. Sculpture like the upper valve, except that it is more or less extensively foliated towards the beak.

Length (alt.) of a lower valve 175 mm.; breadth 108 mm.; weight 32½ oz.

Santo Domingan Oligocene. This is the form identified by Gabb as *Spondylus americanus.*—[Brown and Pilsbry, 1913.]

This species has an elevated, cardinal area in the right valve. The left valve

[25]Cooke, C. W., ibid, pl. 11, figs. 11a 11b, 1919.

[26]Trechmann, C. T., Geol. Mag., vol. LXVII, No. 791, p. 211, 1930.

has a shorter, cardinal area and the whole valve is pectiniform and lacks the concentric, foliated sculpture which usually characterizes the right valve. The concentric ribs differ from those on *S. bostrychites* in that they may extend the full height of the shell. The illustrations of the species in this report show the difference in sculpture between that of the right valve of *S. gumanomocon* and that of the two valves of *S. bostrychites.* The radiating sculpture on the umbonal portion of some valves of *S. bostrychites* may be alternating in character as in *S. gumanomocon.*

This species has been considered as the form in the Caribbean Miocene which attains the greatest size. When the dimensions of the species are compared it is seen that *S. gumanomocon* is only one of several which reaches a ponderous size. The largest measurements given so far for a *Spondylus* of the region is that of *S. cf. chiriquiensis* Olsson found by Trechmann[27] in the Miocene at Navy Island, Port Antonio, Jamaica. That specimen measured 186 mm. in height which is 5 mm. greater than the height of the holotype of *S. gumanomocon.* The holotype of *S. chiriquiensis* Olsson is 151 mm. in height and the *S. bostrychites* specimen figured herein from Bowden, Jamaica has a height of 150 mm. Size alone therefore cannot be taken as of specific value.

Maury[28] and Hubbard[29] identified molds from the Oligocene of Porto Rico as *S. gumanomocon.* The specimens were not figured and the shells have not been examined by the author. Dr. Maury pointed out that there was considerable variation in the size and shape of the Porto Rican molds. Such is the case of the material in the Gabb-Maury Dominican collections.

A comparison of the types of *S. carmenensis* Hodson from Venezuela with the illustrations of *S. gumanomocon* show such a similarity that it is probable that the two forms are conspecific. The holotype of *carmenensis* presents a greater likeness to *gumanomocon* than does the specimen which Olsson found in Costa Rica Miocene identified as *S. gumanomocon.* The holotype locality of *S. carmenensis* is "about 10 miles east and about 4 miles south of Dabajura," District of Buchivacoa, State of Falcón, Venezuela. The mileage of the locality, other than that published[30] was furnished by the Hodsons[31] who also gave their opinion as to the middle Oligocene age of the locality. This would extend the range of *S. gumanomocon* from Middle Miocene back to the middle Oligocene.

The possibility that the produced, rounded, narrow shape of *S. gumanomocon* is not specific but may be assumed by any species of *Spondylus* under certain conditions of attachment is suggested . In that case *S. gumanomocon* and specimens of similar shape would not be species of their present descriptions but environmental forms. Data on living species in regard to results of a like nature are not available.

[27]Trechmann, C. T., ibid, p. 211, 1930.
[28]Maury, C. J., ibid, p. 23, 1920.
[29]Hubbard, B., ibid, p. 97, 1920.
[30]Hodson, F. and Hodson, H. K., Bull. Amer. Pal., vol. 16, No. 59, p. 5 1931.
[31]Hodson, F. and Hodson, H. K., Letter, Aug. 3, 1938.

Holotype and paratype.—No. 2869, Acad. Nat. Sci. Phila.

Occurrence.—Middle Oligocene (Hodson), Venezuela; Gurabo formation, middle Miocene, Dominican Republic (type); Gatun formation, middle Miocene, Costa Rica (Olsson).

MID-TERTIARY SPONDYLI OF THE SOUTHERN UNITED STATES AND TROPICAL AMERICA

1. *S. dumosus* (Morton), 1834, Syn. Org. Remains Cret. U. S., p. 59, pl. 16, fig. 8, text fig. Oligocene, St. Stephens Bluff, Tombigbee River, Ala.

1a. *Spondylus bifrons* Sowerby, 1850 =*S. bostrychites* Guppy, 1867. Miocene, Santo Domingo.

2. *S. americanus* Gabb, 1873 *non* Hermann, 1781; *non* Lamarck, 1818.=*S. gumanomocon* Brown and Pilsbry, 1912 [1913]. Miocene, Santo Domingo.

3. *S. bostrychites chipolanus* Dall, 1898, Trans. Wag. Free Inst. Sci., vol. III, pt. IV, p. 758; Dall, 1915, U. S. Nat. Mus. Bull. 90, p. 125 *partim*, pl. 19, fig. 1; Gardner, 1926, U. S. Geol. Sur. Prof. Paper No. 142-A, p. 51=*S. chipolanus* Dall, Chipola (lower) Miocene (type); Oak Grove sand, lower Miocene.

4. *S. gumanomocon* Brown and Pilsbry, 1912 [1913]. Gurabo (middle) Miocene, Dominican Republic (type); Gatun (middle) Miocene, Costa Rica.

5. *S. scottii* Brown and Pilsbry, 1912, [1913], Acad. Nat. Sci. Phila., Proc. vol. 64, p. 514, pl. XXV, figs. 1, 2. Gatun (middle) Miocene, Panama.

6. *S.* sp. indet. Brown, 1913, Acad. Nat. Sci. Phila., Proc. vol. 65, p. 603. Oligocene, Antigua.

7. *S. filiaris* Dall, 1916, U. S. Nat. Mus., Proc. vol. 51, No. 2162, p. 493, pl. 83, figs. 5, 6. Oligocene, Flint River formation, Georgia.

8. *S. lucasi* Maury, 1920, N. Y. Acad. Sci., Sci. Sur. Porto Rico and the Virgin Islands, vol. III, Pt. 1, p. 23, pl. V, fig. 1. Oligocene, Porto Rico.

9. *S. chiriquiensis* Olsson, 1922, Bull. Amer. Pal., vol. 9, No. 39, p. 206, pl. 20, figs. 1, 2, 5, 6. Gatun (middle) Miocene. Costa Rica (type); ? Pliocene, probably Miocene, Manchioneal beds, Navy Island, Port Antonio, north-east coast, Jamaica, B. W. I.

10. *S. carmenensis* F. Hodson, 1927, Bull. Amer. Pal., vol. 13, No. 49, p. 41, pl. 25, figs. 1, 2, 3. Oligocene, District of Falcón, Venezuela.=*S. gumanomocon* Brown and Pilsbry.

11. *S. falconensis* Harris, 1927, Bull. Amer. Pal., vol. 13, No. 49, p. 40, pl. 23, figs. 4, 5; pl. 24, fig. 9. Miocene, Districts of Colina and Miranda, State of Falcón, Venezuela.

12. *S. colombiensis* Weisbord, 1929, Bull. Amer. Pal., vol. 14, No. 54, p. 14, pl. 2, figs. 10, 11. Miocene, Dept. of Atlantico, near Tubera, Colombia.

13. *S. minus* Olsson, 1931, Bull. Amer. Pal., vol. 17, No. 63, p. 41, pl. 3, fig. 2. Lower Oligocene, Chira formation, Chira valley near Casa Saman, Peru.
14. *S. chipolanus tampensis* Mansfield, 1937, Fla. Dept. Conservation, Geol. Bull., No. 15, p. 215, Lower Miocene, Tampa limestone, Florida=*S. bostrychites* Dall, 1915, U. S. Nat. Mus., Bull. No. 90, p. 124, pl. 19, fig. 4 *non* Guppy, 1867.

EXPLANATION OF PLATES

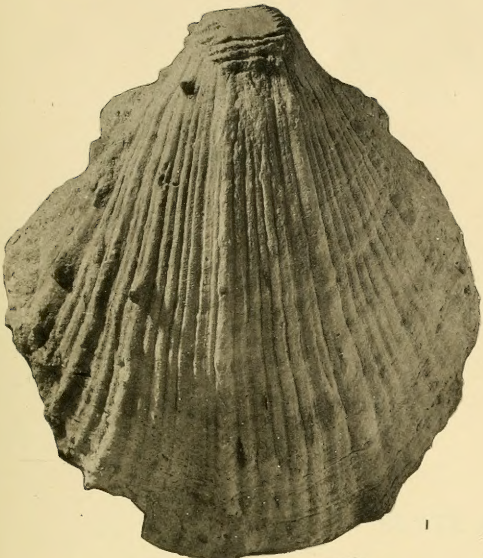
(From photos by K. V. Palmer.)

PLATE 1

(Vol. Pl. 16)

EXPLANATION OF PLATE 1 (16)

Figure		*Page*
1.	*Spondylus bostrychites* Guppy	6
	No. 3414, P. R. I. Height, 150 mm.; length 122 mm.; width, 60 mm., right valve Bowden formation, middle Miocene, Bowden, Jamaica, B. W. I.	
2.	*Spondylus bostrychites* Guppy	6
	Paratype, *S. bifrons* Sowerby, Geol. Soc. London, in Geological Department, British Museum (Natural History) Height, 90 mm.; length, 80 mm.; width, 35 mm., right valve, specimen No. 5 Gurabo formation, middle Miocene, Dominican Republic	
3.	*Spondylus gumanomocon* Brown and Pilsbry	9
	Holotype, Acad. Nat. Sci. Phila. No. 2869 Height, 181 mm.; length, 120 mm., right valve Gurabo formation, middle Miocene, Dominican Republic	
4.	*Spondylus gumanomocon* Brown and Pilsbry	9
	Same specimen as fig. 3	



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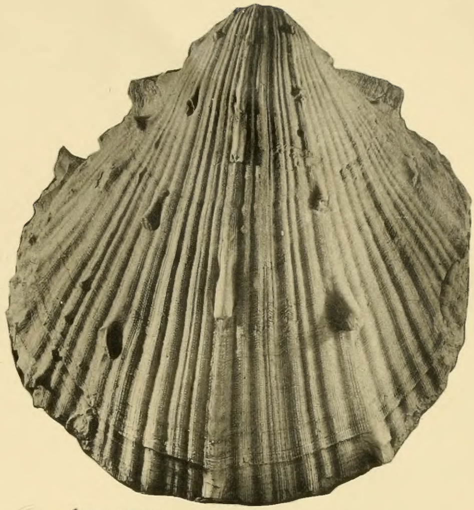

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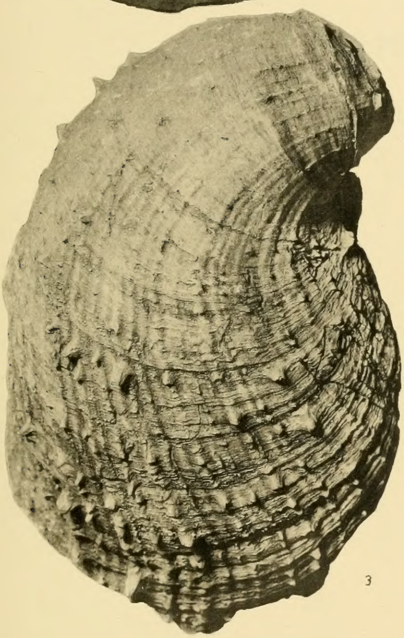

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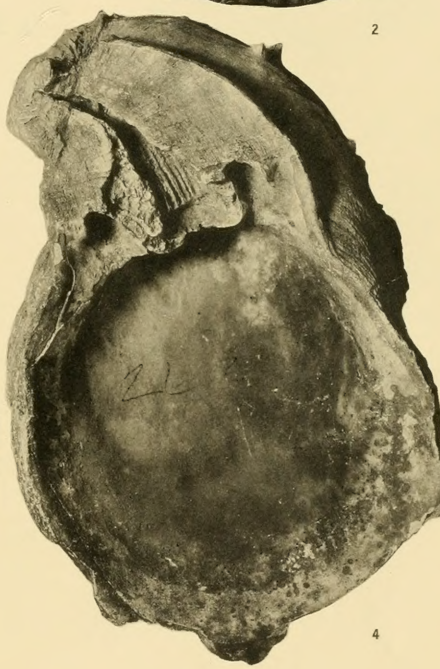

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PLATE 2

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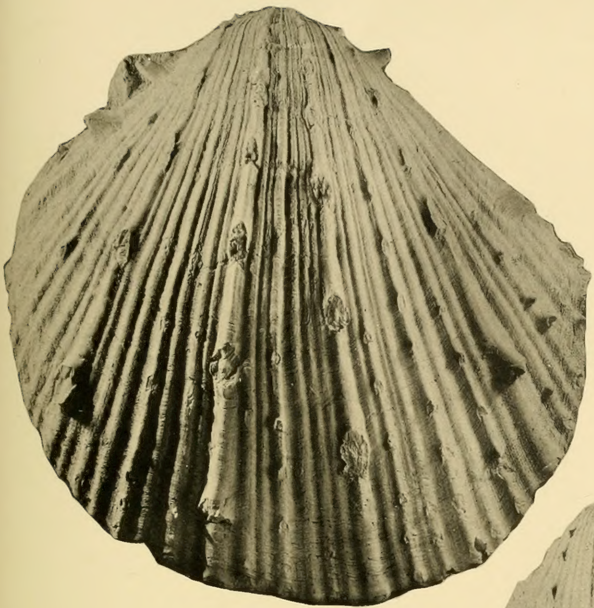
EXPLANATION OF PLATE 2 (17)

Figure *Page*

1. *Spondylus bostrychites* (Guppy) 6
   Paratype *S. bifrons* Sowerby, Geol. Soc. London in Geological Department, British Museum (Natural History)
   Height, 95 mm.; length, 90 mm., width, 26 mm., left valve, specimen No. 3
   Gurabo formation, middle Miocene, Dominican Republic
2. *Spondylus gumanococon* Brown and Pilsbry 9
   Paratype, Acad. Nat. Sci. Phila.
   Height, 138 mm.; length, 97 mm., right valve
   Gurabo formation, middle Miocene, Dominican Republic
3. *Spondylus bostrychites* Guppy 6
   Paratype *S. bifrons* Sowerby, Geol. Soc. London in Geological Department, British Museum (Natural History)
   Height, 95 mm.; length, 90 mm.; width, 30 mm., right valve, specimen No. 4
   Gurabo formation, middle Miocene, Dominican Republic
4. *Spondylus gumanomocon* Brown and Pilsbry 9
   Same specimen as fig. 2
5. *Spondylus bostrychites* Guppy 6
   Same specimen as figure 2, plate 1, both valves
   Figured to show cardinal and umbonal areas



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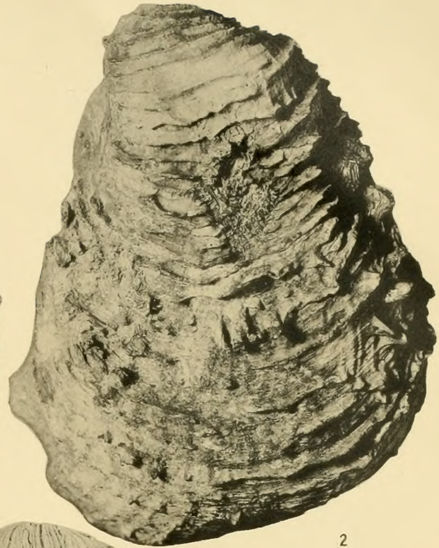

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PLATE 3

(Vol. Pl. 18)

EXPLANATION OF PLATE 3 (18)

Figure *Page*

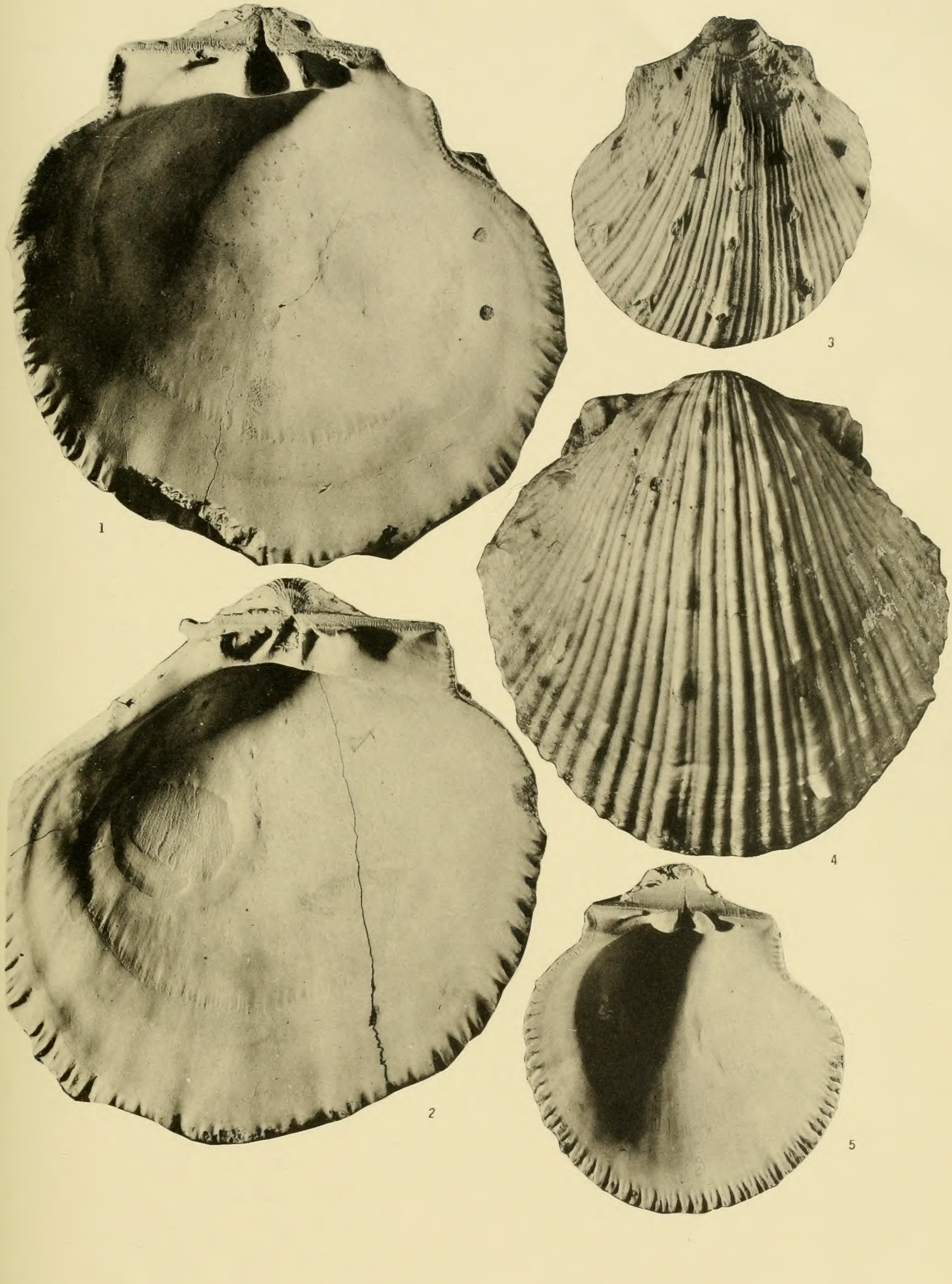
1. *Spondylus bostrychites* Guppy 6
   Paratype *S. bifrons* Sowerby. Same specimen as figure 3, plate 2

2. *Spondylus bostrychites* Guppy 6
   Paratype *S. bifrons* Sowerby. Same specimen as figure 1, plate 2

3. *Spondylus bostrychites* Guppy 6
   Paratype *S. bifrons* Sowerby, Geol. Soc. London in Geological Department, British Museum (Natural History)
   Height, 62 mm.; length, 58 mm.; width, 20 mm., right valve, specimen No. 2

4. *Spondylus bostrychites* Guppy 6
   Lectotype *S. bifrons* Sowerby, Geol. Soc. London in Geological Department, British Museum (Natural History) No. R 12833
   Photo, British Museum, x1
   Gurabo formation, middle Miocene, Dominican Republic

5. *Spondylus bostrychites* Guppy 6
   Interior of specimen figure 3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PALAEONTOGRAPHICA AMERICANA

Volume 2, No. 9

PALAEONTOGRAPHICA AMERICANA

ILLUSTRATED CONTRIBUTIONS

TO THE

INVERTEBRATE PALEONTOLOGY

OF

AMERICA

VOL. II

NO. 9: DEVONIAN BREVICONES OF NEW YORK
AND ADJACENT AREAS

By

Rousseau H. Flower

December 28, 1938

Palaeontological Research Institution
Ithaca, New York, U. S. A.

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CONTENTS (*Continued*)

DEVONIAN BREVICONES OF NEW YORK AND ADJACENT AREAS

By

Rousseau H. Flower

INTRODUCTION

In this paper are included descriptions of the breviconic cephalopods of the Devonian of New York, and a few from other areas as well, that are sufficiently known to permit accurate generic diagnosing, together with a short note on the more obscure species which are known from material which is too poorly preserved or too fragmentary to permit generic and often specific recognition. A large percentage of Hall's figured types show no trace of the aperture or the siphuncle, and nearly all of them leave much to be desired. Hall's descriptions are particularly misleading in regard to the brevicones, for a hyponomic sinus is often described even when the type material shows none. Further, the species as conceived by Hall were very broad, and many of them have had to be divided. In *Gomphoceras absens* Hall included species both with and without a hyponomic sinus, and the four figured types represent four species and three genera.

The brevicones are not a taxonomic group. Under the term are included the "gomphoceroids" which are short, gibbous, and which contract toward the aperture, and also cyrtoconic and orthoconic forms which are short, rapidly expanding and which lack any apertural contraction. Brevicones are as yet too little known to permit a study of their genetic relations. Genera are based largely upon criteria of form and aperture. The siphuncles and early stages are unknown for a great number of species owing to poor preservation. Enough is known, however, to show that the brevicones are a homeomorphic rather than a taxonomic group. Internal structure suggests that externally similar forms may be only remotely related.

Foerste[1] divided the genera of breviconic cephalopods into several groups, the equivalent of families, on the basis of section and aperture. This scheme is a logical and a useful one but is almost certainly not natural. Foerste recognized this fact and refrained from applying family names to the groups, although retaining some of Hyatt's family names for convenience. Foerste's work resulted

[1] Foerste, A. F.: *Actinosiphonate, trochoceroid and other cephalopods*, Denison Univ. Bull., Sci. Lab., Jour. vol. 21, 1924, 100 pp., 22 pls.

in genera which have considerable stratigraphic and zoögeographical value in the Silurian and Ordovician. It is hoped that the present work will serve to make possible a similar study of Devonian brevicones. It is to this end that the available information concerning the species of the classic New York section has been brought together here.

ACKNOWLEDGMENTS

A comprehensive study of a group of forms which are almost universally rare, such as the brevicones, would not have been possible without the coöperation of a number of individuals and institutions. I am indebted to Dr. I. G. Reimann and the Buffalo Society of Natural History for the loan of a large collection of cephalopods. Dr. J. W. Wells and Dr. K. E. Caster have contributed specimens from their collections. One of the species described here is from a collection of Tully cephalopods loaned by the U. S. National Museum through the courtesy of Dr. G. A. Cooper. Dr. C. W. Merriam has kindly loaned such specimens from the Cornell University collection as have been desired.

I wish to thank Dr. Rudolph Ruedemann and Dr. Winifred Goldring not only for an opportunity to study the cephalopods in the New York State Museum, but for the use of library and laboratory facilities over an extended period of study at the museum. Dr. C. C. Adams has very kindly permitted the use of photographic facilities at the museum. Both Dr. Ruedemann and Dr. Goldring have offered helpful suggestions and criticism, and I am indebted to Dr. Goldring for reading the introductory portion of the paper. Dr. K. E. Caster and Prof. G. H. Chadwick have furnished stratigraphic information in regard to the Upper Devonian.

The illustration of many of the type and other specimens would not have been possible at this time without the timely loan of a suitable camera from Miss Bessie Wood, teacher of biology in the Troy High School. It gives me great pleasure to take this opportunity to express my gratitude to Miss Wood. The photographic and library facilities of the Paleontological Research Institution have been of inestimable aid. I am further indebted to the Institution and to Professor Harris for bearing the greater part of the expense of publication.

Rousseau H. Flower

Paleontological Research Institution
July 30, 1938
Ithaca, N. Y.

SEXUAL DIMORPHISM

Ruedemann[2] was the first to suggest that the males and females of brevicones might be represented by individuals of different proportions. This was based upon a series of specimens of *Oncoceras pupæforme* Ruedemann from the upper Utica at Holland Patent, New York. Foerste never discussed the possibility in any of his papers, but from the mature specimens of different sizes which he included in the same species upon more than one occasion, it would appear that he accepted this view.

In Devonian forms differences in proportion have been found which appear to be due to other than specific differences. In *Ovoceras constrictum* Flower of the Cherry Valley there is a slender and gibbous form, but the difference in diameter is not great, and the length of the two forms seems to be about the same. A similar relationship holds between *Verticoceras erectum* Flower and *Verticoceras*, sp., Flower.

In species of *Brevicoceras* from the Schoharie Grit slightly different groups were discernible. Here, there was a division into (1), a gibbous form, more depressed in section, with a slightly broader aperture, and (2), a more slender, less depressed form with a slightly longer living chamber and a more contracted aperture.

These differences are much less marked and less striking than those suggested by Ruedemann, but his specimens are flattened by pressure, thereby altering the sutures, and resulting in an exaggeration of the difference in diameters between the two forms of *Oncoceras pupæforme*. Were the specimens undistorted the differences would be much less marked.

The existence of sexual dimorphism in extinct forms, and particularly in extinct forms which have no close living relatives, is not a thing that can be categorically asserted or denied. It must be reckoned with as a possibility, particularly when similarly differing pairs which might be conspecific are found together in various horizons and localities. Unfortunately the rarity of brevicones in most beds makes the study of a large series difficult. In the reef rocks of the Silurian, where brevicones are occasionally abundant, the multiplicity of genera and species further obscures the problem. When two closely related types are found, sexual dimorphism is a logical deduction but where, as in the Silurian, three or more species of, for example, *Amphicyrtoceras* are found together,

[2] Ruedemann, R.: *Observations on the mode of life of primitive cephalopods*, Geol. Soc. Amer., Bull. vol. 32, 1921, p. 317-318, fig. 4-6.

the problem takes on another and a more perplexing aspect. It is my purpose here only to call attention to some additional evidence for sexual dimorphism. More conclusive results await the careful study of large series of specimens.

EPHEBIC AND GERONTIC FEATURES

There appears to be some confusion among students of cephalopods as to whether the contracted aperture of breviconic forms is to be regarded as gerontic or ephebic, and the present author has not been blameless in this regard. If the ephebic features are taken as those by which the species can be recognized, conchs with contracted apertures must be regarded as ephebic, for until the aperture is contracted, not only the specific but often the generic features are not developed. The contraction of the cameræ in brevicones is frequently a feature of such ephebic specimens. As the aperture begins to contract, the possibilities for the forward migration of the visceral mass in the phragmocone are lessened, consequently shallower cameræ are produced, though it appears that up to the completion of the aperture the cameræ are secreted at regular rythmic intervals.

What, then, are the gerontic features? When the aperture is complete and further forward migration in the shell is impossible, shell secretion does not stop. The elimination of calcareous material remains a physiological necessity, and such material is secreted in several regions.

Material is secreted on the inside of the conch in the region before the aperture, producing a constriction of the internal mold at this point. It would appear, from what is known of the molluscan mantle, that this is brought about by the addition of material to the normally thin nacreous layer of the shell, though brevicones with the shell well enough preserved to permit the study of its original structure by means of thin sections have not been found.

The second area of secretion is at the base of the living chamber. Secretion here is performed by the posterior mantle, the same surface which secretes the septa. Along the surface of the last septum, both against the free and mural parts, additional calcareous material is deposited. This forms a more or less lobed pattern, generally radiate and rarely with a definitely bilaterally symmetrical pattern. The thickness of this deposit causes a constriction of the internal mold. It was referred to as the crenulated zone or crenulated band by Hall.[3] This term is somewhat misleading, as a crenulated appearance is not by any means constant. Foerste in several publications regarded the structure as the seat of muscle attachments, and referred to the structure as an attachment ring in some of his descriptions. The same structure has also been referred to as an impressed zone. This area is not always crenulate. It probably did not have to do with the attachment of the visceral mass, for it is developed only in geron-

3 Hall, J.: Paleontology of New York, vol. 5, pt. 2, 1879, pp. 318-353.

tic specimens of brevicones, where by virtue of the contracted aperture, there was less need for strong shell attachment than in the immature individuals where it is lacking. The use of the term impressed zone, while more descriptive than crenulated zone, is misleading because the same term has quite a different meaning when applied to involute coiled cephalopods. The term *basal zone* is proposed here for the structure.

Deposits within the cameræ are very rare and are known only from a few gerontic individuals. Well developed episeptal deposits are present in *Poterioceras, sensu stricto,* of the Mississippian of Ireland and Belgium. I have seen them elsewhere only in one species, *Hexameroceras cacabiforme* Newell of the Huntington Dolomite of Indiana. In both instances they are revealed only in specimens which possess the basal zone and the contracted zone before the aperture.

Actinosiphonate deposits within the siphuncle may be another manifestation of gerontic secretion. Such deposits are absent in immature specimens. They apparently precede the basal zone and the constricted zone of the aperture in appearance if Barrande's figures are to relied upon, but they do not appear in brevicones until after the mature aperture has been formed. Further, the development of actinosiphonate structure in trochoceroids which appear to be more closely related to certain longiconic cyrtoceraconic and gyroceraconic genera than to any known brevicones, usually accompanies the development of contracted apertures, as in *Adelphoceras* Barrande.

Actinosiphonate structure is present in forms without apparent contracted apertures, and is absent in some true brevicones in which the aperture is markedly contracted. In the forms classified by Foerste as "orthoconic genera" actinosiphonate structure is developed in *Laumontoceras, Jovellania, Mixosiphonoceras* and *Tripleuroceras,* which are Devonian genera, but not in *Allumettoceras, Tripteroceras* or *Murrayoceras* which are Ordovician. Insofar as I am aware the gerontic apertures of the supposedly orthoconic genera which possess actinosiphonate structure have never been figured or described. Foerste[4] mentions that there is indication that the aperture of *Tripleuroceras triangularis* (d'Archiac and de Verneuil) is not simple, and there is indication of contraction of the living chamber.

Actinosiphonate deposits appear to be absent throughout the Lower and Middle Ordovician brevicones, in which the Oncoceratidæ furnish the most abundant and best known examples. *Diestoceras* Foerste of the Upper Ordovician is the earliest form so far known to possess actinosiphonate deposits, and there is a very strong suggestion of an annulosiphonate origin of the deposits in this genus.

Foerste[5] discussed the distribution of actinosiphonate structure and noted that it was not constant within the species of a genus and within the individuals of a species.

[4] *Ibid.*, p. 309.
[5] *Ibid.*, p. 296-301

The variation within individuals of a species may easily be due to the fact that the individuals represent various stages of growth. The difference between species of a genus may be similarly explained. Many brevicones are rare and a number of species are known only from a few specimens. If a specimen which has been selected for sectioning happens to represent the early ephebic stage or an earlier stage, deposits would almost certainly be absent. It is not difficult to see how an erroneous concept may arise concerning a species when the interior of the siphuncle is known from only a single specimen, as is very often the case.

Only in one instance has the presence of actinosiphonate structure been noted in an immature individual. This I have found well shown in a series of specimens of *Herkimeroceras subrectum* (Hall) of the Manlius of New York.

The form of actinosiphonate structure indicates that its function is physiological rather than ecological. Of all the deposits noted in the siphuncles and cameræ of cephalopods it exhibits the poorest economy of space. Heavy annulosiphonate or cameral deposits apparently serve to make possible a horizontal mode of life and to orient the conch with the venter down. Actinosiphonate deposits do not appear to be heavy enough to materially affect the hydrostatic adjustment of the brevicone, and there is no evidence of dorso-ventral differentiation. Rather the radial nature suggests that the deposit is one formed in the interstices of the siphonal vascular system by means of which gas was secreted within the cameræ.

BREVICONIC GENERA KNOWN TO OCCUR IN THE DEVONIAN

Saemann[6] was the first to describe a brevicone from the Devonian of America. This was *Apioceras olla* from the Columbus Limestone, later to become the type of Hyatt's genus *Acleistoceras*. Hall in the Paleontology of New York described numerous species not only from New York, but also from Ohio and Indiana. These were all referred to *Gomphoceras*. Hyatt[7] described a number of breviconic genera which he conceived as passing into the Devonian, but only *Acleistoceras* is based upon a Devonian genotype. Subsequent to Hyatt and previous to the works of Foerste, Devonian brevicones were occasionally referred to *Gomphoceras,* though a large number of them were removed to *Poterioceras* McCoy, a change of very doubtful value. Indeed, *Poterioceras* came to replace *Gomphoceras* very largely as a catch-all for brevicones with moderately contracted apertures not only in the Devonian but also in the Ordovocian and Silurian. The genus is known from species from the Mountain Limestone (Mississippian) of Ireland and Belgium. The genus is not known from pre-Mississippian strata and typical forms have not as yet been recognized anywhere in America.

6 Saemann, I.: *Ueber die Nautiliden,* Paleontographica, Bd. 3, 1854, p. 163, pl. 19, fig. 1a-c.
7 Hyatt, A.: *Genera of fossil cephalopods,* Boston Soc. Nat. Hist., Proc. vol. 22, 1883, pp. 253-338.

Of the numerous papers of Foerste only a few have a direct bearing upon Devonian brevicones. One of these, his study of actinosiphonate, trochoceroid and other cephalopods[1], is particularly important, for it summarizes all of the described breviconic genera and adds many new ones. The genera based upon species of Devonian age were established upon European genotypes and at that time the genera were not recognized in the American Devonian. A number of these are now recognized in America and more will doubtless appear with further study. Devonian genera include:

Karoceras Rousanoff, genotype: *K. typicum* Foerste from the Lower Devonian of Nesnayemi Fjord, Novaya Zemblana.

Wissenbachia Foerste, genotype: *Phragmoceras orthogaster* Sandgerger from the Middle Devonian of Wissenbach, Germany.

Pachtoceras Foerste, genotype: *Gomphoceras rotundum* Pacht from the Upper Devonian of Gräsi, Russia.

Sycoceras Pictet, genoytpe: *Gomphoceras ficus* Roemer, from the Upper Devonian of the Hartz region, Germany.

Mecynoceras Foerste, genotype: *Gomphoceras rex* Pacht, from the Upper Devonian of the upper Don area, Russia.

Paracleistoceras Foerste, genotype: *Phragmoceras devonicus* Barrande, from the Middle Devonian G3 of Hlubocep, Bohemia.

Cyrtoceras Goldfuss, genotype: *Cyrtoceras depressum* Goldfuss, from the Middle Devonian of Eifel, Germany.

Conostichoceras Foerste, genotype: *Cyrtoceras Palinurus* Barrande, from the Middle Devonian G3 of Hlubocep, Bohemia.

Turnoceras Foerste, genotype: *Cyrtoceras turnus* Barrande, from horizon G3 of the Middle Devonian of Hlubocep, Bohemia.

Poteriocerina Foerste, genotype: *Cyrtoceras lumbosum* Barrande from horizon G3, Middle Devonian, Hlubocep, Bohemia.

Archiacoceras Foerste, genotype: *Phragmoceratites subventricosus* d'Archiac and de Verneuil, Middle Devonian, Eifel, Germany.

Coelocyrtoceras Foerste, genotype: *Cyrtoceras ventralisinuatum* Sandberger, from the Middle Devonian of Wissenbach, Germany.

Bolloceras Foerste, genotype: *Phragmoceras rex* Barrande, from horizon G3, Middle Devonian, Hlubocep, Bohemia.

In another paper Foerste[8] referred a number of species from the Alpena Limestone of Michigan to *Acleistoceras* and *Alpenoceras* Foerste, a new genus based upon *A. ulrichi* Foerste of the Alpena.

Rather strangely, perhaps, none of the Silurian genera of brevicones have as yet been recognized in the Devonian.

[8] Foerste, A. F.: *Devonian cephalopods from Alpena in Michigan*, Univ. of Michigan, Mus. of Geol., Contrib., vol. 2, No. 9, 1927, pp. 189-208, 5 pls.

Two breviconic genera were described by Flower and Caster[9] from the Conewango, *Anglicornus* and *Blastoceras*. Flower[10] later described *Ovoceras* and *Vertioceras* from species of the Cherry Valley Limestone of the Middle Devonian, and referred species to *Acleistoceras* Hyatt and *Poteriocerina* Foerste.

DISTRIBUTION OF BREVICONIC GENERA IN THE DEVONIAN

The placing of the previously described breviconic species in modern genera is still in a very incomplete condition, and for this reason any remarks concerning the distribution of the genera must be taken as rather tentative. Further, these views will be greatly supplemented and perhaps extensively revised when other Devonian faunas have been similarly studied. Nevertheless, some of the genera show some interesting and significant features in their distribution which may be of interest to students of Devonian faunas.

No brevicones are as yet known from the Lower Devonian of New York although present in Gaspé and Maryland, but they appear abruptly in the Middle Devonian.

Acleistoceras as at present conceived is a very broad genus, probably representing a form group rather than a single genetic stock. It is not surprising that it has a wide distribution. It is represented by two species in the Schoharie, *A. schohariæ* and *A.* (?) *illænus*. In the Onondaga of western New York large species appear which have been included under A. *eximium*. Closely related forms appear in the Columbus of Ohio and the Jeffersonville of Indiana. The genus seems to favor a limestone facies, for in New York it is present in the Onondaga, Cherry Valley and Tully, but is not known from the shales of the Hamilton. The Tully species is very similar to a species referred to *Gomphoceras cammarus* Hall from the Grand Tower Limestone of Missouri. The genus has not been recognized in Europe. Elsewhere in America it is represented by species from the Alpena Limestone of Michigan, and also from the Devonian of Milwaukee, Wisconsin.

Brevicoceras is widespread in the Devonian. It appears in the Schoharie where it is known from a number of very small species. A single species, *B. conicum* is known from the Onondaga. The genus is well developed in the Hamilton and persists into the Upper Devonian where it is represented by *B. manes* of the Geneseo and *B. concavum* which occurs at the top of the West River. The West River is somewhat above the Genundewa which carries *Manticoceras*. The genus has not yet been recognized in the Tully. *Brevicoceras* has not as yet been noted in the Devonian of Ohio or Indiana, but it is present in Iowa and Michigan.

Ovoceras appears to be restricted in America to limestones of Hamilton age,

[9] Flower, R. H., and Caster, K. E.: *The stratigraphy and paleontology of northwestern Pennsylvania*. Part II, Paleontology. Sec. A: *The cephalopod fauna of the Conewango Series of the Upper Devonian in New York and Pennsylvania*, Bull. Amer. Paleont., vol. 22, 1935, pp. 50-55.

[10] Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont., vol. 22, 1936, pp. 60-74.

being known from the Cherry Valley of New York and the Sellersburg of Indiana. *Apioceras inflatum* Quenstedt, of Germany is a typical *Ovoceras*.

Anglicornus is confined to the Upper Devonian, appearing in the Ithaca and persisting through the Conewango. The progressive widening of the aperture and the increase in the size of the hyponomic sinus, which are apparent as species are traced upward in the section, suggest an origin of *Ovoceras* in the Middle Devonian as the logical source of an orthogenetic line.

Aletoceras is an exotic form for New York, appearing only in the Tully. Another species, undescribed, is from the Nevada Limestone. The wide distribution is responsible for the name which signifies a wanderer. Doubtless further study will bring to light species in intermediate areas.

Blastoceras Flower and Caster is still known only from the genotype of Conewango age.

Exocyrtoceras is well developed in the Schoharie, where it is represented by small species which closely resemble the Schoharie *Brevicoceras* in size and form. In the Columbus Limestone there occurs a larger and more gibbous form which is more strongly curved and is faintly trochoceroid. The genus appears again in the Grand Tower of Missouri.

The Schoharie contains two European genera, which are not known elsewhere in America, *Wissenbachia,* based upon a species from Wissenbach, Germany, and *Turnoceras,* based upon a species from Barrande's horizon G3 of Bohemia.

Cyrtogomphus and *Micronoceras* are both known from a number of species and appear to be confined to the Hamilton, though the former extends westward into southern Ontario. *Cyrtospyroceras* is typically developed in the Hamilton. The one Onondaga species referred to the genus with doubt is not quite typical in several features. Such monotypic genera as *Endoplanoceras* of the Onondaga and *Eleusoceras* of the Hamilton can hardly be considered faunally significant.

Pachtoceras occurs in the Conewango. The horizon of the genotype which is from the Upper Devonian of Russia, is not definitely known. From the literature it appears probable that the horizon is not above Oberdevonstufe II, and that the genus has a considerable vertical range.

The occurrence of phragmoceroid conchs in the Devonian of America has not been previously noted. *Metaphragmoceras* occurs in the Middle Devonian of Bohemia at Barrande's horizon G3, and two new species are described from the Onondaga. *Bolloceras,* which occurs in the Middle Devonian in Europe, appears in the American section in the Ithaca shales of the Upper Devonian.

The endogastric genera *Verticoceras* and *Alpenoceras* are apparently allied though very different in aspect. *Verticoceras* is known from the Cherry Valley and Tully, but not from the Hamilton shales. Possibly it joins *Acleistoceras* and *Ovoceras* in favoring a limestone facies.

Theoretically, if brevicones are floating forms they should be capable of wide distribution generically if not specificially. The present evidence fails to show that as a whole the genera of breviconic cephalopods are much more widely distributed than are genera of other groups. A few genera appear common to the Devonian of America and Europe. Of these *Metaphragmoceras, Ovoceras, Turnoceras* and *Pachtoceras* occupy approximately equivalent horizons, while *Bolloceras* of the European Middle Devonian is as yet known only from the Upper Devonian of America.

Thus far there are few genera which are exclusively characteristic of the Ulsterian or Erian, but the number of genera passing from Middle to Upper Devonian are limited to *Aletoceras* and *Acleistoceras* which appear in the Tully, and *Brevicoceras* which invades the higher beds. Doubtless new genera will be added with further study; the investigation of other faunas will tend to increase the present genera and morphological research may tend to restrict them. Siphuncles have proved particularly elusive thus far, and when known may show that externally similar species may not be closely related.

GEOLOGICAL AND GEOGRAPHICAL DISTRIBUTION OF SPECIES

The brevicones in the Devonian, as in the Silurian, are very definitely limited both geographically and stratigraphically. Unfortunately there is not enough information available to state how the brevicones are distributed in the Upper Devonian where facies play such an important part in the developmental modifications of the faunas. Theoretically the air filled conchs are capable of wide distribution after death, and if, as is generally supposed, the cameræ contained air, the species should be widely distributed geographically. Again, if the brevicones are largely floating forms as has been suggested by several authors, they should be capable of wide distribution during life as well. Thus far no species are known to be common to the Hamilton of western New York as developed in the Lake Erie section, and of central New York as developed between Cayuga Lake and Hamilton, New York. Data are more meagre for the Upper Devonian species, but I believe that it is significant that nothing resembling "*Gomphoceras*" *ajax* of the Naples fauna has been found in the Ithaca, and nothing resembling the small *Anglicornus* species of the Ithaca has been found in the Naples. The only widespread species is *Acleistoceras cf. eximium,* which appears to be common to the Columbus Limestone of Ohio and the Onondaga of western New York, although the species will admittedly stand further investigation.

There are several possible interpretations for these facts. The simplest solution would be to dismiss the whole matter on the grounds of insufficient collecting in a group of forms which are almost universally rare. However, if wide distribution did occur it is strange that in a region such as the Devonian of New York which has been subjected to collecting for nearly a century, there is not better evidence of it in specimens in our museums. Again it may signify that the species were not widely distributed either before or after death; perhaps after all the brevicones were bottom dwellers and not floating forms. The possibility pointed out by Ruedemann[11] that the entire foot of the cephalopod might be extruded through the restricted aperture even of such a form as *Pristeroceras*, suggests that it is possible that the brevicones might have been crawlers dwelling upon the bottom, rather than floating forms propelled by the hyponome or swimming by means of their extended arms. Yet this does not necessarily follow.

The specific criteria of cephalopods are based largely upon proportions. Even allowing considerable latitude Foerste found very few species widely distributed in the Silurian, and the same apparently holds true in the Devonian. It is highly possible that a migrating species is rapidly modified upon penetrating a new environment, the new ecological conditions affecting the growth and modifying the proportions which are the specific criteria, so that a new form, apparently specifically distinct, is developed. And who among us is able to say that it is not distinct?

The accompanying faunal lists will show the occurrence of the described species of brevicones of the New York section. The species are not widely distributed either stratigraphically or geographically. Whenever possible the species have been located in terms of modern stratigraphy; this has not been possible in all cases for Hamilton or Upper Devonian species, for in many instances the only available evidence has consisted of the locality and the lithology, and these have not always been enough. One innovation in the faunal lists should be noted. The fauna of the Cherry Valley is treated as distinct from that of the remainder of the Hamilton. This is not because of any conviction on the part of the author, but because the species are distinct and not particularly closely allied to any found elsewhere in the Hamilton of New York, and such an arrangement has become a matter of convenience. A similar list would be included for the Stafford, which has a rather distinctive fauna, but strangely enough that formation has not as yet yielded any identifiable brevicones.

MIDDLE DEVONIAN

SCHOHARIE GRIT

Although regarded as a facies of the basal Onondaga, the Schoharie contains a fauna which is quite distinct. Grabau[12] lists 123 species of which 46 have been reported from the Decewville of Canada, the Onondaga of New York or both. Whether the number of species common to this and other formations will be increased or decreased by further study it is impossible to say. The only breviconic species of the Schoharie listed as occuring elsewhere is *Gomphoceras absens*, now *Turnoceras absens*. This species was reported from the Onondaga. The

[11] Ruedemann, R.: *Some Silurian (Ontarian) faunas of New York*, New York State Mus. Bull., No. 265, p. 59.

[12] Grabau, A. W.: *Geology and paleontology of the Schoharie valley*, New York State Museum, Bull. 92, 1906, p. 325.

Onondaga specimen is here described as *Brevicoceras conicum.* It is not strikingly similar to any Schoharie species.

Acleistoceras (?) illænus (Hall)
Acleistoceras schohariæ, n. sp.
Brevicoceras compactum, n. sp.
Brevicoceras rotundum, n. sp.
Exocyrtoceras constrictum, n. sp.
Exocyrtoceras micron, n. sp.
Exocyrtoceras sinuatum, n. sp.
Turnoceras absens (Hall)
Wissenbachia gebhardi, n. sp.
"Gomphoceras"[13] (Micronoceras?) fax Hall
"Gomphoceras" rude Hall
"Gomphoceras" (?) cruciferum Hall

ONONDAGA LIMESTONE

Acleistoceras cf. eximium (Hall)
Brevicoceras conicum, n. sp.
Cyrtospyroceras (?) morsum (Hall)
Endoplanoceras gomphus, n. sp.
Metaphragmoceras triangulatum, n. sp.
Metaphragmoceras dubium, n. sp.

Hall's lists are more imposing, but include species from the Columbus Limestone of Ohio and the Jeffersonville of Indiana.

CHERRY VALLEY LIMESTONE

Acleistoceras fischeri (Hall)
Acleistoceras jonesi, n. sp.
Ovoceras oviforme (Hall)
Ovoceras constrictum Flower
Poteriocerina (?) solidum (Hall)
Micronoceras gibbosum (Hall)
Verticoceras conradi (Hall)
Verticoceras erectum Flower

Except for *A. jonesi* which is new, these species have been described and illustrated in a previous paper[14]. *Acleistoceras* is widespread. *Ovoceras* occurs in the Sellersburg in America. *Micronoceras* persists into the overlying shales of the Hamilton.

13 The quotation marks are mine. None of these are true *Gomphoceras*. Generic diagnosis is not possible and most of these species are very poorly known, as is explained elsewhere in this paper.

14 Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont. vol. 22, No. 76, 1936.

HAMILTON (EXCLUSIVE OF CHERRY VALLEY)

The member from which the species is known is given whenever possible. It has not been possible for some of the older species, for the specimens upon which they were based were collected in the days when the only indication of horizon considered necessary was "Hamilton shales".

Collecting has more than doubled the list of species since Hall's day, and judging from inadequate fragments a good many species still await description. A few of these are indicated in the list where generic determination has been possible.

Brevicoceras casteri, n. sp. Windom member, Moscow.
B. planum (Hall)
B. wellsi, n. sp. Skaneateles
B. pompeyense, n. sp. Pompey memb., Skaneateles.
Micronoceras delphicolum, n. sp. Delphi memb., Skaneateles
M. raphanus (Hall) Pompey memb., Skaneateles
M. angulatum, n. sp. Tichenor limestone
M. apertum, n. sp. Skaneateles
Cyrtogomphus curvatus, n. sp. Tichenor
C. lunatus (Hall) , Ludlowville (?)
C. thedfordensis, n. sp. Widder (?)
C. (?) pinguis (Hall), Skaneateles (?)
C., n.sp. aff. pinguis, Pompey memb., Skaneateles[15]
Eleusoceras nicholsi, n. sp. , Pompey memb., Skaneateles
"Gomphoceras" mitriformis Clarke, Chittenango (?)
"Gomphoceras" abruptum Hall, Skaneateles or Marcellus
"Gomphoceras" poculum Hall, Skaneateles (?)

UPPER DEVONIAN

TULLY LIMESTONE

The few brevicones known from the Tully are new. The remainder of the fauna is so predominatingly Hamilton in aspect that some students are inclined to place the formation with the Middle rather than the Upper Devonian. The only previously published data are included in faunal lists[15a] and include but one specificially determined brevicone. That was first referred to *Acleistoceras fischeri.* The specimen upon which this determination was based has not been preserved. I am inclined to suspect that it may have been the same as *A. wellsi,* the only Tully brevicone which compares with *fischeri* in size. The brevicones are not closely similar to any known from the Hamilton proper, but show affinities which are rather puzzling in their variety. *A. wellsi* has its closest relative in the Grand

[15] Based upon a specimen collected after the completion of text and plates.
[15a] Williams, S. G.: *The Tully limestone, its distribution and known fossils,* N. Y. St. Geol., 6th Ann. Rep., 1886 (1887) p. 28.

Tower of Missouri. *Aletoceras* is known from the Nevada Limestone. The *Verticoceras* suggests the Cherry Valley species.

Subsequent collecting made possible by the New York State Museum has brought to light a number of new forms too late for incorporation in this paper. Among these one is of particular interest, a species of *Blastoceras*, which is probably the only form in the Tully which can be said to be of definite Upper Devonian aspect.

Acleistoceras wellsi, n. sp.
Aletoceras gracile, n. sp.
A. amphoroides, n. sp.
Verticoceras tullium, n. sp.

SENECAN SERIES

Genesee Stage.—
Brevicoceras (?) manes (Hall). Geneseo member.
Nunda Stage, Ithaca Fauna.—
Anglicornus, sp. Williams Brook member.
Acleistoceras (?), sp. Six Mile member.
Bolloceras hartti, n. sp., Triphammer member (?)
Nunda Stage, Naples Fauna.—
Brevicoceras concavum, n. sp. West River member.
"Gomphoceras" ajax Hall. Cashaqua member (?)
"Gomphoceras," sp. Genundewa member.

CHAUTAUQUAN SERIES

Chemung Stage.—
Anglicornus, sp.
Canadaway Stage[16].—
Anglicornus goldringæ, n. sp.
Conneaut Stage[16].—
Anglicornus nasutum (Hall)

CONEWANGO SERIES

Venango Stage.—
Blastoceras cylindrostomum Flower and Caster. Lewis Run member[17].
Anglicornus anneliesæ Flower and Caster[17]. Lewis Run member.
Pachtoceras obliquum, n. sp. Lewis Run member.

The only determinable brevicone known elsewhere in the Conewango is a single specimen of *A. anneliesæ* from the Salamanca member of the Venango stage.

16 Prof. G. H. Chadwick, in correspondence, has furnished lithological and stratigraphical data concerning the localities from which the specimens came which make possible the placing of these species in the section with considerable accuracy.
17 *Ibid.*, (footnote 9).

SYSTEMATIC DESCRIPTIONS

SPECIES DESCRIBED IN DETAIL

I. DEPRESSED EXOGASTRIC SPECIES WITH HYPONOMIC SINUS

Acleistoceras wellsi, n. sp. Tully
A. jonesi, n. sp. Cherry Valley
A. schohariæ, n. sp. Schoharie
Brevicoceras casteri, n. sp. Hamilton
B. pompeyense, n. sp. Hamilton
B. planum (Hall) Hamilton
B. wellsi, n. sp. Hamilton
B. manes (Hall) Hamilton
B. concavum, n. sp. West River
B. compactum, n. sp. Schoharie
B. rotundum, n. sp. Schoharie
B. conicum, n. sp. Onondaga
Anglicornus goldringæ, n. sp. Conneaut
Aletoceras gracile, n. sp. Tully
A. amphoroides, n. sp. Tully

II CIRCULAR TO DEPRESSED EXOGASTRIC FORMS WITH SIMPLE APERTURES

Exocyrtoceras exoticum, n. sp. Columbus
E. sinuatum, n. sp. Schoharie
E. constrictum, n. sp. Schoharie
E. micron, n. sp. Schoharie
Turnoceras absens (Hall), Schoharie
Turnoceras, n. sp.
Cyrtogomphus curvatus, n. sp. Hamilton
C. thedfordensis, n. sp. Hamilton (of Thedford, Ontario)
Micronoceras delphicolum, n. sp. Hamilton
M. raphanus (Hall), Hamilton
M. angulatum, n. sp. Hamilton
M. apertum, n. sp. Hamilton
Cyrtospyroceras reimanni, n. sp. Hamilton
C. formosum (Hall), Hamilton
C. (?) morsum (Hall), Onondaga
Endoplanoceras gomphus, n. sp. Onondaga
Eleusoceras nicholsi, n. sp. Hamilton

III. COMPRESSED EXOGASTRIC TO ERECT GENERA

Wissenbachia gebhardi, n. sp. Schoharie
Pachtoceras obliquum, n. sp. Conewango

IV. DEPRESSED ENDOGASTRIC BREVICONES

Verticoceras tullium, n. sp. Tully

V. COMPRESSED ENDOGASTRIC BREVICONES OF PHRAGMOCERATOID ASPECT

Bolloceras (?) hartti, n. sp. Ithaca

Metaphragmoceras triangulatum, n. sp. Onondaga

M. dubium, n. sp. Onondaga

I. DEPRESSED EXOGASTRIC SPECIES WITH HYPONOMIC SINUS

Genus **Acleistoceras**, Hyatt, 1884

Genotype.—*Apioceras olla* Saemann, 1854, Palaeontographica, vol. 3, p. 163, pl. 19, fig. 1A-C.

Acleistoceras Hyatt, 1884, Proc. Boston Soc. Nat. Hist., vol. 22, p. 277.

—— Foerste, 1926, Denison Univ. Bull., Sci. Lab., Jour. vol. 21, p. 336, pl. 44, fig. 6A-C.

—— Foerste, 1927, Michigan Univ., Mus. of Geol., Contrib., vol. 2, p. 196.

—— Flower, 1936, Bull. Amer. Pal., vol. 22, No. 76, p. 61.

Conch exogastric, nearly erect, with the point of greatest gibbosity located well below the base of the living chamber; venter convex to aperture, dorsum nearly straight, faintly convex in adoral third of living chamber; aperture transverse, subtriangular, not greatly contracted, with well defined hyponomic sinus; ventrolateral crests only slightly developed; sutures straight and transverse or with broad shallow ventral and dorsal lobes; siphuncle unknown in genotype; probably located close to center; its internal structure unknown.

Unfortunately the genotype seems to be known only from Saemann's figure. *A. olla* is from the Middle Devonian limestone of Columbus, Ohio, probably the Columbus Limestone. In view of the inability of investigators to recognize this species or *Gyroceras expansum* Saemann, and the probability that his *Orthoceras typus* was poorly drawn, it seems probable that the difficulty may be due to an inaccurate rendering of the proportions of the specimen in Saemann's illustrations.

Foerste, in 1927, referred a number of previously described species to *Acleistoceras*, and described two new species from the Alpena Limestone. Most of the formerly described species are known from material which is too fragmentary to permit a certain generic diagnosis.

On the basis of the genotype *Acleistoceras* is a rather comprehensive genus, being based upon criteria of outline and aperture. Even with the removal of *Brevicoceras* the genus is hardly compact, as there seems to be diversity in both the position and the outline of the siphuncle in species which otherwise show no good generic differences.

It is possible to recognize three groups in species which may be referred to *Acleistoceras*. Whether these groups are genetic remains to be determined when the siphuncles are known for more of the species.

A. Group of *Acleistoceras casei* Foerste

Small and medium sized species with the greatest gibbosity at or near the middle of the living chamber and an aperture which is only slightly lobed. Section depressed, venter and dorsum about equally rounded.

A. casei Foerste

A. jonesi, Flower, n. sp.

B. Group of *A. wellsi* Flower, n. sp.

Large species in which the point of gibbosity is only slightly developed, but is above the base of a living chamber. The section is only slightly depressed, subcircular, the dorsum and venter equally rounded. The lobation of the aperture is well developed.

C. Group of *A. eximium* (Hall)

Large or medium sized species of depressed section in which the aperture is more abruptly contracted, with the hyponomic sinus usually flaring and more or less produced when viewed in lateral or adoral aspect. The segments of the siphuncle are expanded, subspherical to heart shaped, and contain actinosiphonate deposits. This includes the greater number of large species of Ohio, Indiana and New York. Probably Saemann's *A. olla* falls here.

Acleistoceras jonesi Flower, n. sp.

Plate 3, figures 8-9

The holotype is an erect brevicone of depressed section, the dorsum and venter about equally rounded. The specimen expands uniformly from 20 mm. and 25 mm. at its base to 34 mm. and 39 mm. at the point of greatest gibbosity. In 24 mm. more the conch contracts to 32 mm. and 34 mm. at the aperture. The dorsal outline except at the point of gibbosity where it is convex, is nearly straight. The venter is slightly convex throughout, though almost straight adapically. The lateral outlines are faintly convex below and above the point of gibbosity, and more strongly curved over it.

The sutures are straight and transverse. The known portion of the phragmocone has a length of 34 mm. and contains nine cameræ which increase in depth from 3 mm. to 5 mm., with the last two slightly contracted. The septa are shallow, the depth of the basal septum being 5 mm. or one-fifth the transverse diameter. The siphuncle is not preserved, as the mid-ventral part of the phragmocone was destroyed previously to burial.

The living chamber has basal diameters of 33 mm. and 37 mm. The point of greatest gibbosity lies slightly above mid-height, and the aperture lies 40 mm. beyond the base. The aperture is straight and transverse dorsally and laterally as is shown by parts of the aperture and the growth lines. A broad shallow sinus occupies the greater part of the ventral portion of the conch. The ornamentation consists of transverse lines of growth which appear as fine transverse liræ. These are crossed by more distant longitudinal liræ, rather irregularly spaced, which are interrupted or fade out at intervals of about 5 mm., at least near the aperture.

Discussion.—The section, aperture, size and ornamentation serve as adequate criteria for the recognition of this species. The presence of longitudinal markings suggests affinities with the much larger *A. fischeri* with which this species is associated. It is not a very satisfactory *Acleistoceras* and differs from the genotype in the higher position of the point of gibbosity and the weak lobation of the aperture. In proportions it recalls *Acleistoceras casei* Foerste of the Alpena Limestone, but is much less gibbous and has shallower cameræ and a shorter living chamber.

The slight contraction of the last cameræ and the absence of a basal zone indicates that the holotype of *A. jonesi* is an early ephebic specimen.

Holotype.—Paleontological Research Institution, No. 5811.

Occurrence.—From the Cherry Valley Limestone of the Middle Devonian. Collected at Stockbridge Falls, Madison County, New York.

Acleistoceras wellsi Flower, n. sp.

Plate 4, figures 22-24

This species is known from the living chamber and one attached camera. The conch is strongly breviconic and moderately exogastric. The venter is strongly convex apically, but is nearly straight adorally. The dorsum is convex below but concave above. In transverse outline the conch is convex over the apical portion, but the converging sides are nearly straight over the distal three-fourths of the living chamber.

The specimen is depressed in section. At the base the diameters are 78 mm. and 72 mm. These increase to 81 mm. and 74 mm. which is about 10 mm. above the base of the living chamber. From there the conch contracts so that the diameters at the aperture, which measures 65 mm. from the hyponomic sinus to the base of the living chamber, are 60 mm. and 45 mm. The ventral portion of the aperture is occupied by a very wide and deep sinus rising to lateral crests. The dorsal portion of the margin is unknown. The apparent but rather irregular dorsal sinus shown in the figure is due to the condition of preservation and does not represent a morphological feature. It is probable that the dorsal outline was straight and transverse, contracting inward at the mid-dorsal portion as in *Acleistoceras olla* (Saemann), the genotype.

The characters of the phragmocone are incompletely known. The sutures were straight and transverse, the septum shallow, being 12 mm. deep at the base of the specimen, or one-sixth the dorso-ventral diameter. The last camera is 9 mm. in depth, but is plainly gerontic. Just above the base of the living chamber there is a narrow rounded basal zone without any trace of vertical ornamentation.

Discussion.—This species differs from *A. fischeri* (Hall) in the more pronounced ventral sinus but is probably closer to that species in size than to any other.

A large specimen representing the phragmocone of a large brevicone is referred to this species with doubt. The interior of the specimen is filled with calcite and the cameræ are not preserved. The wall of the siphuncle is likewise destroyed, but the path of the siphuncle is marked by an irregular channel of organic material passing through the calcite. I am indebted for both of these specimens to Dr. J. W. Wells for whom the species is named.

Holotype.—Paleontological Research Institution, No. 5813.

Occurrence.—In the Tully Limestone. The holotype is from Tinker's Falls, near Tully, New York. The other specimen mentioned is from a heap of Tully Limestone at the south end of Skaneateles Lake.

Acleistoceras schohariæ Flower, n. sp.

Plate 4, figures 16-17

Gyroceras spinosum Hall, 1879, Paleontology of New York, vol. 5, pt. 2, pl. 99, fig. 8.

Among the types of *Gyroceras spinosum* Hall are two specimens which definitely do not belong to this species. One is a living chamber of a trochoceroid, probably a species of *Nœdyceras* Hyatt, the other is a true brevicone and is refigured here. The specimen consists of the greater part of a living chamber and is apparently not distorted. The adoral part of the specimen bearing the aperture is missing. The section is depressed, with the venter and dorsum equally rounded at the base of the living chamber, where the diameters are 49 mm. and 40 mm. The conch contracts gradually orad, with the lateral outline convex, the venter convex, and the dorsum faintly concave. The specimen has a maximum ventral length of 36 mm. The septum is deep, being about one-fourth the dorso-ventral diameter, or 10 mm., an unusual feature in brevicones. The siphuncle is circular in section and is located close to the venter. Its structure is unknown. No trace of the ornamentation is preserved.

Discussion.—The generic position of this species which is undoubtedly new, is uncertain in the absence of the aperture. The straight sutures eliminate the possibility of *Brevicoceras*. The section is of the type found in *Cyrtogomphus* and in *Acleistoceras*. The concavity of the dorsum can be duplicated in *Acleistoceras*, but not in any species which can be referred to *Cyrtogomphus*, which by virtue of the contracted condition of the dorsal outline, is faintly convex. *Acleistoceras* becomes the only good possibility by elimination. No described species from the Schoharie equals this in size. *Acleistoceras* (?) *fax* is the nearest in size, but is smaller, its section is unknown, and the living chamber is much more gradually contracted basally and tends to flare slightly adorally. The species can be readily distinguished from *Gyroceras spinosum* Hall which is a longiconic ornamented gyroceracone belonging to the Rhyticeratidæ. In form the species falls in the group of *Acleistoceras wellsi.* In basal section and in outline the species is reminiscent of certain *Amphicyrtoceras* such as *A. simulans*[18] Foerste of the Port Byron. It is not surprising that one of the earliest *Acleistoceras* should resemble a genus which precedes it in the Silurian and from which it may possibly be derived.

Holotype.—New York State Museum, No. 12225/15.

Occurrence.—In the Schoharie Grit, from Schoharie, New York.

BREVICOCERAS Flower, n. gen.

Genotype.—*Brevicoceras casteri* Flower, n. sp.

This genus is erected for the reception of species which superficially resemble *Acleistoceras,* but which differ from that genus in the narrow small hyponomic sinus, the more flattened dorsum, the more sinuate sutures, and the proximity of the greatest gibbosity of the base of the living chamber.

Section depressed. In the earliest stage known the venter is only slightly more rounded than the dorsum. Near the base of the mature living chamber the dorsum is flattened, and near the aperture the section tends to become more or less subtriangular as in *Streptoceras* but without the flaring condition of that genus. In vertical outline the venter is slightly and fairly evenly convex throughout. The dorsum is faintly concave adapically, but is convex, though sometimes only faintly so over the adoral part of the phragmocone and the adapical part of the living chamber, and is straight or faintly concave just before the aperture. The transverse outline is fusiform, the sides being convex throughout, but more strongly curved over the point of greatest gibbosity than elsewhere. The internal mold bears a constriction just before the aperture which affects the outline variously in different species. The point of greatest gibbosity is variable. In the genotype it is just below the living chamber; in other species it is slightly higher occurring at the base of the living chamber.

The septa are shallow and evenly curved. The sutures are sinuate, bearing broad shallow ventral lobes, lateral saddles, and a narrow often conspicuous dorsal lobe which occupies about one-third of the dorsal surface. In the adapical portion where the dorsum is less transverse the sutures do not show the dorsal lobe. The siphuncle is nummuloidal, expanding more strongly transversely than dorsoventrally, but subcircular at its passage through the septa. It is scalariform dorso-ventrally and slender in the genotype. Actinosiphonate deposits are present in *B. pompeyense,* the only species in which a gerontic individual was available for sectioning.

The aperture is transverse, little contracted, the shell not curving over the oral surface. There are a broad low dorsal crest, lateral sinuses, and ventro-

[18] Foerste, A. F.: *Port Byron and other Silurian cephalopods,* Denison Univ. Bull. Sci. Lab., Jour., vol. 25, 1930, p. 69, pl. 9, fig. 3A, B.

lateral crests separated by a small and inconspicuous hyponomic sinus.

The internal mold bears evidence of faint distant longitudinal markings, which appear to be connected with structures of the nacreous layer of the shell. The surface bears coarse or fine transverse markings or lines of growth.

Discussion.—The species which are placed in this genus may be distinguished from *Acleistoceras* by the characters of the aperture and sutures, which will also serve to distinguish it from *Ovoceras,* which has the shell curved over the oral surface and a nearly circular section. *Brevicoceras* is known from a number of species described below from the Devonian of New York. The genus has been noted in collections of Middle Devonian of Michigan and Iowa.

Brevicoceras casteri Flower, n. sp.

Plate 1, figures 5-7

The outline of the species, both vertical and transverse, is as described for the genus of which it is the type. The holotype shows the following measurements in millimeters:

	d.v.		tsv.	interval
Base of undistorted phragmocone	34	x	39	
				20
Greatest dorso-ventral gibbosity	38	x	46	
				11
Base of living chamber	37	x	45	
				20
Middle of constriction	31	x	39	
				7
Aperture	29.5	x	38	

The phragmocone consists of an apical crushed portion and an adapertural undistorted portion which is 31 mm. in length and consists of five cameræ which measure as follows, beginning adapically: 5.1 mm., 6 mm., 6 mm., 5.5 mm., and 4 mm. A slight impression beyond the last septum indicates the beginning of the development of either another suture or more probably the basal zone, 2 mm. beyond the last septum. The septa are shallow but too poorly exposed for measurement. The sutures are as described for the genus. An immature specimen shows the vertical outline of the siphuncle. Where the diameters of the conch are 19 mm. and 14 mm., the siphuncle is .8 mm. in diameter at the septal foramen, and is 1 mm. from the ventral wall of the conch. The segments expand within the siphuncle to twice their diameter at the septal foramen, and the greatest diameter is found two-thirds the distance from the adoral to the adapical septum. The segments are scalariform in dorso-ventral section. The neck is strongly recurved dorsally but nearly erect ventrally. No organic deposits have been found in the siphuncle.

The living chamber is 30 mm. in length along the mid-dorsal region and 34 mm. in length along the venter. The conch does not contract over the oral surface, and the lobation of the aperture is not shown well in an oral view of the specimen. There are : a broad dorsal crest, lateral sinuses, high ventro-lateral crests and a small hyponomic sinus, 16 mm. across and 3 mm. deep . The surface of the shell is unknown. The internal mold bears faint longitudinal impressions which are probably connected with the structure of the interior of the shell wall. There are five longitudinal grooves in 10 mm.

Discussion.—This species is based upon two specimens, the first an ephebic living chamber with a part of the phragmocone, the second a much earlier part of the phragmocone which has furnished the information concerning the siphuncle. This specimen differs from the larger one in that the dorsal lobation of the sutures is less marked, but agrees with the holotypes in general proportions.

Types.—Holotype: Paleontological Research Institution, No. 5800. Paratype: Paleontological Research Institution, No. 5801.

Occurrence.—The holotype is from the Windom member of the Moscow at Filmore Glen, Moravia, New York. The paratype is from the same horizon at Portland Point, on Lake Cayuga. Both of the specimens were collected by Dr. K. E. Caster for whom the species is named.

Brevicoceras pompeyense Flower, n. sp.

Plate 1, figure 1; Plate 2, figures 1-2

This is an exogastric brevicone of depressed section. Only a portion of the phragmocone is known. The venter is faintly convex throughout. The dorsum is faintly convex adorally, straight adapically, and in more apical portions may have been faintly concave. The section is depressed, with the venter rounded and the dorsum flattened in the apical portion, though in the region of greatest gibbosity the convexity of dorsum and venter become nearly equal. The conch increases from diameters of 22 mm. and 26.5 mm. to 35 and 43 mm. in 48 mm., which extends from the base of the specimen to the point of greatest gibbosity. In the remaining 18 mm., the conch contracts to a transverse diameter of 38 mm. The corresponding dorso-ventral diameter is not known. The sutures are nearly straight ventrally, not rising from the venter to the sides. The dorsal lobes are shallow and broader than in most other *Brevicoceras.* The septa are shallow, being 8 mm. in depth where the diameters are 35 mm. and 43 mm. The cameræ vary somewhat erratically in depth, but increase from 3 mm. to 5 mm., twelve occupying a length equal to the adoral transverse diameter of 48 mm. The last camera present is contracted to 4 mm., showing the approach of the mature condition.

The siphuncle is large and is located close to the venter. Where the dorso-ventral diameter of the conch is 22 mm., the siphuncle is circular in section and

3 mm. in diameter at the septal foramen. It is 1.5 mm. from the venter. Where the dorso-ventral diameter is 30 mm., the siphuncle is depressed in section, measuring 4.6 mm. and 5 mm., and is 2 mm. from the wall of the conch. In transverse section the segments of the siphuncle expand markedly within the cameræ. In sectioning it was noted that the adapical ends of the segments appeared first, indicating a scalariform condition as in many other brevicones. Where the transverse diameter of the conch is 33 mm., and the depth of the camera is 3 mm., the segments expand from 3 mm. to 6 mm., and are elliptical in shape. The inner end of the septum curves slightly apicad and bears a very short brim. The remainder of the segment is made up of the connecting ring which is strongly adnate adapically, much expanded at the adoral end, but narrowly separated from the free part of the septum. Actinosiphonate deposits are present at the level of the septal necks and are slightly irregular.

The living chamber is unknown. The internal mold shows no trace of longitudinal markings. The surface of the shell is known only from a small fragment which shows no ornamentation.

Discussion.—The section and sutures indicate that this species is a *Brevicoceras,* even in the absence of the living chamber. It is intermediate in size between *B. casteri* and *B. planum.* It is intermediate between the two species in the condition of the dorsal sutures and differs from both in the convexity of the dorsum over the region of greatest gibbosity.

Holotype.—Paleontological Research Institution, No. 5802.

Occurrence.—The holotype, the only known specimen, is from the Pompey member of the Hamilton, from Pratt's Falls, Onondaga County, New York. Collected by Dr. J. W. Wells.

Brevicoceras planum (Hall)

Gomphoceras (?) *planum* Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 352, pl. 57, fig. 1-2.

The holotype represents only a portion of the phragmocone which is depressed in section with the dorsum only faintly convex and the venter broadly rounded. The conch was nearly erect, faintly exogastric. The specimen increases in a length of 30 mm. from diameters of 40 mm. and 31 mm. to diameters of 48 mm. and 40 mm. The specimen is 48 mm. in length. The conch does not expand over the adapertural portion which represents the points of greatest gibbosity. The sutures are straight over the venter but describe broad shallow lobes over the dorsum. These lobes are broader and less pronounced than those of *B. casteri* or *B. pompeyense.* The septum is shallow, the convexity being 6 mm. where the diameters are 40 mm. and 31 mm. The siphuncle is known only at the apical end of the specimen. Here it is 2 mm. in diameter and is 3 mm. from the ventral wall. Its structure is unknown.

The living chamber and aperture are unknown. The internal mold shows no traces of shell structure, and the surface of the shell is unknown.

Discussion.—The section is typical of *Brevicoceras,* and the lobation, while broader than typical, is connected with the typical condition by *B. pompeyense.* The proportions furnish the specific criteria, discussed under *B. pompeyense.*

Holotype.—New York State Museum, No. 12196/1.

Occurrence.—Hamilton beds, Borodino, Onondaga County, New York. It is impossible to say from what part of the Hamilton the specimen came.

Brevicoceras wellsi Flower, n. sp.

Plate 1, figures 8-9

This is a small brevicone of the Hamilton so far known only from flattened specimens. Vertical outline unknown; probably similar to that of the other species of *Brevicoceras.* In transverse outline the sides diverge to the base of the living chamber. The outline is convex to a point near the aperture where there is an abrupt decrease in the contraction. The holotype is a flattened specimen 44 mm. in length. The transverse diameter increases from 23 mm. to 31 mm. in 18 mm. The lower 20 mm. of the specimen contains the eight cameræ of the phragmocone present. In the first to the fifth there is an increase in depth from 4 mm. to 6 mm. The last three together occupy a length of 4.5 mm. The sutures bear broad low ventral lobes and narrower conspicuous dorsal lobes. The point of greatest gibbosity is below the base of the living chamber. The chamber contracts in the lower 13 mm. from 31 mm. to 26 mm. In the remaining 6 mm. it contracts to 22 mm. The aperture bears a well defined hyponomic sinus which is more conspicuous than is that of *Brevicoceras casteri.* Where the transverse diameter of the crushed aperture is 22 mm., the sinus is 6.5 mm. across and 4 mm. deep.

The surface of the shell, the position and structure of the siphuncle are unknown.

Discussion.—This species is known from a number of specimens, all of which are flattened. It is recognizable by the characters of the sutures and the aperture. The only species with which it is likely to be confused, *Micronoceras raphanus,* possesses no hyponomic sinus, though Hall did attribute to *raphanus* a specimen which appears from the figure to be a typical representative of *B. wellsi.*[19]

Types.—Holotype: Paleontological Research Institution, No. 5479. Paratype: Paleontological Research Institution, No. 5480.

Occurrence.—In the soft shales of the Hamilton, from Delphi Falls and from Skaneateles Lake. Apparently confined to the Skaneateles formation. Collected by Dr. J. W. Wells.

Brevicoceras (?) manes (Hall)

Gomphoceras manes Hall, 1879, Paleontology of New York, vol. 5, pt. 2 p. 339.

19 Hall, J.: Paleontology of New York, vol. 5, pt. 2, 1879, pl. 94, fig. 5.

Gomphoceras manes Hall, 1888, Paleontology of New York, vol. 5, pt. 2, suppl., (in vol. 7,) pl. 123, fig. 2.

This species is known only from the holotype, which is a large brevicone, completely flattened. The original proportions are unknown. The one side of the specimen exposed appears to represent the dorsum, as is indicated by the transverse condition of the aperture and the narrow median lobes of the sutures. Hall's original figure gives a faithful reproduction of the characters. The specimen is 162 mm. in length, and attains a maximum diameter of 87 mm. at the apical end of the last camera.

In view of the state of preservation, it is impossible to refer any undistorted specimen to this species with certainty. The form described here as *Brevicoceras concavum* exhibits a general similarity in size, but the type of *B. manes* is inadequate for a comparison.

Holotype.—New York State Museum, No. 12190/1.

Occurrence.—In the Genesee Shale, south of Alden, Erie County, New York.

Brevicoceras concavum Flower, n. sp.

Plate 1, figures 15-16

The holotype is a large brevicone 120 mm. in length. The point of greatest gibbosity is below the living chamber. The venter is convex throughout, more so over the point of greatest gibbosity than elsewhere. The dorsum is convex at this point, but is markedly concave orad of it, and faintly concave apicad. Lateral outline convex, the convexity greatest at the point of greatest gibbosity. The section is nearly circular at the base, depressed oval with the dorsum more flattened than the venter at the base of the living chamber, and subtriangular at the aperture. The measurements are summarized as follows:

	d.v.		tsv.	interval
Aperture	42	x	46	(on venter)
				50 mm.
Base living chamber	48	x	61	
				26 mm.
Greatest gibbosity	52	x	64	
				55 mm.
Base of specimen	38	x	38	

The sutures form well defined broad lobes on the venter which rise gradually to lateral saddles. The suture is transverse dorso-laterally, but a lobe occupies about one-third of the dorsal surface as in other *Brevicoceras*. The cameræ increase in depth from 6 mm. at the apex to 7 mm. in an interval of 33 mm. The last four cameræ measure 7 mm., 7 mm., 6 mm., and 5 mm. respectively, followed by a basal zone of 5 mm. The siphuncle is slightly compressed in section, the diameters being 4 mm. and 3 mm. It is 5 mm. from the ventral wall of the conch. Its structure is unknown.

The living chamber contracts gradually to the aperture which is obscure ventrally due to weathering. There are a broad low dorsal crest, lateral sinuses, and ventro-lateral crests probably separated by a small hyponomic sinus. Calcite represents the shell of the holotype, but retains no trace of the ornamentation. On the living chamber it is 2 mm. thick. A well defined impressed zone occurs at the base of the living chamber.

Remarks.—In curvature, section, sutures and aperture this is a typical *Brevi-coceras* and is very similar to the genotype in the outline and section. The sutures become lobed at a relatively late stage. The holotype is a gerontic specimen showing a good basal zone and the thickening of the shell wall over the living chamber. The siphuncle was not sectioned as there was reason to doubt whether the internal characters were well preserved. No trace of actinosiphonate structure could be observed at the septal foramen.

Holotype.—New York State Museum, No. 12072/1.

Occurrence.—From "the upper limestone of the Genesee shale in the Genesee valley." The matrix contains traces of crinoid stems, but is without any *Stylio-lina,* showing that the horizon is probably not Genundewa. It is suspected that the specimen is from a nodular limestone occurring at the top of the West River Shales, above the Geneseo proper.

Brevicoceras compactum Flower, n. sp.

Plate 2, figures 17-22

This species is known only from internal molds of the living chambers. The conch is breviconic, depressed in section with the venter more rounded than the dorsum. The conch is exogastric. The ventral outline is convex throughout, the internal mold showing only a faint constriction just before the aperture. The constriction does not affect the dorsal or lateral outlines. The dorsal outline is straight at the base of the living chamber, faintly concave in the adoral half. The lateral outlines are evenly convex and converge toward the aperture. The point of greatest gibbosity must lie at the base of the living chamber or very near to it in the phragmocone. The suture at the base of the living chamber shows well defined rather rounded lateral saddles which separate broad shallow dorsal and ventral lobes. The greatest depth of the septum is 2 mm., or one-seventh the dorso-ventral diameter. The siphuncle is shown at the base of the living chamber. It is circular in section, 1.2 mm. in diameter and 1 mm. from the ventral wall of the conch. The living chamber contracts gradually toward the aperture, which is depressed in section, transverse on the dorsum, showing slight rounded sinuses on the lateral regions, rising from the lateral to the ventral region, but with a small hyponomic sinus.

The proportions of the four specimens from which this species is known divide into two slightly different groups, one a rather broad, gibbous slightly shorter form with a rather large aperture, the other a more slender, slightly longer form with a more contracted aperture. The measurements in millimeters are summarized as follows:

Base living chamber	14 x 19.5	14 x 18
Length living chamber dorsal	11	13.6
Length living chamber ventral	17	18.5
Aperture	9 x 14	8 x 13

It is believed that these represent sexual differences.

Discussion.—Isolated living chambers of this species are easily confused with those of *Exocyrtoceras micron*, particularly when the apertures are not clearly preserved. *E. micron* is noticeably shorter, the lateral saddles of the sutures are poorly developed, the septum is less convex, the plane of its aperture is less inclined to that of the last septum, the constriction of the internal mold before the aperture is more prominent, and the aperture differs in the absence of the hyponomic sinus and in the stronger development of lateral sinuses.

Types.—Holotype: New York State Museum, No. 12070/1. Paratype: New York State Museum, No. 12070/2.

Occurrence.—Schoharie Grit, Schoharie, Schoharie County, New York.

Brevicoceras rotundum Flower, n. sp.

Plate 1, figures 10-12

This species is very similar to *B. compactum* from which it differs in section and the course of the sutures more than in size. The holotype represents a complete living chamber and a part of the phragmocone. The section is depressed. The dorsum is slightly and uniformly concave over the living chamber, but is straighter on the phragmocone becoming faintly convex at the base of the specimen. The venter is convex, nearly uniformly so, with the curvature very slightly greater at the base of the living chamber than elsewhere. The sides expand to the point of greatest gibbosity just below the base of the living chamber and contract to the aperture. They are convex in outline.

The phragmocone expands from 13 mm. and 10 mm. to 18 mm. and 14.5 mm. in a ventral length of 15 mm. and a dorsal length of 11 mm. The lower four cameræ are about 3 mm. in length, the fifth and last is 1 mm. At the base of the living chamber the suture has well developed lateral saddles. The septum has a lateral depth of 3 mm. and a ventral depth of .5 mm. The siphuncle is circular in section, 1.5 mm. in diameter and 1.8 mm. from the venter. The internal mold of the living chamber is without any constriction before the aperture which is attained in a ventral length of 19 mm. and a dorsal length of 15 mm. The aperture is nearly transverse dorsally with a faint, low broad sinus, well developed subangular lateral lobes which rise to rather high ventro-lateral crests which in turn flank the hyponomic sinus. The diameters of the aperture are 11 mm. and 15 mm.

Discussion.—The species resembles *B. compactum* but is more slender, less gibbous, has a slightly longer living chamber, better developed lateral lobes on the aperture and is less depressed and more evenly rounded in section.

Holotype.—New York State Museum, No. 12076/1.

Occurrence.—In the Schoharie Grit, at Schoharie, New York.

Brevicoceras conicum Flower, n. sp.

Plate 1, figures 2-3

Gomphoceras absens Hall, 1888, Paleont. of New York, vol. 5, pt. 2, suppl., pl. 122, fig. 3; not fig. 1-2;

Not *Cyrtoceras absens* Hall, 1876, nor *Gomphoceras absens* Hall, 1878.

Only the living chamber is known for this species. It is that of a nearly exogastric brevicone of depressed section. At the base the venter is slightly more rounded than the dorsum, the diameters being 15 mm. and 21 mm. The internal mold bears a broad constriction which occupies about half the length of the living chamber and considerably affects the outline. The sides converge rapidly toward the aperture and are straight adapically and faintly concave adorally on account of the constriction. The venter is faintly convex adapically and faintly concave adorally. The dorsum is straight adapically and concave adorally. The septum at the base of the living chamber shows slight rounded lateral saddles separating dorsal and ventral lobes. The siphuncle is depressed in section, measuring 1 mm. x 2.5 mm., and is 1 mm. from the venter. Due to the constriction of the internal mold the transverse diameter of the living chamber contracts to 16.5 mm. 9 mm. above its base. The dorsum is missing at this point and the corresponding dorso-ventral diameter is unknown. The aperture is approximately parallel to the plane of the last septum and is 19 mm. from the base of the living chamber. It is transverse dorsally, bears slight lateral sinuses, and a well defined hyponomic sinus is placed between rounded ventro-lateral crests. The surface is unknown.

Discussion.—The lack of lateral convexity in the outline distinguishes this from all other species of *Brevicoceras* and will also serve to distinguish it from all Ulsterian brevicones. The species is considerably larger than either of the two Schoharie species of *Brevicoceras* described here. The holotype was figured by Hall as *Gomphoceras absens.* It can be separated from *Turnoceras absens* (Hall) which it does not in the least resemble, by the characters of the genera.

Holoytpe.—New York State Museum, No. 12181/4.

Occurrence.—From the Onondaga Limestone, Clarence Hollow, Erie County, New York.

Genus OVOCERAS Flower, 1936

Genotype.—*Ovoceras oviforme* (Hall); Flower, 1936, Bull. Amer. Paleont., vol. 22, p. 334.

In this genus are placed small erect brevicones of exogastric affinities. The section is very slightly depressed, often subcircular. The conch expands to a point at or slightly above the base of the mature living chamber, where all outlines become convex, and the shell forms an arch over the adoral end of the conch to the aperture. The sutures are straight and transverse. The siphuncle is close to the ventral wall of the conch. Its structure is not yet known. The aperture bears a prominent hyponomic sinus, ventro-lateral crests, lateral sinuses, and the dorsum may be transverse or faintly convex. The surface of the shell bears fine transverse striæ.

Discussion.—Typical representatives of this genus are known from the Cherry Valley of New York. There *Ovoceras oviforme* (Hall) and *Ovoceras constrictum* Flower occur. The genus is present in the Sellersburg of Indiana, being represented by *O. turbiniforme* (Meek and Worthen). *Ovoceras* is not confined to America, but is represented in the Middle Devonian of Germany by *Apioceras inflatum* Quenstedt, sp. as figured by Saemann[21].

Genus **ANGLICORNUS** Flower and Caster, 1935

Genotype.—*Anglicornus anneliesæ* Flower and Caster, 1935, Bull. Amer. Paleont., vol. 22, p. 249.

This is a genus of essentially erect brevicones of exogastric affinities. The section is slightly depressed, sometimes subcircular, with dorsum and venter equally rounded. The gibbosity is greatest at a point slightly above the base of the living chamber. The living chamber is more gibbous dorsally than ventrally, the ventral curvature being more uniform. The sutures are straight and transverse. The siphuncle is close to the venter, its segments are fusiform, being slightly expanded but longer than wide. The internal structure of the siphuncle is not known. The aperture bears a hyponomic sinus, ventro-lateral rounded crests, and is transverse dorsally.

Discussion.—Two species have been referred to the genus at the time of its original description. One is the genotype, *A. anneliesæ* of the Lewis Run Sandstone of the Conewango. In this species the aperture flares slightly and the aperture bears a slight broad sinus on the dorsum, so broad as to be transverse over the greater part of the dorsal surface. *A. nasutum* (Hall) is a smaller species, with a smaller and more sharply defined hyponomic sinus and without the dorsal sinus. The age of this species is doubtful. It is recorded by Hall as "Chemung group, Belmont, Allegany County, New York." The species is listed by Chadwick among the diagnostic species of the Canadaway. The outcrops about Belmont include the Cuba Sandstone, which marks the base of the Conneaut, and several members of the Canadaway beneath. *A. goldringæ,* described below, is evidently from the Canadaway. *A. nasutum* is of doubtful horizon. It is probable, from the condition of the material within the living chamber—a coarse sand, probably originally with a considerable amount of lime—that it is from the Cuba of the basal Conneaut.

Anglicornus is represented by species which have been referred to *Gomphoceras tumidum* ranging from the Ithaca up through the true Chemung, and the genus

[21] Saemann, L.: *ibid.*, pl. 19, fig. 2a-2c.

continues upward into the Conewango where the genotype occurs. There are evidently several species involved in the specimens occurring from the Ithaca through the Chemung. The only available specimens have been badly flattened and usually preserve only one side and have not been considered adequate as types.

Anglicornus agrees in form and aperture with *Acleistoceras* and *Ovoceras*. It is closer to the latter in the transverse condition of the dorsal part of the aperture and the clarity of the hyponomic sinus. Both characters are better marked in Senecan species than in younger forms from the Chautauquan or Conewango.

Anglicornus goldringæ Flower, n. sp.

Plate 4, figure 25

The holotype consists of a living chamber with two gerontic cameræ attached. The specimen has been flattened by pressure directed through a plane nearly coinciding with the dorso-ventral diameter of the conch. The conch was erect, probably faintly exogastric below. The section was originally slightly depressed. The vertical outline is largely modified by distortion but both the dorsum and venter are convex over the known portion. The transverse outline is faintly convex throughout.

The specimen enlarges from diameters of 17 mm. and 25 mm. to 14 mm. and 28 mm. in a length of 9 mm., the distance from the base of the specimen to the point of greatest gibbosity. In the remaining 20 mm. of the length, the conch contracts gradually to the aperture which has diameters of 22 mm. and 15 mm.

The phragmocone is represented by only two gerontic cameræ. These occupy a length of 4 mm., and the upper suture is poorly defined. The sutures are transverse and straight, with no dorsal modification. The siphuncle is circular in section, 2 mm. in diameter, and is 2.4 mm. from the ventral wall of the conch. Its structure is unknown.

The living chamber is 26 mm. in length. The point of greatest gibbosity lies just above its base. The aperture bears a low round sinus which is 9 mm. across and 4 mm. deep. It appears that the dorsal portion of the aperture is curved as in *Ovoceras constrictum* Flower and not transverse as in *O. oviforme* (Hall).

Discussion.—The slender form, small size, and the gradual and even contraction of the living chamber serve to characterize the species. Most of the other species of *Anglicornus* are somewhat larger, less contracted adorally, and usually have shorter living chambers. *A. nasutum*, from the same locality, is shorter, more gibbous, and the tip of the aperture tends to flare slightly. The two species are not from the same horizon, as is indicated by the very different aspect of the material within the living chambers.

Holotype.—New York State Museum, No. 12025/1.

Occurrence.—The original designation of the locality is as follows: "Chemung group, Belmont, Allegany County, New York; horizon below the conglomerate."

According to Dr. Chadwick[22], the "conglomerate" mentioned, and which occurs in that area is the Cuba Sandstone which marks the base of the Conneaut. The underlying shales are therefore Canadaway.

Genus **ALETOCERAS** Flower, n. gen.

Genotype.—*Aletoceras gracile* Flower, n. sp.

Conch breviconic, erect, the apex faintly exogastric, slightly depressed in section. The dorsal outline is faintly concave adapically, nearly straight over the greater part of the phragmocone, becoming faintly convex over the adoral part of the phragmocone and the lower half of the living chamber. It becomes concave and flaring before the aperture. The transverse outline expands to the point of greatest gibbosity, which is located just above the base of the living chamber, contracts over the basal two-thirds of the living chamber, and flaring, becomes more or less concave in the adapertural third. The ventral outline is convex throughout except for a slight contraction and decrease in convexity before the aperture. Convexity is strongest over the region of greatest gibbosity.

The sutures are straight and transverse in the young but bear slight lateral saddles in the ephebic portion. The siphuncle is separated from the ventral wall by slightly more than its own diameter and is composed of nummuloidal segments which are longer than wide and slightly scalariform in vertical section. No deposits are known within the siphuncle.

The aperture bears a broad shallow hyponomic sinus placed between ventrolateral crests which give place to dorso-lateral sinuses. The mid-dorsal area is not well preserved in any specimens so far studied, but a low mid-dorsal crest is suggested. The surface of the shell bears fine transverse striæ separated by relatively broad interspaces. In the early portion of the conch the markings are transverse and show no trace of the pattern of the aperture.

Discussion.—Besides the two species from the Tully Limestone of New York, which are described below, I have seen but one other representative of the genus. This, a specimen as yet undescribed, from the Middle Devonian of Nevada, is in the collection of Dr. C. W. Merriam of Cornell University.

In form the genus suggests some species of *Amphicyrtoceras* Hyatt rather than any Devonian genus, but may be readily distinguished by the lateral saddles, the marked depressed section, the flaring aperture, and the different development of the crests and sinuses of the aperture. Further, the siphuncular segments of *Amphicyrtoceras* are more cylindrical within the cameræ, contracting more abruptly at the ends, and the siphuncle is not noticeably scalariform in vertical section. The characters of the aperture recall the features of *Blastoceras* Flower and Caster in which the aperture is produced but not expanded and in which the sec-

22 Chadwick, G. H., *fide litt.*, 1938.

tion is subcircular and the sutures are transverse throughout.

Aletoceras gracile Flower, n. sp.

Plate 3, figures 10-11; Plate 4, figure 1

This is a small slender brevicone which is faintly exogastric and moderately depressed, with the dorsum and venter about equally rounded. The vertical outline is as described for the genus. In the earliest portion of the holotype the dorso-ventral diameter is 8 mm. The corresponding transverse diameter is not known. In the length of the phragmocone, 32 mm., the dorso-ventral diameter increases to 22.4 mm. and the transverse diameter is 25 mm. The point of greatest gibbosity is 9 mm. above the last septum. Here the diameters are 23 mm. and 26 mm. The aperture is 23 mm. above the base of the living chamber. Its diameters cannot be ascertained, save that the conch contracts and the section becomes more depressed. The dorsum is missing. The lateral outline becomes faintly concave just before the aperture.

In the length of the phragmocone, 32 mm., there are ten cameræ of which the first nine grade in depth from 2.2 mm. to 3 mm. The last is gerontically contracted to 2 mm. The sutures appear to be straight and transverse in the young portion but at the base of the living chamber faint rounded lateral saddles are apparent. The septum is rather more deeply curved than in other Devonian brevicones, being 4.5 mm. deep where the dorso-ventral diameter is 22 mm., or about one-fifth the dorso-ventral diameter.

The siphuncle is separated from the venter by slightly less than its own diameter adapically, but adorally is slightly more distant. The segments appear to be uniform in outline throughout. They are longer than wide, scalariform dorso-ventrally, with the ventral side of the neck sharply recurved, nearly recumbent, the dorsal neck bent at an angle of about 110 degrees. The connecting ring is faintly convex throughout and adnate dorsally. There appear to be no deposits. In the second camera below the living chamber the segment is 4.5 mm. long and expands from 2 mm. to 3 mm. within the camera.

The aperture is only partially known. There appear to be a broad shallow ventral (hyponomic) sinus, and ventro-lateral crests which descend on the lateral extremities. The remainder of the aperture has been destroyed by weathering.

The surface of the conch is marked by regular, transverse striæ with flat distant interspaces. There are between 4 and 6 of these striæ in a length of 1 mm.

Discussion.—This species can be separated from the genotype by the more slender section, smaller size and less flaring aperture. It is not congeneric with any species previously described from the Middle or Upper Devonian of New York.

Holotype.—Paleontological Research Institution, No. 5810.

Occurrence.—In the Tully Limestone at the Kingsley quarry, Kingsley Hill, .75 mile north of railroad underpass, Cortland County, New York. Collected by Dr. J. W. Wells.

Aletoceras amphoroides Flower, n. sp.

Plate 3, figures 3-4

This is a moderate sized rapidly expanding brevicone of marked depressed section. At the base of the holotype the diameters are 9 mm. and 11 mm.; dorsum and venter are equally curved. In the length of the phragmocone, 42 mm., the diameters expand to 24 mm. and 29 mm. There the dorsum is more flattened than the venter. The point of greatest gibbosity is 6 mm. above the base of the living chamber. Here the diameters have increased to 26 mm. and 31.5 mm. In 10 mm. the diameters have decreased to 29 mm. and 24 mm., and in the most adapertural part, 23.5 mm. above the last septum, the dorso-ventral diameter remains at 24 mm. but the transverse diameter increases to 30 mm., by reason of the flaring aperture. The sutures bear rounded lateral saddles separating dorsal and ventral lobes of which the ventral is the deeper. The septa are deep, the one at the base of the living chamber is 8 mm., or one-third the dorso-ventral diameter. The apical cameræ are not well preserved in the holotype. The last two are both 4 mm. deep. The basal zone is smooth and 3 mm. deep. The siphuncle is slightly removed from the ventral wall. It is compressed at the septum by reason of the oblique section cut through it by the septum. The diameters are 2.5 mm. and 3 mm. The siphuncle is removed from the venter by a distance of 2.5 mm. Where a segment is 4 mm. in length the diameters increase from 2.5 mm to 3 mm. The outline is scalariform dorso-ventrally. No deposits are known within the siphuncle.

The aperture is incompletely preserved. Ventro-lateral crests are low and rounded, giving place to lateral sinuses. These apparently rise to a low broad dorsal crest. The hyponomic sinus is not present but must have been very shallow. No trace of the surface of the shell is preserved.

Discussion.—This species can be distinguished from *A. gracile* by its size, rapid expansion and depressed section. From other described Devonian species it can be separated by the generic characters.

Type.—United States National Museum, unnumbered.

Occurrence.—West Brook member of the Tully Limestone. Werner's Gully, one mile northeast of Georgetown, New York.

II. CIRCULAR TO DEPRESSED EXOGASTRIC FORMS WITH SIMPLE APERTURES

Genus **EXOCYRTOCERAS** Flower, n. gen.

Genotype.—*Exocyrtoceras exoticum* Flower, n. sp.

This genus is erected for the reception of depressed exogastric brevicones which are characterized by a transversely elliptical aperture with no hyponomic sinus. The phragmocone is unknown. The sutures show dorsal and ventral lobes separated by rounded lateral saddles. The siphuncle is close to the ventral wall. Its outline is unknown.

The living chamber is gibbous over the basal portion, becoming markedly constricted some distance before the aperture, and becoming more cylindrical beyond the constriction. The venter is convex throughout, the convexity being greater in the adapical portion than in the adoral portion. The dorsal outline is convex adapically and straight or faintly concave adorally. The sides converge toward the aperture and are convex to the point of the constriction, after which they converge less rapidly and become straighter. The point of greatest gibbosity is located at or just above the base of the living chamber. The aperture is transverse, nearly straight on the dorsum and venter, strongly rounded laterally.

Discussion.—The marked constriction before the aperture and the attendant modification of outline together with the shape of the aperture will serve to distinguish this genus from other breviconic forms. It belongs in the form group which Foerste labeled as "depressed cyrtoceracones with hyponomic sinus", in which were originally included *Conostichoceras, Turnoceras, Poteriocerina* and *Gonatocyrtoceras.* Of these genera only *Poteriocerina* and *Gonatocyrtoceras* exhibit gibbous living chambers. Both lack the marked constriction before the aperture which is too marked in *Exocyrtoceras* to be regarded as internal, and both have straight sutures. In neither of these genera is the contraction of the aperture so marked dorso-ventrally.

The species which are here placed in *Exocyrtoceras* are all of early Middle Devonian or Ulsterian age. The genotype is large, strongly curved, and strongly contracted near the aperture. It is from the Columbus Limestone of Ohio. The other species are much smaller, less curved, more slender, and the living chamber is less contracted. No fundamental differences which would warrant placing these forms in a distinct genus have been found.

Gomphoceras missouriense Branson and Williams[23] of the Grand Tower Limestone of Missouri is a typical *Exocyrtoceras* in the form of the living chamber but is described as having a subcentral siphuncle. It resembles *E. exoticum* in being gibbous over the lower part of the living chamber but is more slender, slightly less curved, and the aperture is more produced.

Exocyrtoceras exoticum Flower, n. sp.

Plate 2, figures 12-15

This species is known only from the living chamber. The section is depressed, the conch is gibbous and strongly exogastric. All outlines are convex over the basal half of the living chamber. At about mid-height a constriction causes the dorsal and lateral outlines to become concave. Orad of this, the lateral outlines remain faintly concave to the aperture, the dorsum becomes faintly convex, and the venter is straight and inclined about 30 degrees to the plane of the last septum. The section at the base of the living chamber is strongly depressed. The venter is flattened. The mid-dorsal portion is missing but is either strongly flattened or possibly faintly emarginate. The diameters are 31 mm. and 41 mm. In a length of 7 mm., at the region of greatest gibbosity, the diameters increase to 34 mm. and 43 mm. The living chamber is 24 mm. in length dorsally, and 34 mm. when

23 Branson and Williams, in Branson: *The Devonian of Missouri,* Missouri Bur. Geol. and Mines, vol. 17, 2d ser., 1923, p. 160, pl. 37, fig. 2-4, not pl. 58, fig. 2.

measured along the curving venter. The aperture measures 12 mm. and 27 mm. and is a transverse oval with the ventral part scarcely more convex than the dorsal part, and the sides strongly rounded.

The characters of the phragmocone are known only from the last septum. The suture is transverse dorsally and ventrally but rises into rounded saddles laterally. The lateral depth of the septum is 4 mm., about one-tenth the transverse diameter. The siphuncle is 1 mm. in diameter, circular, and is close to the ventral wall.

The conch shows a slight trochoceroid condition. The siphuncle is 22 mm. from the left side and 24 mm. from the right side. The aperture is very slightly inclined toward the right. There was probably no spire as such, but coiling was dextral.

Discussion.—The slight trochoceroid condition, the strong curvature, and the gibbosity of the living chamber serve to distinguish this species. Other species of *Exocyrtoceras* are less strongly curved, much smaller, less gibbous and do not show a trochoceroid condition. The trochoceroid condition appears to be connected with strong curvature, and other differences are largely those of degree of gibbosity. It has not seemed advisable to make finer generic distinctions.

Holotype.—Paleontological Research Instution, No. 5805.

Occurrence.—From a stone heap near Columbus, Ohio. By lithology the species is from the Columbus Limestone of the Middle Devonian.

Exocyrtoceras sinuatum Flower, n. sp.

Plate 2, figures 6-11

Gomphoceras absens Hall, 1888, *pars*, Paleontology of New York, vol. 5, pt. 2, suppl., (in vol. 7), pl. 122, fig. 2. (not fig. 1 or 3.) ; not Hall, 1876 nor 1879.

The holotype represents the internal mold of a complete living chamber. The phragmocone is unknown. The conch is breviconic, exogastric, depressed in section, with the venter rounded and the dorsum flattened so that the greatest transverse diameter at the base of the living chamber lies two-thirds the distance from venter to dorsum. The suture is strongly sinuate with well developed lateral saddles separating a deep ventral lobe from a shallower and narrower dorsal lobe. Where the diameters at the base of the living chamber are 18 mm. and 22 mm., the septum is 4 mm. in depth when measured from the dorsum, 5 mm. from the dorso-lateral region, 4 from the lateral region and 2 mm. from the ventral region. The siphuncle is circular in section, 1 mm. in diameter, and 2 mm. from the ventral wall.

The point of greatest gibbosity is slightly above the base of the living chamber. The aperture is transversely oval, strongly depressed, with no hyponomic sinus. The two well preserved specimens upon which this description is based show slight discrepancies in measurement, one being slightly more depressed than the other, slightly more gibbous, and with a broader aperture:

		Holotype	Paratype
Base living chamber		18 x 22	18 x 25
Length living chamber	dorsal	19.5	17
	ventral	24	25
Aperture		12 x 18	12 x 19.5

Discussion.—The size, prominent constriction before the aperture and sinuate sutures distinguish this from other species of *Exocyrtoceras.* The species was formerly included in *Gomphoceras absens* Hall. The holotype was figured by Hall under that name, not however, at the time of the original description. The paratype was found bearing a label *"Gomphoceras absens."*

Types.—Holotype: New York State Museum, No. 12181/1. Paratype: New York State Museum, No. 12152/1.

Occurrence.—In the Schoharie Grit, Schoharie, N. Y. The species has not been observed in the Helderberg area.

Exocyrtoceras constrictum Flower, n. sp.

Plate 2, figures 3-5

The holotype consists of the internal mold of a living chamber. The section is depressed with both venter and dorsum flattened, though the dorsum is the more transverse of the two. The diameters are 21 mm. and 15 mm. The suture is markedly sinuate. A broad lobe occupies the entire venter. Laterally the suture rises to form rather narrow but well rounded lobes on the lateral extremities. These slope gradually apicad toward the dorsum. The middle third of the dorsum is occupied by a narrow accentuated lobe in the center of a broader and shallower one formed between the lateral saddles. The siphuncle is circular in section, 1.4 mm. in diameter and located 2 mm. from the venter.

The living chamber is nearly erect, with a conspicuous constriction just before the aperture. Apicad of this the venter is faintly convex and the dorsum is perfectly straight. The constriction begins 16 mm. from the last septum on the venter, and 12 mm. from it on the dorsum. The diameters are 19 mm. and 14 mm. The aperture is transversely oval, appearing at a ventral length of 25 mm. and a dorsal length of 22 mm. Its diameters are 11 mm. and 16 mm.

Discussion.—Aside from the measurements the species is distinctive in the more erect form, the more marked constriction before the aperture—which is better developed dorsally than in any other species from the Schoharie—and in the mid-dorsal lobation of the suture.

The holotype and one other representative of the species were labeled *Gomphoceras absens* in the collection of the New York State Museum. The determination seems to be on Hall's authority.

Holotype.—New York State Museum, No. 12152m/1.

Occurrence.—From the Schoharie Grit, Schoharie, New York.

Exocyrtoceras micron Flower, n. sp.

Plate 4, figures 8-10

Gomphoceras absens Hall, 1888, *pars*, Paleontology of New York, vol. 5, pt. 2, suppl., (in vol. 7,) pl. 122, fig. 1. not fig. 2-3.; not Hall, 1876 nor 1879.)

The type represents the living chamber of a small exogastric brevicone of depressed section. The vertical outline of the living chamber is typical for the genus. The section is depressed, the dorsum and the venter both flattened in the middle giving a subquadrangular appearance. At the base of the living chamber the diameters are 14 mm. and 18 mm. The septum is moderately and evenly curved. The suture bears dorsal and ventral lobes separated by lateral saddles. The siphuncle is 1 mm. in diameter and is located 1.4 mm. from the venter. The diameter of the conch does not increase above the base of the living chamber. In the basal 12 mm. the conch contracts to diameters of 12 mm. and 14 mm. Beyond this, contraction is less rapid. The aperture is so inclined that it is 14 mm. from the base of the living chamber on the venter and 12.5 mm. on the dorsal side. The apertural diameters are 12 mm. and 18 mm. The aperture is a transverse oval without a hyponomic sinus.

Discussion.—This species is the smallest known in the genus, and size alone will separate it from the other species. The holotype of *E. micron* was figured by Hall under *Gomphoceras absens*, but is not congeneric or conspecific with the holotype of that species.

Holotype.—New York State Museum, No. 12181/2.

Occurrence.—In the Schoharie Grit, Schoharie, New York.

Genus TURNOCERAS Foerste, 1924

Genotype.—*Cyrtoceras turnus* Barrande

Turnoceras Foerste, 1924, Denison Univ. Bull., Sci. Lab., Jour. vol. 21, p. 342, pl. 53, fig. 2A-C.

This genus belongs to a group of depressed exogastric cyrtoceracones in which the aperture is not contracted and there is no hyponomic sinus. The venter is rounded, the dorsum flattened. The sides are nearly straight, diverging toward the aperture. The dorsum and venter are curved over the phragmocone, but are more or less abruptly straightened over the living chamber, where they cease to diverge and become nearly parallel. The sutures are transverse to the curving axis of the conch. The siphuncle is close to the venter. Its segments are concavosiphonate and contain actinosiphonate deposits.

Conostichoceras Foerste appears to be closely allied, but differs in that the lateral outline is faintly convex, the sides converging slightly near the aperture, and the siphuncular outline is cyrtochoanitic.

Turnoceras turnus (Barrande) is from the Middle Devonian, from Barrande's G3, of Hlubocep, Bohemia. The genus has not been recognized previously in America.

Turnoceras absens (Hall)

Plate 4, figures 18-19

Gomphoceras absens Hall, 1876, Illustrations of Devonian Fossils: Cephalopoda, pl. 47, fig. 7-8.

Gomphoceras absens Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 324, pl. 46, fig. 8-9.

Not *Gomphoceras absens* Hall, 1888, Paleontology of New York, vol. 5, pt. 2, suppl., (in vol. 7,) pl. 122, fig. 1-3.

This is a small breviconic exogastric cyrtoceracone with an uncontracted aperture. Adapically the dorsum is concave and the venter convex, the conch being slightly but definitely curved. The ventral portion of the living chamber is nearly straight. The dorsal portion is absent beyond the base but shows the development of a straighter outline.

The section is depressed, with the venter rounded and the dorsum transverse. In the basal 10 mm. of the lectotype the conch enlarges from 9 mm. and 12 mm. to 13 mm. and 15 mm. The phragmocone is 17 mm. in length and represents six cameræ. The diameters at the base of the living chamber are 17 mm. and 14 mm. Hall's drawing is incorrect in indicating a slight contraction of the last camera. The sutures are straight and transverse to the curving axis of the conch. The septa are shallow and evenly curved. The siphuncle is located close to the venter, and is exposed by weathering in the holotype. Though poorly preserved the segments appear to be concavosiphonate. The condition of any internal deposits which may be present is unknown.

The living chamber has a ventral length of 24 mm. and does not retain the aperture. As in the genotype lateral expansion continues over the living chamber, but the dorsum and venter become parallel. Nothing is known of the ornamentation of the shell.

Discussion.—The curvature of the species is slight and suggests *Conostichoceras* Foerste[24] rather than *Turnoceras,* but the siphuncle of *T. absens* is apparently concave within the segments, and is certainly not expanded. Further, I have found it to hold true that brevicones of the Schoharie Grit are often less strongly curved than their closest relatives from other formations.

Hall's description was based upon more than one specimen and more than one species. The four specimens figured by Hall represent four species of which one is a *Turnoceras,* one a *Brevicoceras,* and the two others are *Exocyrtoceras* The *Turnoceras* was the first specimen figured, and the only one figured in the *Illustrations of Devonian Fossils,* from which the species dates, and it is the only specimen figured in the Paleontology at the time of the first true description of the species. That species is the holotype. It is evident, however, that a large part of Hall's description is based upon other figured specimens.

In addition to the figured specimens, there is a good series of unfigured specimens in the New York State Museum which bear the label *Gomphoceras absens.* The labels appear to be in Hall's handwriting. From these specimens and the types it appears that *G. absens,* as originally conceived, contains the following:

Turnoceras absens (Hall)
Exocyrtoceras micron, n. sp.
Exocyrtoceras constrictum, n. sp.
Exocyrtoceras sinuatum, n. sp.
Brevicoceras conicum, n. sp.
Brevicoceras compactum, n. sp.

24 Foerste, A. F.: *Actinosiphonate, trochoceroid and other cephalopods,* Denison Univ. Bull., Sci. Lab., Jour. vol. 21, 1924, p. 341, pl. 38, fig. 1A-E.

Brevicoceras rotundum, n. sp.

Holotype.—New York State Museum, No. 12181/1.

Occurrence.—In the Schoharie Grit, at Schoharie, New York.

Turnoceras, n. sp.

Plate 4, figure 20

The only representative of this form is a badly flattened specimen consisting of a living chamber and three cameræ. Flattening is slightly oblique to the dorso-ventral plane, so that when seen from the apical end the siphuncle is considerably to the right of the center, and the dorsum—as figured—is considerably to the left. The conch is apparently straight, probably originally faintly exogastric, with the phragmocone 8 mm. in length, consisting of three cameræ which measure 3.5 mm., 4 mm. and 2 mm. respectively, the last camera being abruptly contracted. The sutures bear dorsal and ventral lobes separated by lateral saddles. The diameters at the base of the specimen are 13 mm. and 18.5 mm., but the condition of the septum shows that the transverse diameter has been increased and the dorso-ventral diameter decreased by distortion. The siphuncle is .2 mm. in diameter and is 1.5 mm. from the ventral wall. The septum has a curvature of 4 mm., and is rather irregular.

The living chamber is 20 mm. in length. The ventral side is not preserved. The transverse diameter is 21 mm. at the base and is estimated as 22 mm. at the aperture. The dorsum is straight, the lateral outline very faintly gibbous. Only the dorso-lateral portion of the aperture is preserved and is straight and transverse.

Discussion.—The sinuate condition of the sutures was evidently original and is sufficient to distinguish this species from *T. absens* (Hall). Other differences are to be found in the larger size of this species and the proportions of the living chamber, which is much shorter in proportion to its diameter than is that of *T. absens*. It agrees with *T. absens* and differs from the genotype in the straight or nearly straight form.

In view of the flattened and incomplete condition of the specimen I have refrained from giving it a specific name.

Holotype.—New York State Museum, No. 12590/1.

Occurrence.—From the Schoharie Grit of Schoharie, New York.

Genus **CYRTOGOMPHUS** Flower, n. gen.

Genotype.—*Cyrtogomphus curvatus* Flower, n. sp.

Conch exogastric, depressed in section, the dorsum and venter about equally rounded. The venter is uniformly convex, the dorsum faintly concave over the phragmocone, becoming faintly convex over the base of the living chamber and returning to the concave condition near the aperture. The sutures are straight, slightly inclined orad on the venter in the adoral part of the phragmocone though transverse adapically. The segments of the siphuncle are subspherical. No internal deposits have been observed. The siphuncle is close to the venter. The aperture is straight and transverse. The surface of the shell bears fine lines of growth or regular transverse striæ and liræ. No trace of longitudinal shell structure has been noted. See text figure 1.

Discussion.—The species of this genus resemble certain species of *Amphicyrtoceras* in general build and appearance, but the siphuncular segments are spherical, and there is no hyponomic sinus. These characters serve to distinguish the genus from all depressed brevicones except *Micronoceras*, which is erect and has transverse sutures throughout and more slender siphuncular segments. Although at the present time only two species can be referred to the genus with certainty, it is suspected that a number of the less adequately known species may belong here.

Gomphoceras lunatum Hall is typical of the genus in section, form, and in the form of the siphuncular segments. The aperture is obscure but is too poorly preserved to justify any statements concerning its form. Hall believed that a hyponomic sinus (small aperture) was present but has found it in other species where it did not exist.

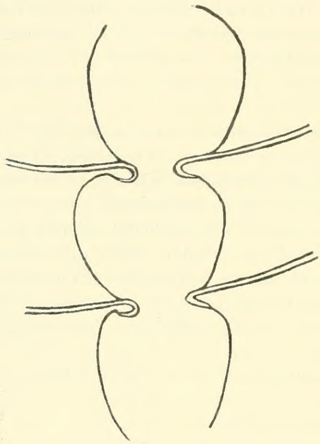


Fig. 1.— Camera lucida drawing of siphuncle of *Cyrtogomphus curvatus*. The right side is closer to the venter than the left, the section being slightly oblique ; x 5

Cyrtogomphus curvatus Flower, n. sp.

Plate 2, figures 26-27; text fig. 1

The ventral outline is uniformly convex to the middle of the living chamber, where the convexity increases. The dorsum is concave to the base of the living chamber, becoming slightly straighter there. The remainder of the dorsum is lost by weathering but apparently becomes very faintly convex. The lateral outline expands gradually to the middle of the living chamber where it becomes convex and contracts gradually to the aperture.

The apical portion of the specimen is faintly compressed, but the section becomes depressed in the later part, with the dorsum slightly more flattened than the venter. The phragmocone expands in its length of 95 mm. from 14 mm. and 13 mm. to 48 mm. and 50 mm. Thirty-five mm. below the base of the living chamber the diameters are 32 mm. and 34 mm.

The sutures are straight and transverse to the curving axis in the apical portion, but adorally they rise orad on the venter. In the last 50 mm. there are nine cameræ. These increase from 4 mm. to 7 mm. in depth, and the last camera is contracted to 5.5 mm. The siphuncle is compressed at the septal foramen, and where the dorso-ventral diameter of the conch is 32 mm., it is 4.5 mm. from the ventral wall and is 1.2 mm. in width and 1.7 mm. in height. A segment 4.5 mm. in length expands in oblique section from 1.8 mm. to 5 mm. within the camera. The brims are short and recumbent, the segment pyriform, expanding more on the dorsal than on the ventral side, and joining the preceding septum with no area of adnation. Calcite is concentrated on the ventral side of the siphuncle but its irregular form seems to indicate that it does not represent an organic deposit.

The living chamber has basal diameters of 48 mm. and 50 mm. It has a maximum ventral length of 40 mm. The sides become convex 15 mm. above the base. The remainder of the outline is not preserved, having been removed by weathering. Surface markings, consisting of rather irregularly spaced rounded liræ and narrow striæ, are transverse and indicate that no hyponomic sinus was present. The only part of the aperture which is preserved is a narrow ventro-lateral area.

Discussion.—The size and proportions of the conch serve to distinguish this from *C. lunatus* (Hall) and from *C. thedfordensis* Flower both of which are larger and more depressed.

Holotype.—Buffalo Museum of Science, No. E 8570.

Occurrence.—In the Tichenor Limestone, Cazenovia Creek, New York State.

Cyrtogomphus thedfordensis Flower, n. sp.

Plate 2, figures 26-27

The holotype consists only of a living chamber which has diameters at its base of 50 mm. and 39 mm. with the venter and dorsum equally rounded. The venter is 42 mm. in length and uniformly curved except in the last 5 mm. where the convexity is slightly increased. The sides are nearly parallel at the base of the specimen but become faintly convex at the middle and converge slightly toward the aperture. The dorsum is faintly convex over the lower half of the living chamber, the adoral half being removed by weathering. It appears, however, that it must become straight or faintly concave in the adoral portion. The aperture is rather poorly preserved but appears to be straight and transverse. It has a transverse diameter of 47 mm. and the dorso-ventral diameter must have been slightly less than 30 mm.

The basal septum has a depth of 9 mm. The suture is straight and transverse to the axis of the conch. The siphuncle is 2 mm. in diameter, circular in section and is 4 mm. from the venter.

Discussion.—This species is distinguished from *C. lunatus* (Hall) by its slightly smaller size, and the more contracted living chamber; from *C. curvatus*, by the transverse position of the last suture, the circular section of the siphuncle at the septal foramen and the much larger size.

Holotype.—Buffalo Museum of Science, No. E 186.

Occurrence.—"Hamilton. Thedford, Ontario."

Genus **MICRONOCERAS** Flower, n. gen.

Genotype.—*Micronoceras delphicolum* Flower, n. sp.

This genus is erected for the reception of small, nearly erect brevicones of slightly depressed section and simple apertures. The conch enlarges evenly to the middle of the living chamber, from which it contracts gradually adorally.

The sutures are straight and horizontal. The cameræ and septa are shallow and show no distinctive features. The siphuncle is separated from the venter by slightly more than its own diameter. The outline of the segments is known only from *M. apertum*; here the segments are elongate and expand slightly within the cameræ. The internal structure of the siphuncle is not known.

The aperture is round, nearly circular in the genotype and shows no trace of of a hyponomic sinus. In *M. gibbosum* (Hall) the aperture is faintly subtriangular, one angle being ventral and representing the rudiment of the hyponomic sinus. The surface of the shell bears transverse striæ and lines of growth. The internal mold often bears a fenestrate pattern which appears to represent a structure of the interior of the shell.

Discussion.—This genus is related to the group of *Poteriocerina* Foerste[25]. It can be distinguished by the erect condition, the location of the point of greatest gibbosity high on the living chamber, and the only slightly depressed section.

All of the species which can be definitely referred to this genus are of Hamilton age, and are small forms.

The earliest representative of the genus so far recognized is *M. gibbosum* of the Cherry Valley Limestone. The obscurely subtriangular condition of the aperture of this species suggests affinities with some of the genera which possess a hyponomic sinus, such as *Ovoceras*, in which I had previously placed the species, and *Acleistoceras*. It may be that *Micronoceras* is derived from such forms; certainly its siphuncle, so far as known from a single species of the genus, shows no affinities with associated exogastric genera with simple apertures. At the present time there are insufficient morphological data to demonstrate the relationships of any of these genera.

Micronoceras delphicolum Flower, n. sp.

Plate 3, figures 14-15; Plate 4, figures 6-7

Conch erect, faintly exogastric, slightly depressed in section. The diameters at the base of the living chamber are 18 mm. and 20 mm. In 10 mm. these enlarge to 21 mm. and 23 mm. which is the greatest diameter attained. The adapertural part of the specimen from which these measurements were taken is crushed, but from a somewhat flattened specimen it is clear that this represents a point slightly above the middle of the living chamber, beyond which the conch contracts. The cameræ and septa are shallow, the latter scarcely curved. The last two cameræ are contracted, but the base of the living chamber is without an impressed zone.

The aperture is unmodified by any crests or sinuses and must have been a

[25] Foerste, A. F.: *Actinosiphonate, trochoceroid and other cephalopods.* Denison Univ. Bull., Sci. Lab., Jour., vol. 21, 1926, p. 343, pl. 45, fig. 1A-C.

transverse oval, though it is impossible to give measurements from the crushed specimens at hand. The internal mold bears impressed upon its surface a number of transverse markings which may represent the ornamentation of the shell.

Discussion.—This species is known from two specimens, both of which are figured. The one represents a flattened specimen consisting of a complete living chamber and portions of several cameræ. The other represents a portion of the living chamber. The basal portion is undistorted, but the adapertural portion is badly crushed.

Types.—Holotype: Paleontological Research Institution, No. 5806. Paratype: Paleontological Research Institution, No. 5807.

Occurrence.—From the Delphi member of the Hamilton, at Delphi Falls, New York. One specimen is from the collection of Dr. John W. Wells; the other was collected by the author.

Micronoceras raphanus (Hall)

Plate 4, figure 3

Gomphoceras raphanus Hall, 1879, *pars*, Paleontology of New York, vol. 5, pt. 2, p. 347, pl. 94, fig. 2-4. Not pl. 94, fig. 5, 10.

This species is represented by a number of more or less flattened conchs none of which retains the complete aperture. The following description is based mainly upon the lectotype:

Conch nearly erect, probably originally faintly exogastric. The ventral outline is slightly and uniformly convex throughout. The dorsal side of the specimen is not preserved except at the apical end. Another specimen which shows the dorsal outline is too badly flattened to furnish reliable evidence, save that the dorsum was plainly convex over the adapertural portion of the living chamber. The lectotype is only slightly flattened. The pressure acted through a plane which is inclined about 10 degrees from the dorso-ventral diameter of the conch. At the apical end the diameters are 18 mm. and 20 mm., the section being depressed. The dorsal side of the conch is transverse and scarcely convex as in *Brevicoceras*. The transverse diameter increases to 29 mm. at the region of greatest gibbosity which is 24 mm. above the base of the specimen. In the remainder of the length of the specimen, 20 mm., the conch contracts, the diameter at the adapertural end being estimated at 18 mm. The lower 20 mm. of the specimen is occupied by seven cameræ, of which the last is slightly shallower than the one directly preceding it. The sutures are transverse. The paratypes show that there are no dorsal lobes. The siphuncle is preserved in the lectotype. It is 1.5 mm. in diameter and is .8 mm. from the ventral wall of the conch.

The living chamber has a transverse diameter at the base of 28 mm. The point of greatest gibbosity lies 4 mm. above this. The aperture is incomplete, but the ventral portion appears to be circular in outline. None of the specimens shows any trace of a hyponomic sinus, nor has any trace of such a structure been found in any fragments of the shell which bear surface markings.

The middle layers of the shell exhibit the fenestrate structure previously noted in *Ovoceras* (?) *gibbosum* (Hall). The surface bears striæ about 1 mm. apart between which can be seen faint lines of growth.

Discussion.—This species is referred to *Micronoceras* on the basis of the general similarity of the proportion of this species to the genotype, and upon the absence of any evidence of a hyponomic sinus. *M. raphanus* can be distinguished from *M. delphicolum* by the much larger size. The characters of the aperture of this species would bear additional evidence. It is clear, however, that the specimen upon which Hall apparently based his description of the aperture and siphuncle is not conspecific with the first three specimens figured under this name, which seem to be the legitimate basis for the species. This specimen, the type of pl. 94, fig. 5, is not conspecific with the others. The aperture is incomplete, the living chamber is conical rather than dome-like in its contraction, and the base of the living chamber is higher in relation to the point of greatest gibbosity.

The type of pl. 94, fig. 10, shows similar characters but the aperture is more contracted. Only one side of the specimen is preserved and it is not possible to determine the form of the aperture. The marked contraction suggests *Ovoceras* rather than *Micronoceras*.

The type of pl. 94, fig. 4, is apparently conspecific with the lectotype but represents an immature individual.

Type.—Lectotype: New York State Museum, No. 12199/1. Paratype: New York State Museum, No. 12199/2. Hypotype: Paleontological Research Institution, No. 5808.

Occurrence.—From the Hamilton of Pratt's Falls, Onondaga County, New York, apparently from the Pompey member of the Skaneateles Shale.

Micronoceras gibbosum (Hall)

Plate 1, figures 13-14

Cyrtoceras gibbosum Hall, 1876, Illustrations of Devonian Fossils; Cephalopoda, pl. 47, fig. 3-4.

Gomphoceras oviforme Hall, 1879, in part Paleontology of New York, vol. 5, pt. 2, p. 344-46, pl. 46, fig. 3-4; (not pl. 45, fig. 1-4, nor pl. 94, fig. 6-7).

Ovoceras ? gibbosum Flower, Bull. Amer. Paleont., vol. 22, p. 68, pl. 4, fig. 6; pl. 8, fig. 3.

A specimen of this species which retains the aperture in an excellent state of preservation shows that the form is allied to *Micronoceras* and not to *Ovoceras*, in which it was previously placed. The specimen consists of a living chamber of circular section which is 22 mm. in length, with a basal diameter of 29.4 mm. The aperture is slightly broader than high, measuring 17 mm. and 19 mm., and is obscurely subtriangular, with the hyponomic or ventral sinus slightly more prominent than the others. All, however, are very slight.

Discussion.—This species differs from other *Micronoceras* in the slight lobation of the aperture. Other species show no lobation, but it is impossible to say at present to what extent this may be due to inadequate preservation. *Cyrtoceras gibbosum* fits *Micronoceras* better than any other described genus, and the differences do not appear to be sufficient to warrant the erection of a new genus for this species. In other characters, such as the absence of curvature, the fenestrate condition in the middle layer of the shell, and the general section and proportions of the conch, the species is a typical *Micronoceras*.

Holotype.—New York State Museum, No. 12316/1.

Occurrence.—In the Cherry Valley Limestone, Onondaga County, New York. Collected by James Hall.

Micronoceras angulatum Flower, n. sp.

Plate 2, figure 16

Conch erect, small, strongly depressed in section, with the dorsum slightly more flattened than the venter. The venter is straight to the point of greatest gibbosity, which is located just above the base of the mature living chamber, where it becomes faintly convex but becomes faintly concave just before the aperture. The lateral outline is strongly bent at the point of greatest gibbosity, but the sides orad and apicad of this point are straight though there is marked expansion and contraction.

The conch enlarges from 10 mm. and 14 mm. to 14 mm. and 23 mm. in 25 mm., and in the remaining 12 mm., contracts to 13 mm. and 19 mm. at the aperture. The sutures are straight and transverse. The phragmocone is filled with calcite and the depth of the cameræ cannot be ascertained. The siphuncle is close to the venter, and the sutures are straight and transverse. At the base of the living chamber the diameters are 22 mm. and 13 mm. The septum has an apparent depth of 6 mm., due to calcite filling the basal zone which is in a line with the middle part of the septum. The actual depth of the septum is estimated at 3.5 mm.

The aperture is straight and transverse to the axis of the conch. The shell is thickened internally just before the aperture, producing the concavity of the venter at this region. The surface of the shell shows only rather irregularly spaced transverse lines of growth.

Discussion.—This differs from other species of *Micronoceras* in the straight condition of the outline before and after the point of greatest gibbosity is reached, together with the subangular condition at that region. The holotype represents the greater portion of the conch. The phragmocone and the shell are represented by white calcite; matrix fills the living chamber. The dorsal outline was poorly preserved, but sufficient indication of it was found in extracting the specimen to show that it is essentially like the venter, but slightly straighter.

Holotype.—Buffalo Museum of Science.

Occurrence.—In the Tichenor Limestone of the Hamilton, Eleven Mile Creek, Darien, New York.

Micronoceras apertum Flower, n. sp.

Plate 4, figure 4-5

The holotype is a badly flattened specimen 40 mm. in length which expands from 9 mm. to 28 mm. in the basal 30 mm., and contracts to 22 mm. at the aperture. The point of greatest gibbosity is located just below the middle of the living chamber. The sutures are straight and transverse. The cameræ are shallow, the adoral three markedly contracted from 2.5 mm. to 1 mm. and .8 mm. The siphuncle is exposed on the ventral side. The segments are slender, subcylindrical over the greater part of their length, and contracted abruptly at the septal foramina. No trace of deposits can be seen.

The aperture is preserved only dorsally. It is straight and transverse, and is preceded by a distinct ridge or lip. The surface of the shell shows transverse lines of growth. No trace of the fenestrate pattern, which is an internal feature, can be seen.

Discussion.—This species is much larger than *M. delphicolum.* From *M. angulatum* it may be distinguished by the prominent lip, the more open aperture, and the higher position of the point of greatest gibbosity. The specimen appears to be at or near maturity.

Holotype.—Paleontological Research Institution, No. 5809.

Occurrence.—From the Skaneateles member of the Hamilton, Skaneateles Lake, New York. Collected by Dr. J. W. Wells.

CYRTOSPYROCERAS Flower, n. gen.

Genotype.—*Cyrtospyroceras reimanni* Flower, n. sp.

This genus is erected for the reception of a group of species which resemble *Spyroceras* in ornamentation but are exogastric cyrtoceracones of depressed section. The curvature is gentle, and the latter part of the conch probably becomes straight. The section is strongly depressed, with the dorsum and venter equally convex. The sutures are straight and transverse. The siphuncle is close to the ventral wall of the conch. The segments are slender, cylindrical within the cameræ, but abruptly constricted at the septal foramen. The ornamentation consists of transverse rounded annuli sharply set off from flat interspaces. Fine regular longitudinal liræ are present, with finer transverse liræ which they cross. There is no trace of a hyponomic sinus.

Discussion.—Crushed fragments of members of this genus cannot be distinguished from *Spyroceras* with which it is associated stratigraphically. The genus differs from *Spyroceras* in the curvature, the nature of the annuli, and the ventral position of the siphuncle. The segments of the siphuncle differ from those of *Spyroceras* only slightly. It is not possible to say at the present time whether this genus is related to *Spyroceras,* or whether the similarity in ornamentation and siphuncular outline is isomorphism.

At present one species besides the genotype is placed in the genus with certainty, *Cyrtoceras* (*Gomphoceras*) *formosum* Hall. The species is redescribed and refigured below. *C. reimanni* which is known only from the holotype shows no gerontic characters. *C. formosum* is known only from a gerontic living chamber which contracts slightly. *Cyrtoceras morsum* Hall is placed here provisionally for want of a better resting place. The ornamentation is not typical, though the differences are probably not supra-specific. The curvature is more marked, the section apparently subcircular, and the characters of the phragmocone are unknown.

There are several annulated species in the Hamilton which are known only from crushed fragments. Though apparently orthoceraconic, it is not possibly to say whether they are true orthoceracones with subcentral siphuncles, in which case they should be placed in *Spyroceras,* or whether they are cyrtoconic forms with ventral siphuncles which might be placed in *Cyrtospyroceras.* Two of these show the close spacing of the annulations and the fine even longitudinal markings of *Cyrtospyroceras*. These are *Orthoceras rudens* Hall[26] and *Orthoceras lima* Hall[27]

The similarity of the ornamentation and siphuncle with *Spyroceras* as now restricted, suggests that *Cyrtospyroceras* may have been derived from *Spyroceras*. On the basis of the outline of the siphuncle *Spyroceras* is referred to the Pseudorthoceratidæ,[28] and is apparently one of several ornamented derivatives of *Dolorthoceras* which appear in the Middle Devonian.

Fig. 2.— Camera lucida drawing of the siphuncle of *Cyrtospyroceras reimanni*, transverse section ; x 4

Cyrtospyroceras reimanni Flower, n. sp.

Plate 3, figures 5-7; Text fig. 2

The holotype is 105 mm. in length, the apical two-thirds cyrtoconic, the adoral third straight and somewhat flattened dorso-ventrally by pressure. The section is strongly depressed, with the dorsum and venter equally rounded. In 40 mm., the conch expands from 8 mm. and 5.5 mm. to 18 mm. and 15 mm., in the apical portion. In the next 40 mm. the conch expands to 26 mm. transversely, but, due to crushing, the dorso-ventral diameter is 15 mm.

The sutures are straight and transverse to the axis of the conch. The depth of the septa has not been observed. There are six cameræ in a length equal to an adoral dorso-ventral diameter of 18 mm., and between seven and seven and a half in the corresponding transverse diameter of 23 mm.

The siphuncle is located close to the venter, and is exposed by weathering in the holotype. The outline of the segment is cylindrical within the camera, but there is an abrupt contraction at the septal neck. The relative length of brim and neck is about 1:1. There is no area of adnation. The segments slender; where it is 3.5 mm. in length, it expands from 1.3 mm. at the septal foramen to 2 mm. within the camera.

The ornamentation consists of low, rounded, well defined, transverse annulations separated by flat interspaces which are about twice as broad as the annuli.

26 Hall, J.: *ibid.*, vol. 5, pt. 2, suppl., 1888, p. 28, pl. 118, fig. 1.

27 Hall, J.: *ibid.*, vol. 5, pt. 2, 1879, p. 303, pl. 93, fig. 24-25.

28 The structure of *Spyroceras*, together with its redefinition and a discussion of its affinities will appear in a study of the family Pseudorthoceratidæ which is now (May, 1938) near completion. The previous conception of *Spyroceras* as a derivative of *Kionoceras*, as based on the ontogeny of the ornamentation, is opposed by the evidence offered by the structure of the siphuncle.

The annuli are spaced eight in 10 mm. in the apical part at diameters of 11 mm. and 14 mm., but between five and six in 10 mm. in the adoral part. The annuli are straight, showing no trace of a hyponomic sinus. The annuli are crossed by fine regular longitudinal liræ, spaced thirteen to fifteen, in 5 mm. Well preserved portions of the conch show fine transverse liræ, about equally spaced, which are crossed by the longitudinal liræ.

The length of the living chamber has not been observed. The adoral 30 mm. of the holotype shows no trace of septa or siphuncle, but it is not certain whether this represents part of the living chamber, or whether the condition is due to poor preservation.

Discussion.—Hall described as *Orthoceras rudens* an annulated conch from the Hamilton which might be congeneric, though it is known only from crushed specimens. It agrees with the species described here in the narrow annulations and broad flat interspaces but differs in the character of the fine ornamentation. The ornamentation differs from Hall's other annulated orthoceracones of the Hamilton.

Holotype.—Buffalo Museum of Science, No. E 9048.

Occurrence.—The locality is unknown. The specimen bears the following label: "Found in the collection of western New York material, but without data. Presumably Tichenor." The matrix appears somewhat too shaly for the typical Tichenor, but there can be no doubt but that the specimen came from the Hamilton of western New York.

Cyrtospyroceras formosum (Hall)

Plate 1, figure 17

Cyrtoceras (*Gomphoceras* ?) *formosum* Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 362, pl. 95, fig. 8-9.

This species is still known only from the holotype, which consists of an almost completely flattened living chamber compressed in the sediments. In its present condition the specimen has a basal dorso-ventral diameter of 51 mm., which expands to 57 mm. and contracts to 52 mm. at the aperture, in the ventral length of 68 mm. and a dorsal length of 65 mm. The gibbosity is very slight. The basal septum and suture are not well preserved, but it appears that the suture was straight and transverse.

The ornamentation consists of raised, rounded, transverse annulations which do not bend apically at any point to form a sinus. They are separated by relatively wide interspaces three and a half in 10 mm., and become slightly more closely spaced at the region of the aperture. There are rounded raised distant longitudinal liræ, occurring eight or nine in a width of 10 mm. Between these, but not crossing them, can be made out a background of transverse liræ, which vary from four to eight in an interspace between annuli. Hall's enlargement of the surface does not show the ornamentation correctly but exaggerates the transverse markings and minimizes the longitudinal liræ and the annuli.

Discussion.—The low, frequent annuli and the curved form of the conch are used in referring the species to *Cyrtospyroceras*. In the absence of the section and the information concerning the siphuncle, this is a bit rash, but the species must either be placed here or in a new genus. It differs from *Cyrtospyroceras* in its faintly gibbous living chamber, but the living chamber of *C. reimanni* is unknown. *C. reimanni* apparently becomes straight adorally, while *C. formosum* remains curved throughout.

Holotype.—New York State Museum, No. 12105/1.

Occurrence.—From the Hamilton Shales, Dresden, Yates County, New York.

Cyrtospyroceras ? morsum (Hall)

Plate 4, figures 12-13

Cyrtoceras morsum Hall, 1861, Descriptions of new species of fossils from the Upper Helderberg, Hamilton and Chemung groups, p. 43[29]; Hall, 1862, 15th Ann. Rept. of the Regents of the University of the State of New York on the condition of the State Cabinet of Natural History, App. D, p. 71, pl. 9, fig. 6; Hall, 1867, Illustrations of Devonian Fossils, Cephalopoda, pl. 46, fig. 3-4; Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 367, pl. 47, fig. 3-4.

The holotype is a cyrtoceracone describing a curve of about 80 degrees, with a ventral length of 50 mm. The section is probably circular throughout, though one side is reduced by weathering near the aperture giving it a compressed appearance. The conch enlarges in 50 mm. from 8 mm. and 8 mm. to 18 mm. and 19 mm. No trace of the phragmocone can be seen. The surface bears low narrow transverse annulations which are faintly frilled and are spaced 2 mm. to 4 mm. apart. Between these there are seven or eight transverse liræ in an interspace. There is absolutely no trace of a hyponomic sinus, although a number of transverse annuli are clearly marked on the venter. Hall's illustrations are incorrect in this respect, and also in exaggerating the clarity and prominence of the annuli.

Discussion.—The curvature and the absence of a hyponomic sinus indicate that this species may belong in *Cyrtospyroceras*. *C. morsum* differs from the genotype in the absence of any sign of depression in the section, and in the fine ornamentation. Although it may eventually prove that *C. morsum* should be regarded as generically distinct from *C. reimanni*, it is inadequate as a genotype because the characters of the phragmocone are unknown. The absence of a hyponomic sinus indicates that it is not related to the Rhyticeratidæ, with which it is associated.

Holotype.—New York State Museum, No. 12109/1.

Occurrence.—From the Onondaga Limestone, Schoharie, New York. Gebhard collection.

Genus **ENDOPLANOCERAS** Flower, n. gen.

Genotype.—*Endoplanoceras gomphus* Flower, n. sp.

This genus is erected for a single inadequately known species which differs from all other known forms in its markedly depressed section, the dorsal position of the siphuncle, and the rapid transverse expansion. The supposed venter is convex. The dorsum is concave over the phragmocone and the lower portion of the living chamber; its adoral part is unknown. The sides expand rapidly to well beyond the base of the living chamber, probably to its middle, where they become slightly convex. The adapertural part of the living chamber is unknown.

[29] This constitutes an advance copy of the text of the following citation, with different pagination and without plates.

The sutures are straight and are transverse to the curving axis of the conch adapically, but appear to rise slightly on the venter in the gerontic portion. The siphuncle is located about half way between the center of the conch and the concave side. Its structure is not known.

The aperture is unknown. The surface bears rounded distant longitudinal liræ.

Discussion.—The ornament suggests *Nephriticerina* Foerste which has a dorsal siphuncle, but is more curved, less rapidly expanding and shows no trace of an apertural contraction. Among the depressed endogastric brevicones there is no previously described genus which resembles this one in section, outline or ornamentation.

Endoplanoceras gomphus Flower, n. sp.

Plate 3, figures 16-17

The ventral outline is uniformly convex over the known portion of the phragmocone and the known portion of the living chamber which probably constitutes only its basal half. The dorsal outline is slightly concave over the base of the living chamber and the phragmocone, becomes straighter adorally. The dorsal portion appears to terminate at about the middle of the living chamber. The lateral outline expands rapidly to the middle of the living chamber, the sides being approximately straight, but becoming faintly convex at their adoral termination.

The conch expands from 34 mm. and 60 mm. at the base to a transverse diameter of 104 mm. in 104 mm. In 25 mm. at the base of the living chamber, the diameters have increased to 55 mm. and 87 mm. The basal septum is 12 mm. deep, and is curved more dorso-ventrally than transversely. The siphuncle is located between the venter and the concave side. It is 10 mm. from the dorsum 3 mm. in the diameter and 24 mm. from the venter. Its structure is unknown. The sutures are straight. The cameræ are much deeper on the venter than on the dorsum. The second camera is deeper than the first, the last two shallower. The dorsal and ventral measurements of the cameræ are as follows: (1) 10 mm. and 7 mm.; (2) 11 mm. and 7 mm.; (3) 10 mm. and 6 mm.; (4) 9 mm. and 6 mm.

The internal mold preserves traces of elevated, distant, longitudinal liræ of which there are about four in 6 mm.

Discussion.—The relatively great dorso-ventral curvature of the septum suggests flattening by pressure, but the absence of fracture or other traces of distortion leads to the belief that the condition may be normal. The species is unlike anything previously known from the Devonian, at least in America. The general form suggests *Turnoceras* somewhat, but the siphunle is endogastric. Previously two endogastric forms of depressed section have been described: *Clinoceras* Mascke of the Ordovician and *Coleocyrtoceras* of the Devonian. Neither have as yet been recognized in America. Later *Alpenoceras* Foerste and *Verticoceras* Flower have been described from the American Devonian but neither are as strongly depressed, nor as rapidly expanding as *Endoplanoceras,* nor do any of them possess longitudinal ornamentation.

The singular form of the species should be adequate for its specific and generic identification even in the absence of definite information concerning the aperture or the siphuncle.

Holotype.—New York State Museum, No. 12138/1.

Occurrence.—One mile east of Babcock Hill, Bridgewater, New York, in the Onondaga Limestone. Collected by C. A. White, 1860.

Genus **ELEUSOCERAS** Flower, n. gen.

Genotype.—*Eleusoceras nicholsi* Flower, n. sp.

Conch erect, probably of exogastric affinities, breviconic, the point of greatest gibbosity occurring well below the base of the mature living chamber. The section is circular adapically but becomes slightly depressed, with the dorsum and venter equally rounded. The sutures are straight and transverse. The septa are shallow, the siphuncle is close to the venter. Its segments are nummuloidal, apparently not scalariform in dorso-ventral section, or only slightly so. The brims and the adoral ends of the connecting rings are recumbent; the apical ends are free, with no areas of adnation. The interior of the siphuncle bears actinosiphonate deposits which are confined to the region of the septal foramen and are not continuous from segment to segment.

The aperture of the genotype is not known, but the lines of growth indicate that there is no hyponomic sinus.

Discussion.—This genus is erected for the reception of a species which it is impossible to place in any described genus, the closest being *Poteriocerina* Foerste, which differs in the outline and structure of the siphuncle, the nature of the actinosiphonate deposits and the curved condition of the conch. There are other erect brevicones which lack a hyponomic sinus in the Devonian of America. It would appear that those with slender siphuncular segments and a fenestrate inner shell layer should be placed in *Micronoceras*, while those with broad segments and without a fenestrate inner layer may be placed in this genus. Unfortunately the aperture is not preserved on the genotype. The lines of growth are transverse and straight and indicate that no hyponomic sinus is present.

Eleusoceras nicholsi Flower, n. sp.

Plate 3, figures 1-2

The holotype is an erect brevicone, circular in section apically but slightly depressed adorally. The conch expands from 20 mm. and 20 mm. to 31 mm. and 31 mm. in the first 20 mm. In 20 mm. the maximum transverse diameter of 43 mm. is attained. The corresponding dorso-ventral diameter is unknown, for the ventral side of the specimen was destroyed adorally before burial. The base of the living chamber is 5 mm. beyond the point of greatest gibbosity; here the transverse diameter is 40 mm. The living chamber contracts adorally. The preserved portion is 25 mm. in length. Enough is not preserved to determine either diameter with certainty, though the transverse diameter is estimated at 36 mm.

The sutures are straight and transverse. The cameræ increase in depth from 3 mm. at the apical end of the specimen to 4.5 mm. just below the point of greatest gibbosity, with eleven cameræ in 34 mm. The succeeding five cameræ contract gradually from 4 mm. to 3 mm.

The siphuncle is circular in section at the septal foramen and is separated from the ventral wall by about its own diameter. In transverse longitudinal section the segments are subspherical in outline. A segment 3 mm. in length expands from 2 mm. to 3.5 mm. The necks are sharply recurved and short, so that both the brim and a part of the connecting ring lie in contact with the transverse part of the septum. The adapical end of the connecting ring is free.

The interior of the siphuncle contains actinosiphonate deposits which are concentrated at the septal foramen and which are not continuous throughout the segment.

The aperture is not preserved. The ornamentation consists of fine transverse lines of growth, which show no indication of lobation.

Discussion.—The species may be distinguished from *Brevicoceras* species with which it is associated by the straight sutures, the lack of any evidence of a hyponomic sinus, and the section which is as well rounded dorsally as ventrally. From *Micronoceras* it differs in its form and also in the expanded condition of the segments of the siphuncle. The siphuncular segments and the section agree with *Cyrtogomphus*, but actinosiphonate structure is not yet known in either of the two species of the genus for which the siphuncle has been studied in section; and a further difference is to be found in the erect condition of the conch and the nearly straight outline of the living chamber on the dorsum beyond the point of greatest gibbosity.

The specimen is of interest for the condition of the gerontic features. The contraction of the cameræ is slight and shows in itself no markedly gerontic characters. However, a slight basal zone is developed. Calcite indicates a general thickening of the wall of the living chamber which is more marked adorally than adapically. Actinosiphonate deposits are present, but have probably not yet attained their full development in the individual before death.

Holotype.—Paleontological Research Institution, No. 5812.

Occurrence.—In the limestone band occurring at the top of the Pompey member of the Skaneateles Shale of the Hamilton, from Pratt's Falls, Onondaga County, New York.

Genus **POTERIOCERINA** Foerste, 1926

Genotype.—*Cyrtoceras lumbosum* Barrande.

Poteriocerina Foerste, 1926, Denison Univ. Bull., Sci. Lab. Jour., vol. 21, p. 343, pl. 45, fig. 1A-C, 2; Flower, 1936, Bull. Am. Paleont., vol. 22, p. 340.

The genotype is an exogastric depressed brevicone with a straight aperture. The siphuncle is close to the venter, and is composed of slightly expanded segments which contain actinosiphonate deposits. The deposits fill the segments, and are not confined to the region of the septal foramen. One species from the Devonian of America was referred to the genus, *Gomphoceras solidum* Hall. It differs from typical *Poteriocerina* in its more erect form, the ornament, and the less gibbous outline. The region of greatest gibbosity occurs near the base of the living chamber as in the genotype. The outline and internal structure of the segments of the siphuncle are unknown. Though this species may eventually prove to be generically distinct, there is not enough evidence at the present time to warrant setting it apart from *Poteriocerina*. It is not strikingly similar to *Eleusoceras* in outline, section, or ornamentation. *Gomphoceras manitobense* Whiteaves[30] is evidently closely related to the Cherry Valley species, which it resembles closely in outline and general appearance. *Casteroceras tyrelli* from the same formation also has its counterpart in the Cherry Valley Limestone, in *Casteroceras alternatum* (Hall).

III. COMPRESSED, EXOGASTRIC TO ERECT GENERA

Genus **WISSENBACHIA** Foerste, 1926

Genotype.—*Phragmoceras orthogaster* Sandberger.

Wissenbachia Foerste, Denison Univ. Bull., Sci. Lab., Jour., vol. 21, 1926, p. 319.

The conch is breviconic, with a marked exogastric curvature. The venter is uniformly convex throughout, the dorsum is faintly concave, nearly straight. The conch is moderately compressed, with the venter slightly more narrowly rounded than the dorsum. The sutures are straight and transverse. The siphuncle is ventral, consisting of nummuloidal segments which contain actinosiphonate deposits. The genotype bears faint longitudinal and transverse markings on the shell. The aperture is not mentioned in Foerste's description of the genus, and its form is apparently doubtful in the genotype. In *W. gebhardi* there appears to be a broad shallow hyponomic sinus. Rounded ventro-lateral crests attain their greatest height dorsad of the middle. The dorsal part of the aperture is obscure and may be transverse or may bear a slight sinus.

Discussion.—This genus can be readily recognized by the exogastric curvature, the compressed form and the low position of the greatest gibbosity which occurs just below the base of the living chamber. The genotype is from the Nassau Middle Devonian of Germany. When describing the genus Foerste remarked the similarity of *Cyrtoceras sanum* Barrande[31], which differs from the genotype in the higher position of the point of gibbosity and the sutures which slope apicad slightly on the venter.

The only representative of the genus thus far recognized in America is from the Schoharie Grit of the Middle Devonian. Its siphuncle is unknown, but in form it agrees in every essential feature with the genotype.

Wissenbachia gebhardi Flower, n. sp.

Plate 1, figure 4; Plate 4, figure 2

The holotype consists of a living chamber and eleven cameræ, probably including the greater part of the phragmocone, and is 66 mm. in length. The venter is uniformly convex. The dorsum is faintly concave in the extreme apical portion, straight over the greater part of the phragmocone and the lower part of the living chamber, becoming faintly convex and then concave in the adoral half of the living chamber. The lateral outline is distorted, but apparently was originally convex adapically, attaining the greatest gibbosity just apicad of the base of the living chamber, and becoming faintly concave just before the aperture. The conch is compressed, and further compression has been produced by pressure. In a ventral length of 40 mm. including the eight cameræ which precede the living

[30] Whiteaves, J. F.: *Descriptions of some new or previously unknown species of fossils from the Devonian rocks of Manitoba*, Royal Soc. Canada, Transactions, vol. 8, ser. 4, 1890, p. 102, pl. 7, figs. 7, 7a.

[31] Barrande, J.: Système Silurien du centre de la Bohême, vol. 2, 1867, p. 564, pl. 145.

chamber, the dorso-ventral diameter increases from 15 mm. to 29 mm. The present transverse diameter at the base of the living chamber is 20 mm. The septum is broken longitudinally, the broken ends turned apicad by crushing. The width of the septum is 24 mm.; the width of the conch at this point could not have been less than 22 mm.

The sutures are straight and are transverse to the axis of the conch. The cameræ increase in depth from 4 mm. to 6 mm., with the last two slightly contracted. There is no trace of the siphuncle.

The living chamber is 24 mm. in length and contracts from 20 mm. and 29 mm. to 14 mm. and 22 mm. The aperture is slightly produced, but its outline is not well preserved. There are a broad shallow ventral sinus, lateral crests, and the dorsum appears to be transverse.

There is no indication of ornamentation on the holotype, which is an internal mold.

Discussion.—This species agrees strikingly with *Wissenbachia orthogaster* (Sandberger) in outline and proportions. Its most salient characteristic is the faint concavity of the outline in the region just preceding the aperture. The compressed condition of the conch and its curvature will serve to distinguish this species from its associates. It is at present the only representative of the genus thus far noted in America. The genotype of *Wissenbachia* is *W. orthogaster* (Sandberger)[32] from the Middle Devonian of Wissenbach, Germany.

Holotype.—New York State Museum, No. 12650/1.

Occurrence.—In the Schoharie Grit, from Schoharie, New York. The holotype is from the Gebhard collection.

Genus **PACHTOCERAS** Foerste, 1926

Genotype.—*Gomphoceras rotundum* Pacht[33].

Pachtoceras, Foerste, Denison Univ. Bull., Sci. Lab., Jour., vol. 21, 1926, p. 328.

This genus is based upon a species from the Upper Devonian of the upper Don area of Russia. The genotype is inadequate in that the aperture is not known; but even in the absence of that important character it is possible to recognize the genus. It contains compressed erect brevicones, probably of exogastric affinities. The section is only slightly longer than wide, and the dorsum is more broadly rounded than the venter. The siphuncle is ventrad of the center but well removed from the margin of the shell. The living chamber of the genotype is short, and the original figure shows nothing to indicate the condition of the aperture.

The genus has not hitherto been noted in America, but a species from the Conewango is described below which appears to be a fairly typical representative of the genus, and which further serves to supply data on the aperture. The genus is known only from the Upper Devonian. The section and the position of the siphuncle serve largely as identifying characters.

I have been unable to determine with any degree of certainty the horizon of the

[32] Sandberger, G. and F.: *Versteinerungen des Rheinischen Schichtensystems in Nassau*, 1856, p. 150, pl. 14, fig. 4, 4A, 4B.

[33] Pacht, Helmersen and Pacht: *Beiträge zur Kenntniss des Russischen Reiches*, vol 21, 1858, p. 84, pl. 2, fig. 2, 2A.

genotype. The specimen is from Gräsi, on the Matyra river, from the upper Don area of Russia. Kayser[34] lists the highest Devonian of the Ural region as Oberdevonstufe II, but in central Russia the beds with *Hypothyris cuboides* and *Spirifer verneuili* are overlain by a limestone bearing *"Arca" oreliana*. While the *cuboides* beds suggest the Senecan of New York and the "Arca" beds may possibly represent Chemung, it is all very uncertain. The American species occurs in the Lewis Run Sandstone of the Upper Devonian. *Sporadoceras milleri* (Flower and Caster)[35] is either Panama, basal Conewango, in age or possibly slightly older. The species suggests by its affinities a tentative correlation of the beds from which it came with the Oberdevonstufe III of Europe[36].

It is quite probable that *Pachtoceras* may have a considerable vertical range in the Upper Devonian, and that the genus reached America much later than it appeared in Europe, a possibility which is at least not inconsistent with what little is known of the distribution of other breviconic genera in the Devonian.

Pachtoceras obliquum Flower, n. sp.

Plate 2, figures 23-25

The species is known from a single specimen which consists of a living chamber and two cameræ. The section is very slightly compressed. The sutures are straight but markedly oblique, sloping orad on the supposed venter where the section is slightly less broadly rounded than on the dorsum.

At the base of the specimen the diameters are 39 mm. and 44 mm. The two cameræ measure 5 mm. and 3.5 mm. in depth respectively, the last being somewhat contracted. The basal septum is not preserved. The next one shows a large area in the center where the course of the shell is not preserved, an area which is roughly circular and about 25 mm. in diameter. Outside, the septum is very shallow and shows no trace of the siphuncle.

The living chamber is 15 mm. in length on the supposed dorsum and 13 mm. in length on the venter. The aperture is contracted only slightly, the conch contracting gradually from just below the base of the living chamber, and is 27 mm. and 28 mm. in diameters. The outline of the aperture is rather indistinctly preserved but appears to be complete except on the mid-ventral and one ventrolateral region. Elsewhere it is apparently circular. There is no evidence of a hyponomic sinus which, if present, must be very narrow.

The living chamber shows traces of obscure transverse markings on its surface. Faint distant longitudinal markings can be seen on the septate portion.

Discussion.—*Pachtoceras* is founded upon a rather inadequately known species. The original figure shows a short living chamber with an apparently broken aperture, and does not seem to be sufficient to warrant any conclusion concerning the form of the aperture. Our specimen agrees in the short living chamber, the compressed section, the location of the siphuncle relatively far from the wall of the conch, and the more broadly rounded condition of the dorsum than the venter

[34] Kayser, E.: Lehrbuch der Geologie, Bd. III, 1923, p. 227, Stuttgart.
[35] Flower, R. H. and Caster, K. E.: *ibid.*, p. 252, pl. 22, fig. 1-2
[36] Miller, A. K. and Flower, R. H.: *A Sporadoceras from America*, Journal of Geology, vol. 44, 1936, pp. 751-757.

though it is by no means really certain that the conch has been oriented correctly in either species. It differs from *P. rotundum* (Pacht) mainly in its larger size and the oblique sutures. The very shallow living chamber is one of the most distinctive features of *P. obliquum*. The aperture is indistinct, as in all forms preserved in the Lewis Run, and is broken in places, but by reconstructing one side on the basis of the other it is possible to show that the aperture is unlobed, except possibly on the mid-ventral region. However, only the extreme mid-ventral portion is missing, and there is no evidence of any modification of outline in the most ventral portion of the aperture preserved.

Holotype.—Buffalo Museum of Science.

Occurrence.—In the Lewis Run Sandstone, Lewis Run, Pennsylvania.

IV. DEPRESSED ENDOGASTRIC BREVICONES

Genus **VERTICOCERAS** Flower, 1936

Genotype.—*Verticoceras erectum* Flower.
Verticoceras Flower, 1936, Bull. Amer. Paleont., vol. 22, p. 342.

This genus includes nearly erect endogastric brevicones of a slightly depressed section. The sutures are transverse and straight; the siphuncle is close to the ventral wall but not in contact with it. The region of greatest gibbosity is located at the lower portion of the living chamber. The aperture is only slightly contracted, rounded except for a hyponomic sinus.

Verticoceras tullium Flower, n. sp.

Plate 4, figures 14-15

Conch breviconic, probably endogastric, nearly erect, slightly depressed in section. The specimen is 34 mm. in length. The supposed dorsum is faintly convex throughout. The other side is faintly convex above, straight over the middle portion, and very faintly concave below. At the base of the specimen the diameters are 8 mm. and 9.4 mm. In 19 mm. at the point of greatest gibbosity, these have increased to 14 mm. and 15 mm. Contraction is gradual to the aperture which is only partially preserved. The transverse diameter appears to be about 40 mm. The aperture is 8 mm. beyond the point of greatest gibbosity.

It appears that the lower 15 mm. of the specimen represent the phragmocone. The sutures are not preserved, except for a faint impression which is taken to represent the base of the living chamber. Here the suture is transverse and straight. The position and structure of the siphuncle are unknown.

The living chamber is 18 mm. in length along the convex side and has diameters at the base of 13 mm. and 14 mm. The aperture is preserved only on the convex or dorsal side. It is straight and transverse. The surface markings indicate that there is no modification of the aperture laterally. They are unfortunately not preserved on the venter, but a sinus is to be expected there.

The surface is marked with transverse, low, rounded liræ with equal striæ between. There are six to eight liræ in the space of 2 mm.

Discussion.—This species is referred to *Verticoceras* on the basis of the general resemblance of *V. conradi*, from which is differs in possessing a coarser ornamentation and a very slightly greater size. The species are doubtless closely related.

Holotype.—Paleontological Research Institution, No. 5814.

Occurrence.—In the Tully Limestone from the most easterly of the three quarries at Borodino, New York. Collected by Dr. J. W. Wells.

V. COMPRESSED ENDOGASTRIC BREVICONES OF PHRAGMOCERATOID ASPECT

Devonian Phragmoceratoids.—In the Middle Devonian of Bohemia there are compressed endogastric brevicones of phragmoceratoid aspect which show no good distinction in external features from Silurian species. Foerste[37] referred the species described by Barrande to three genera, *Phragmoceras* Broderip, *Bolloceras* Foerste and *Paraconradoceras* Foerste. The outline of the siphuncle is known for only a few of the Devonian phragmoceratoids, but where known the segments are cylindrical to concavosiphonate and are filled by actinosiphonate deposits. True actinosiphonate deposits are lacking in Silurian species referrible to *Phragmoceras,* though present in many genera of the Trimeroceratidæ[38]. In all of the Silurian genera the segments of the siphuncle are cyrtochoanitic. Hedström[39] has presented excellent illustrations of the phragmoceratoids of the Silurian of Gotland. In general the segments are strongly cyrtochoanitic, and actinosiphonate deposits are entirely lacking. A few of the figures suggest incipient segmental deposits developed at the region of the septal foramen which, if actinosiphonate (which is doubtful but not impossible) are very different from the actinosiphonate deposits found in Devonian species, for in the Devonian forms the deposits are concentrated in the middle of the segment, and though adjacent deposits may join, there is a definite break at the region of the septal foramen. This suggests that the Devonian and Silurian species may in reality be entirely unrelated, and that the resemblance may be due to homeomorphy. The two groups of externally similar species are separated by a stratigraphic gap which comprises the greater part of the Upper Silurian and the entire Lower Devonian. The existence of such a stratigraphic interval in which no species of phragmoceratoid aspect occur is suggested but not conclusive, for our knowledge of the cephalopods of this period is admittedly very meagre.

Foerste separated *Bolloceras* from Devonian species which he retained in *Phragmoceras* by the characters of the aperture. The aperture of *Bolloceras* is transversely extended, producing somewhat the effect of a *Trimeroceras,* save that the dorsal margin is curved with the convexity directed dorsad instead of ventrad. The following of Barrande's species appear to have typical *Phragmoceras*-like apertures:—

Phragmoceras dux

[37] Foerste, A. F.: *ibid.*, pp. 350-352, 362.

[38] In the Zittel-Eastman textbook of Paleontology, vol. 1, a section through the phragmocone of *Phragmoceras loveni* Barrande shows actinosiphonate structure in a cyrtochoanitic siphuncle. The species is from the Silurian, étage E. The contradiction furnished by this species is more apparent than real. The species is a *Tetrameroceras,* belonging to the Trimeroceratidæ and not to the Phragmoceratidæ.

[39] Hedström, H.: *Ueber die Gattung Phragmoceras in der Obersilurformation Gotlands,* Sveriges Geologiska Undersökning, Uppsatser och avhandlingar, i, 4:0, ser. C a, N:o 15, 1917.

P. raptor
P. princeps
P. baro
P. comes
P. angustum
P. broderipi

The species which appear to be typical *Bolloceras* in the outline of the aperture are the following:—all have actinosiphonate deposits within the siphuncle, but the outline of the segments of the siphuncle has not been figured for any of the species.

Phragmoceras hospes
P. clypeatum
P. gutterosum
P. rex
P. pigrum
P. murale

The last species is unique in having a pair of longiturinal grooves on the dorsal side of the living chamber which considerably modify the section, but is typical of the group in all other respects.

There remain a few species which cannot be placed with certainty in either genus owing to the incomplete condition of the aperture. These include:

Phragmoceras suessi
P. forbesi

Foerste considered *P. forbesi* a *Bolloceras.*

The distinction between Devonian *Phragmoceras* and *Bolloceras* is beset with practical difficulties. The two types of aperture intergrade. It is difficult to say in which genus *P. inflexum*[40] should be placed.

Specimens which Barrande referred to *P. hospes*[41] and *P. clypeatum*[42], both typical *Bolloceras,* retain the outline of a *Phragmoceras.*

In all phragmoceratoid conchs the ephebic aperture is developed late, and the pre-ephebic aperture, as indicated by the lines of growth, is usually rather different. The lines of growth in *Bolloceras* show that a slightly pre-ephebic aperture would be indistinguishable from a *Phragmoceras.* Different stages of growth may account for the intergradation; certainly the similarity of proportions indicates that the specimens with the *Phragmoceras*-like apertures are probably not specifically distinct from those showing the typical *Bolloceras* type of aperture. From this it would appear that a good distinction between Devonian *Phragmoceras* and *Bolloceras* is not possible, and the simplest solution would be to place all Devonian species in *Bolloceras.* This is justified by the concavosiphonate condition of the siphuncle of the Devonian species.

Paraconradoceras Foerste seems to be known only from the genotype, which

40 Barrande, J.: *ibid.*, pl. 540.
41 Barrande, J.: *ibid.*, pl. 543, fig. 4-7.
42 Barrande, J.: *ibid.*, pl. 538, fig. 1-4.

differs from the Silurian *Conradoceras* in the concavosiphonate condition of the siphuncle and the presence of actinosiphonate deposits, just as *Bolloceras,* as here redefined, differs from *Phragmoceras.*

A group of aberrant species remains which differ from the species referred to *Bolloceras* in the remarkable dorsal development of the living chamber and aperture. *P. bohemicum* has the dorsal part of the living chamber greatly expanded, and the aperture is open on the dorsal as well as on the adoral surface. *P. verneuili* has the dorsum somewhat similarly expanded, but there is a slight collar developed as in the Silurian *Tubiferoceras* from which it differs in the more complex lobation of the dorsal part of the aperture, which, as in the preceding species, is open dorsally as well as adorally. Two new species from the Onondaga of New York, described below, fall into this group, differing mainly in their more erect condition and the lower appearance of the dorsal expansion on the living chamber. A new genus, *Metaphragmoceras* is erected for the reception of these singular forms. The siphuncles are actinosiphonate so far as known. The outline of the segments is unfortunately not known for any of the species.

Genus **BOLLOCERAS** Foerste, 1926

Genotype.—*Phragmoceras rex* Barrande.

Bolloceras Foerste, 1926, Denison Univ. Bull., Sci. Lab., Jour., vol. 21, p. 351.

As originally conceived, this genus differs from *Phragmoceras* in the transverse development of the dorsal lobe of the aperture. However, it is apparent that it intergrades with Devonian species referred to *Phragmoceras*. A better criterion for the genus is to be found in the cylindrical to concavosiphonate outline of the siphuncular segments which characterize the Devonian phragmoceratoid species for which the siphuncular outline is known. The Bohemian species have been listed in the preceding pages. The only known American representative of the genus is from the Ithaca Shales of the Upper Devonian.

Bolloceras hartti Flower, n. sp.

Plate 3, figure 13

This species is known from a single flattened individual which retains a large portion of the phragmocone and about two-thirds of the living chamber. It has a maximum length of 103 mm. and a width of 94 mm. The specimen is compressed by pressure, but must have been originally considerably compressed. The conch is cyrtoconic, rapidly expanding, with the dorsum convex and the venter concave. The phragmocone expands from 18 mm. to 65 mm. dorso-ventrally. In the present condition of the specimen the transverse diameter at the apex is only 8 mm. Only one surface is preserved in the adoral portion.

The sutures are straight apically and are inclined slightly adorally on the dorsum. In the adoral part the sutures are essentially transverse, but bear broad shallow lateral lobes. Sixteen cameræ are preserved, which increase in depth from 4 mm. to 10 mm. The last camera is slightly contracted, measuring 9 mm. in depth.

The surface ornamentation is retained on part of the internal mold, where it appears as fine liræ separated by broad flat interspaces. The liræ are arched into broad rounded ventro-lateral crests which descend rapidly on the venter and more gradually on the dorsum.

The aperture is not preserved. The siphuncle is represented on the apex of the specimen by a slight irregularity on the septal surface close to the venter. Its structure is unknown.

Discussion.—The absence of the aperture leaves some reason to doubt whether the dorsal lobe is transversely elongated, but as has been shown, the character appears to be variable in the Bohemian species.

The type was collected from the Ithaca Shales by Professor Hartt of Cornell University, probably some sixty years ago. Although constant collecting has been going on in the region, at least until very recently, the only specimens which resemble *P. hartti* remotely are two fragments, each representing a part of a phragmocone, one of which is in the collection of Dr. J. W. Wells, while the other is in the collection of the author. Both are too fragmentary for positive identification and are evidently distorted by flattening. The species is evidently a rare one and the possibility of obtaining better material is exceedingly remote. The lines of growth are sufficient together with the curvature and the rapid expansion to show that the species is a phragmoceratoid, and evidently a *Bolloceras*. The genus has not been previously recognized in America, and elsewhere it has not been found above the Middle Devonian insofar as I am aware.

Type.—Cornell University collection, No. 5362.

Occurrence.—From the Ithaca Shales of the old Cornell University quarries, collected by Professor Hartt, for whom the species is named. These quarries have been partially filled in, forming the present slope behind the University Library, and in part are occupied by the University dormitories. Only a small part of the original exposure remains. The section includes the middle part of the Ithaca section, including the Williams Brook horizon, and the underlying Cascadilla Shale. Higher members may have been included but the section obviously did not extend far into the underlying Six Mile Shale, if at all.

Genus **METAPHRAGMOCERAS** Flower, n. gen.

Genotype.—*Phragmoceras verneuili* Barrande, Système Silurien du Centre de la Bohême vol. 2, pl. 67, figs. 1-3.

This genus contains endogastric compressed brevicones which differ from *Phragmoceras* in the remarkable dorsal inflation of the living chamber and the modification of the aperture. The dorsal outline is abruptly expanded dorsad. The ventral part of the aperture is similar to that of *Phragmoceras*. The dorsal lobe is subquadrate and the opening curves abruptly in such a way that it faces the dorsal side as well as the adoral side. The siphuncle of the genotype is actinosiphonate, but the form of the segments is not known.

Discussion.—Four species appear to fall in this genus. The dorsal expansion of the genotype suggests the Silurian *Tubiferoceras* in the development of a collar. *Phragmoceras bohemicum* Barrande[43] has the dorsum less abruptly expanded and

[43] Barrande, J., *ibid.*, pl. 533, fig. 3-4; pl. 534.

lacks the collar, but the aperture is open on the dorsal side and is apparently of similar form. Both of these Bohemian species are actinosiphonate and occur in the Middle Devonian, at Barrande's horizon G3.

The two American species are both from the Onondaga of New York. *M. triangulatum* resembles *M. verneuili* in lateral and dorso-ventral outline, but lacks the collar. *M. dubium* is closer to *M. bohemicum* in the more rounded and oblique condition of the adoral surface but differs in having the dorsum more expanded. The outlines of these species are shown in the accompanying text figures, 3-6.

Metaphragmoceras triangulatum Flower, n. sp.

Plate 4, figure 11; text figures 9-10

The conch is strongly compressed, essentially erect, with the venter straight to the beginning of the aperture. The dorsum is nearly straight over the phragmocone, becoming rapidly concave and flaring over the lower part of the living chamber. The adoral surface, so far as preserved, is transverse. The dorsal part of the aperture is not preserved. The holotype has a length of 130 mm. and a width of 115 mm., and is incomplete dorsally. Expansion is slight in the adapical portion but is so rapid over the basal part of the living chamber that the dorsal surface becomes transverse.

The conch attains a maximum width of 40 mm., one-third the distance from the venter to the dorsum; the sides become slightly concave toward the dorsum, though converging. The width of the broken dorsal part of the aperture is 35 mm. The middle part of the aperture is a narrow slit, widening gradually on the venter to the hyponomic sinus. The broken dorsal surface is 35 mm. in length; the remainder has a length of 95 mm.

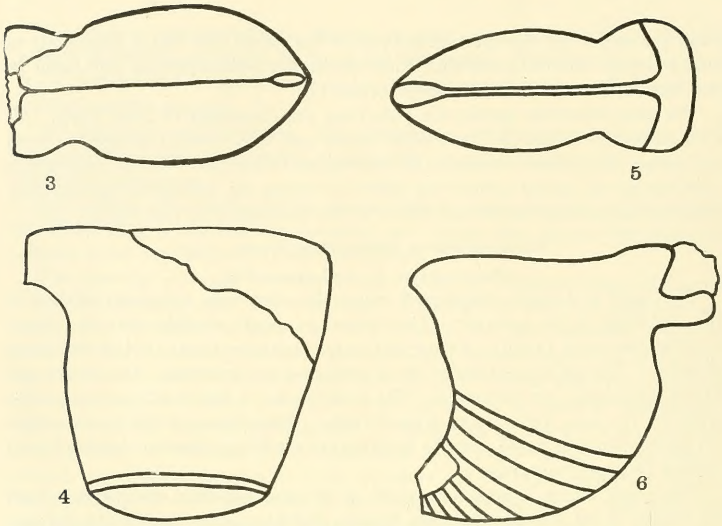
The sutures are slightly oblique, rising orad on the dorsum. The three basal sutures are well indicated, showing that the cameræ increase from 7 mm. to 10 mm. The succeeding cameræ are obscure, but evidently two shallower cameræ follow.

Discussion.—The transverse condition of the adoral surface and the transverse condition of the dorsum over the expanded area recall the genotype. In *P. triangulatum* the expansion appears much lower on the living chamber and lacks the dorsal collar. The aperture so far as known is typical of the genus.

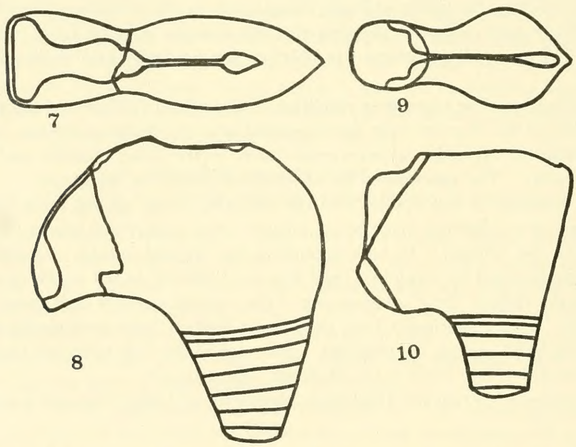
The holotype of this species and the following occur on the same slab, which was part of a collection made by an amateur who apparently believed in improving upon the original. In both specimens the original sutures are strengthened and supplemented by scratches, until it is very difficult to tell which of the markings were original. In *P. dubium* one of the scratches occurs high upon the living chamber. Other specimens from the same collection have been similarly treated. Only the basal septum is preserved. No trace of the siphuncle can be found.

Holotype.—New York State Museum, No. 12315/1.

Occurrence.—From the Onondaga Limestone of Leroy, Genesee County, New York.



Figs. 3-6 European species of *Metaphragmoceras*. Figs. 3-4, adoral and lateral aspects of *M. bohemicum* (Barrande). According to Barrande the two figures are taken from the same specimen. In view of the loss of the dorsum which is restored in fig. 4, it does not seem possible. Figs. 5-6 adoral and lateral aspects of *M. verneuili* (Barrande). All greatly reduced. Based upon Barrande's original illustrations. About ¼ natural size.



Figs. 7-10. Restorations of American species of *Metaphragmoceras*. Figs. 7-8 *M. dubium*, adoral and lateral aspects. Figs. 9-10 *M. triangulatum*, adoral and lateral aspects. Figures reduced to scale.

Metaphragmoceras dubium Flower, n. sp.

Plate 4, figure 21; text figures 7-8

The conch is compressed by pressure and only one side of the holotype is preserved. The section was evidently originally strongly compressed. The ventral margin is faintly convex to a point near the aperture, where the curvature increases. The apertural margin, so far as known, slants orad from the venter toward the dorsum. The dorsal margin is faintly concave over the phragmocone, but becomes rapidly more concave just above the base of the living chamber. The dorsal part of the living chamber is missing, but can be reconstructed as in the accompanying figure by the markings of the external mold. The aperture is obscure. It is evidently linear in the middle portion, expanding on the venter into a rather elongate hyponomic sinus. The dorsal part of the aperture is largely unknown. Its most ventral portion is preserved, and there is an indication of a slight crest dividing the aperture into two portions. The section is compressed, with the greatest width occurring at the junction of the dorsal lobes and the median slit of the aperture. From here the sides are straight, converging slightly to a point opposite the middle of the hyponomic sinus, beyond which the outline becomes convex and contraction is rapid.

The sutures are very poorly preserved, being complicated by scratches which are apparently the work of some collector[44].

The sutures are inclined slightly orad on the dorsum but are not curved laterally. There appear to be eight cameræ in the length of the phragmocone, 90 mm., in which the dorso-ventral diameter of the conch increases from 30 mm. to 90 mm. The living chamber has a length of 110 mm. and a width of 140 mm.

Discussion.—The markings upon the slab upon which the holotype is preserved form the basis for the reconstruction of the dorsal outline of the living chamber as represented in text figure 8. In form the expansion is similar to that of *M. bohemicum* (Barrande). The expansion occurs much lower in both of the American species than it does in the Bohemian forms.

Holotype.—New York State Museum, No. 12314/1.

Occurrence.—From the Onondaga Limestone of Leroy, Genesee County, New York.

SUMMARY OF THE DEVONIAN BREVICONIC SPECIES DESCRIBED BY HALL

The accompanying synopsis of Devonian brevicones is intended to summarize what information can be gleaned from the original descriptions, figures and speciments of Devonian brevicones described by Hall, supplemented whenever possible by additional material. Some of the species have been described in detail in the systematic portion of this paper, and most of these have been re-illustrated. Others

[44] Other cephalopods from the same collection, made by an amateur collector and later acquired by the New York State Museum, have been similarly ''restored'', often with even worse results.

are too little known to permit certain generic determination or to merit a detailed redescription or re-illustration. For each of these species the information available has been summarized, and attention is called to points which need further verification. In many instances the types show no indication of some of the salient characters, and information concerning them can be found only by an examination of further material. In many instances the probable generic position can be suggested; in others it can not. In a few instances the type is so poorly preserved that it is highly improbable whether a complete and well preserved specimen could be recognized as conspecific. Usually it has been possible to ascertain whether all of the specimens figured and described as a single species are conspecific, even when the generic position is uncertain. All of the types now deposited in the New York State Museum have been examined. A few of the types could not be located, and a few others have not been examined owing to the increasing unwillingness of institutions to loan types and the expense involved in the journeys which would be necessary.

No attempt is made here to give bibliographic reference, and no reference is given except where it has been necessary to refer to a specific illustration. The descriptions are to be found in volume 5 of the Paleontology of New York and its supplement in volume 7, and Hall's arrangement of species has been followed here. It is hoped that aside from summarizing the available information this will be of use to students of Devonian faunas in serving as an index to the present status of Hall's species.

I. HELDERBERGIAN

No breviconic cephalopods are known from the Lower Devonian of New York. *Oncoceras ovoides* Hall[45] and *Herkimeroceras subrectum* (Hall)[46] are regarded as of Upper Silurian age, though Foerste[46] regarded the latter as Lower Devonian.

Both species were described from material from Jerusalem Hill, Herkimer County, New York. Most of this material was loose. *Oncoceras ovoides* is known only from two specimens from this locality. One is the type, deposited in the Jewett Collection at Cornell University, the other is a specimen in the New York State Museum. The species is plainly not an *Oncoceras*, but cannot be placed in any genus with certainty until material showing the aperture, section and at least the position of the siphuncle has been studied. *Herkimeroceras subrectum* (Hall) is known from a number of specimens from Litchfield, and also from some material from the Manilus of the Schoharie Valley.

II. SCHOHARIE

Gomphoceras fax Hall

The holotype, the only known specimen, is a badly flattened portion of an erect brevicone in which the greatest diameter occurs at the middle of the living chamber. The aperture is transverse and straight on the side represented in Hall's

[45] Hall, J.: Paleontology of New York, vol. 3, 1859, p. 342, pl. 69, fig. 2a, b. Hall, J., *ibid*, p. 342, pl. 69, fig. 3a-d.
[46] Foerste, A. F.: *ibid.*, p. 327.

original figure, and the condition appears to be the same on the opposite side, although the preservation here is too poor to permit a definite statement. The sutures are slightly undulate, but this may be the result of flattening. The siphuncle is unknown. The available information suggests that the species may belong to *Micronoceras,* a genus thus far known only from the Hamilton.

Gomphoceras illænus Hall

The holotype, the only specimen I have seen which can be referred to the species, is a flattened living chamber. The specimen is depressed by pressure. The aperture is not so well preserved as Hall's figure would lead one to believe. There is a hyponomic sinus. Whether there are lateral sinuses is doubtful, due to the weathered condition. The suture at the base of the living chamber appears to lack lobation. The species probably belongs to the group of depressed exogastric brevicones with a hyponomic sinus and might be referred tentatively to *Acleistoceras.*

Gomphoceras clavatum Hall

The type of this species I have not seen. Hall's figure and description show that it is a nearly erect brevicone with an exogastric, or apparently exogastric living chamber with an endogastric apical portion. The section is depressed, and the living chamber bears a faint and rather doubtful hyponomic sinus. On the basis of these characters the species appears to be most closely related to *Verticoceras* Flower of any of the described genera. It differs from typical *Verticoceras* in its larger size and in the more gibbous living chamber. The holotype is in the American Museum of Natural History, No. 2877/1.

The hypotypes which are figured on plate 93 of the *Paleontology* are not conspecific with the holotype or with each other. The type of pl. 93, fig. 2 is larger than the true *clavatum,* is apparently erect, and the evidence of the section and aperture is inconclusive. Aside from the difference in size, this species is strongly constricted before the aperture, and the gibbosity of the living chamber is less marked and is not confined largely to one side. The sutures show no lobation. It is not possible to refer this species to any genus, and the condition of the type does not appear to justify the proposal of a new specific name. The type is in the New York State Museum, No. 12184/2.

The type of pl. 93, fig. 3 is No. 12184/1 in the New York State Museum. It is even larger than the other two species and does not contract toward the aperture. It suggests a dorso-ventrally flattened portion of a gyroceracone such as "*Gyroceras*" *validum* Hall, but it might as easily represent a fragment of one of the smooth trochoceroids of the Schoharie which are properly referred to *Nœdyceras* Hyatt.

Gomphoceras absens Hall

The four figured specimens have been redescribed in detail in another part of this paper. They represent four species and three genera. See *Turnoceras absens* (Hall), *Exocyrtoceras micron* Flower, *Exocyrtoceras sinuatum* Flower and *Brevicoceras conicum* Flower. Other specimens in the New York State Museum labeled

G. absens are described as *Brevicoceras compactum, Brevicoceras rotundum,* and *Exocyrtoceras constrictum.* All of the types are in the New York State Museum.

Gomphoceras beta Hall

The holotype is a badly flattened portion of a small brevicone. The aperture is not preserved. The sutures bear broad lobes which strongly suggest the dorsal lobes of *Brevicoceras,* but it is not impossible that this might be the result of flattening. Several *Brevicoceras* are described in this paper from the Schoharie Grit, but it has not been possible to identify any of these (which are based upon unflattened specimens) with the holotype of *G. beta.*

The second specimen, which is adequately represented by Hall's figure, is not conspecific with the first, but plainly belongs to a much larger species. The dorsal surface is destroyed, and of the venter only the base of the living chamber and a portion of the phragmocone remain. The sutures are straight and transverse ventrally. The siphuncle has been weathered away, and the impression which remains shows no trace of the original form of the segments save that they were probably not markedly expanded. The fragment is inadequate for specific or generic determination. The types are in the New York State Museum, Nos. 12183/1-2.

Gomphoceras rude Hall

The holotype retains only the ventral surface of a badly flattened brevicone representing the greater part of the phragmocone and the basal half of the living chamber. The aperture is not known. The siphuncle is ventral and submarginal in position. The segments are subcylindrical within the cameræ, but probably contract abruptly at the septal foramen. The sutures bear low ventral saddles, though the lobation may be the result of flattening. A well developed basal zone is present. It is not possible to refer the species to any genus on the basis of the present evidence. The type is in the New York State Museum, No. 12200/1.

Gomphoceras (?) cruciferum Hall

The species is known only from the holotype. This is a flattened specimen only one side of which is preserved, that exposing the convex surface of a septum. The section appears to be faintly compressed. The siphuncle is about three times as far from the dorsum as from the venter. The surface of the septum bears cruciform impressions and some radial striæ which represent the mold of episeptal deposits in a moderately advanced condition. Orad of the exposed septum are traces of several cameræ which indicate that unless flattening has produced some unusually deceptive results the conch was an exogastric gyrocercone or cyrtoceracone.

No Schoharie brevicone is known which agrees with this species in section. Similar cruciform markings, though with a more central siphuncle are to be found in several orthoceracones. The species is probably valid but probably could not be recognized again unless conditions of preservation and distortion were duplicated. It is not even certain what the original form of the conch of this species was.

The type is No. 12185/1, New York State Museum.

III. ONONDAGA (IN THE OLD SENSE)

Gomphoceras eximium Hall

It has been customary to refer to this species large brevicones from the Columbus Limestone of Ohio and from the Onondaga of New York. The first specimen figured is from the Columbus Limestone. It is somewhat flattened and does not preserve the aperture. There is not enough evidence to refer the specimen to any genus with certainty. The second figured specimen is from the Onondaga Limestone near Buffalo, New York. Again there is no trace of the original section or of the aperture. The Buffalo specimen differs from the Columbus specimen in having shallower cameræ, and a living chamber which is only slightly contracted.

Four specimens from the Columbus Limestone are figured as *G. eximium* by Hall in the supplement. The type of pl. 120, fig. 1 agrees with the first specimen figured in proportions. The second specimen, pl. 120, fig. 2-3, is a sectioned portion of the phragmocone showing the outline of the siphuncular segment and traces of actinosiphonate deposits. The segments of the siphuncle are broadly heart-shaped. The area of adnation is broad. The necks are recurved but not recumbent. The type of pl. 21, fig. 1 represents a more slender species. The surface is preserved and lines of growth indicate the presence of a hyponomic sinus from an early stage as in *Acleistoceras fischeri.* The type of pl. 121, fig. 2 represents a portion of a phragmocone. It is impossible to say what the relationship of this fragment is, but the siphuncle which is exposed does not agree in form with that of the type of pl. 120, fig. 2-3.

It is evident that in the types at least three species are involved, probably more. Not one of the types preserves the aperture, and in only one is there any indication of the hyponomic sinus.

Specimens from the Onondaga of western New York which I have examined show that there are two species involved, both of about the size of the types of *G. eximium.* One is an *Acleistoceras* with a subtriangular aperture in which the hyponomic sinus is moderately developed; the other is an erect form probably without a hyponomic sinus.

Gomphoceras mitra Hall

This is a large species from the Jeffersonville of Indiana. It is erect and depressed in section, with straight transverse sutures. A plastotype shows a trace of a slightly produced hyponomic sinus on the right side of the specimen as oriented in Hall's figure. The reverse side of the specimen is not preserved. Nothing is known of the siphuncle. The form seems to warrant placing the species in *Acleistoceras.*

Gomphoceras impar Hall

The type of pl. 120, fig. 4 is here selected as the lectotype. The figure represents the ventro-lateral aspect with the hyponomic sinus on the left. In form this species is a good *Acleistoceras* showing gerontic features. The species is from the Columbus Limestone. The type of pl. 121A, fig. 1 is not conspecific with the lectotype. The generic position of the species is uncertain, but *Acleistoceras* is suggested by the produced aperture and the slender form of the siphuncular segments.

I have not been able to locate either of the types of this species.

Gomphoceras cammarus Hall

I have not been able to locate the type of this species. Hall's description includes mention of a hyponomic sinus, but there is no evidence of any such structure in his figure. Until the type can be relocated and the condition of the aperture verified, generic determination is not possible. The species is from Lexington, Scott County, Indiana, probably from the Jeffersonville.

Gomphoceras gomphus Hall

This is a large exogastric brevicone of depressed section, with the aperture only slightly contracted. A hyponomic sinus is described, but the condition of the aperture of the type shows that the ventral part is missing. The undulate condition of the outline of the phragmocone is a character not known in any described genus of brevicones, and it is quite probable that this species represents an undescribed genus.

Branson referred a specimen from the Grand Tower Limestone of Missouri to this species. His specimen seems to be sufficiently different to be regarded as a distinct species, nevertheless the two are doubtless closely related.

IV. HAMILTON

Gomphoceras fischeri Hall

Referred to *Acleistoceras*[47].

Gomphoceras solidum Hall

Referred to *Poteriocerina* Foerste[48], but neither this nor the other American species are truly typical, for they are too erect, and typical *Poteriocerina* is definitely, though not greatly, curved. The advisability of creating a new genus for the reception of these forms, which include species from Michigan and Wisconsin as well as the Cherry Valley species and *Gomphoceras manitobense* Whiteaves, is still uncertain.

Gomphoceras abruptum Hall

The holotype is badly flattened and shows no trace of the aperture or siphuncle. The original section is uncertain. The condition of the specimen suggests that the sutures were originally straight and transverse on the one side on which they are preserved. The proportions of a flattened and poorly preserved specimen are all that serve as specific criteria. The species is probably valid, but it is very doubtful whether the species can be recognized from other material unless similarly flattened. The holotype is inadequate for generic diagnosis.

Gomphoceras manes Hall

This species, which characterizes the Geneseo Shale of the Upper Devonian, is referred to *Brevicoceras*.

[47] Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont., vol. 22, 1936, p. 332, pl. 30, fig. 8-10.

[48] Flower, R. H.: *ibid.*, p. 340, pl. 31, fig. 8-10.

Gomphoceras poculum Hall

Both of the figured specimens represent early portions of the conch, one retaining the basal portion of the living chamber. The sutures are straight; the siphuncle submarginal; its segments cyrtochoantic but barrel-shaped to subcylindrical within the cameræ. Without the aperture generic determination is not possible. The longitudinal markings of the internal mold and the form of the siphuncular segments suggest *Micronoceras*. However, each of these characters is shown on a different specimen, and while no specific difference can be found, it is not certain that the two belong to the same species.

Gomphoceras lunatum Hall

The outline of the siphuncle, the section, and condition of the sutures, together with the outline are sufficient to warrant placing the species in *Cyrtogomphus*. Hall's statement concerning the presence of a hyponomic sinus (or small aperture) is opposed to this but is not borne out by his figure. I have been unable to locate the type.

Gomphoceras oviforme Hall

Ovoceras oviforme (Hall)
Ovoceras constrictum Flower
Micronoceras gibbosum (Hall)

Gomphoceras pingue Hall

The type of pl. 94, fig. 9, I have been unable to locate. The curvature, the apparently straight aperture and the straight suture suggest *Cyrtogomphus*[49]. The type of pl. 95, fig. 6 belongs to a more rapidly expanding form, as is shown not only by the rate of expansion which is unreliable in a flattened specimen, but by the rapid increase in the depth of the cameræ. The generic position of this specimen cannot be determined, and the fragment itself does not warrant the erection of a new specific name.

Gomphoceras raphanus Hall

This species is redescribed in the earlier portion of this paper. Two of the figured specimens appear to be specifically distinct from *raphanus*. The type of pl. 94, fig. 10 is too rapidly contracted over the living chamber, and appears to be an *Ovoceras*. The type of pl. 94, fig. 5 is of uncertain affinities in view of the absence of the aperture. The siphuncular segments appear to be broader than those of the only species of *Micronoceras* for which this character is known. The proportions suggest *Brevicoceras wellsi*. The gibbosity is too low on the living chamber for *M. raphanus*.

Gomphoceras conradi Hall

Hall's type includes two species, *Verticoceras erectum* Flower and *Verticoceras conradi* (Hall). *Verticoceras*, sp.[50] Flower is prabably a sexual form of *V. erectum*.

[49] A specimen from the Pompey member of the Skaneateles, collected by the author too late for incorporation in this paper save in the faunal list, is a typical *Cyrtogomphus* and differs from the holotype of *pingue* only in its considerable smaller size.
[50] Flower, R. H.: *ibid.*, p. 343, pl. 28, fig. 6.

V. UPPER DEVONIAN

Gomphoceras ajax Hall

The species is known only from the holotype, which furnishes no information concerning the section, aperture or siphuncle. The sutures are oblique, but the obliquity is probably the result of distortion.

Gomphoceras tumidum Hall

The numerous types of this species are evidently not conspecific. All are flattened, and generally only one side of the specimen is preserved. The position of the siphuncle is not known in most instances, and there is no certain means of determining whether the portions exposed are ventral or dorsal. The description does not seem to favor one specimen more than another. As none of the specimens can be placed generically with any degree of certainty, it has not seemed advisable to restrict *tumidum* to a lectotype and to propose new names for the other species.

The first two specimens figured are totally inadequate for generic or specific recognition. The type of pl. 93, fig. 5 is an adoral part of a living chamber, retaining a sinus. Enough of the living chamber is not preserved for recognition of the species. The type of pl. 93, fig. 6 retains part of the aperture which is straight and transverse. The outline of the living chamber and phragmocone is not well enough preserved to show the point of greatest gibbosity.

The types of pl. 95 may be summarized as follows:

Fig. 2.—An apical part of a phragmocone, not attaining the greatest diameter. Sutures straight and transverse.

Fig. 3.—This is evidently not conspecific with any other of the types of *tumidum.* It retains part of a phragmocone and the base of the living chamber, not showing the point of greatest diameter. The cameræ are very shallow, and the conch expands slowly for a brevicone.

Fig. 4.—This is a flattened living chamber. The outline suggests that the specimen is compressed rather than depressed. The aperture is not preserved. Possibly this is conspecific with the type of pl. 95, fig. 2.

Fig. 5.—The type does not expand to a point beyond the middle of the living chamber as represented in the drawing. The sutures are straight and transverse, as is the aperture. The specimen is flattened. This is smaller than the other living chambers attributed to *tumidum.* The other types are from the Ithaca Shales; this is from a coquinite which by its lithology cannot be lower than the Cayuta of the true Chemung, and may possibly belong to a higher horizon. The outline and aperture suggest *Micronoceras*, but it is not certain that the side exposed is ventral, and consequently the absence of a hyponomic sinus is not certain.

Fig. 7.—This is a badly flattened specimen which is larger and broader than the others, and contracts more strongly toward the aperture. Unfortunately the outline of the aperture cannot be determined with certainty.

There are a number of species involved in the types. Those which are known to possess a hyponomic sinus show a narrow rather well defined sinus, clearly set off from the remainder of the aperture. These species should be placed in *Anglicornus* Flower and Caster, and are discussed under that genus. Most of the available specimens have been too poorly preserved to justify basing new species upon them.

Gomphoceras potens Hall

This species is of uncertain position. It is of Mississippian age. It does not suggest *Poterioceras, sensu strictu.*

Gomphoceras (?) planum Hall

The flattened dorsum, the rounded venter and the slight dorsal lobes suggest *Brevicoceras* and are deemed adequate for the generic determination. In most other *Brevicoceras* the lobation is more marked. The species is of Hamilton age, and is known only from the type.

VI. SPECIES DESCRIBED IN THE SUPPLEMENT

Gomphceras crenatum Hall

Although the type does not preserve the aperture, the position of the point of greatest gibbosity, the straight sutures and general form seem sufficient to warrant placing the species in *Acleistoceras.* The species is from the Columbus Limestone.

Gomphoceras plenum Hall

This species is so close to Saemann's figure of *Acleistoceras olla* that it is suspected that the two are really conspecific, and that the differences are due to Saemann's inaccuracy in drawing. *G. plenum* differs in possessing contracted adoral cameræ, a gerontic feature, but the outline and size of the two are closely similar. *G. plenum* is certainly a typical *Acleistoceras.* The species is from the Columbus Limestone.

Gomphoceras minum Hall

This is a small erect brevicone from the Falls of the Ohio. The trilobate aperture reported by Hall, and the general similarity in size and proportions, suggest that this may be an *Ovoceras,* a genus which is known to occur in the Sellersburg Limestone of that region, where it is represented by several species.

ADDITIONAL SPECIES OF *GOMPHOCERAS*

Only one other species of *Gomphoceras* has been described from the Hamilton of New York. This is *Gomphoceras mitriforme* Clarke[51]. The specimen which forms the basis of the description, is a badly flattened compressed individual. The dorso-ventral outline is suggestive of *Brevicoceras,* but the sutures are destroyed, and the aperture is very incompletely preserved. According to the description the siphuncle is preserved in a apical part of the specimen. The structure discussed and figured, proved on examination of the type, to be a part of a crinoid stem. Isolated joints occur abundantly elsewhere in the specimen. It is very doubtful whether the species can be recognized again. The type is flattened, but it

[51] Clarke, J. M.: *New or rare species of fossils from the horizons of the Livonia Salt shaft,* 13th Ann. Rept. of the State Geologist for the year 1893, vol. 1, 1894, Geology, p. 171, pl. 3, fig. 1.

is uncertain whether flattening has caused the shell to become greatly expanded horizontally, dorso-ventrally in this instance. The specimen is from Chapinville, Ontario County, New York. It occurs in the Marcellus, probably in the Chittenango member.

PLATES

PLATE I (VOL. PL. 19)

EXPLANATION OF PLATE I (19)

Figure		*Page*
1	*Brevicoceras pompeyense* Flower, n. sp. Transverse longitudinal section of holotype showing siphuncle with segmental actinosiphonate deposits. See also Pl. II. P. R. I. No. 5802; x1½. Pompey member, Skaneateles, Hamilton stage, from Pratt's Falls, Onondaga County, New York.	26
2-3	*Brevicoceras conicum* Flower, n. sp. Holotype, (2) left lateral aspect, (3) ventral aspect; x1. N. Y. S. No. 12181/4. Onondaga Limestone, Clarence Hollow, Erie County, New York.	32
4	*Wissenbachia gebhardi* Flower, n. sp. Holotype, lateral aspect; x1. N. Y. S. M. No. 12650/1. Schoharie Grit, Schoharie, Schoharie County, New York.	57
5-7	*Brevicoceras casteri* Flower, n. sp. Holotype; x1, (5) dorsal, (6) ventral and (7) left lateral aspects. P. R. I. No. 5800. Moravia, New York. Windom member, Moscow, Hamilton stage.	25
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10-12	*Brevicoceras rotundum* Flower, n. sp. Holotype; x1, (10) dorsal, (11) right lateral and (12) ventral aspects. N. Y. S. M. No. 12076/1. Schoharie Grit, Schoharie, Schoharie County, New York.	31
13-14	*Micronoceras gibbosum* (Hall) Hypotype; x1, (13) lateral aspect with venter on left, (14) adoral aspect, slightly oblique, showing aperture. N. Y. S. M. No. 12316/I. Cherry Valley Limestone, Onondaga County, New York.	48
15-16	*Brevicoceras concavum* Flower, n. sp. Holotype; x8, (15) lateral aspect, dorsum on left, (16) dorsal aspect. N. Y. S. M. No. 12072/1. West River Shales, Naples stage, from the Genesee Valley, New York.	29
17	*Cyrtospyroceras formosum* (Hall) Holotype; x1, lateral aspect. N. Y. S. M. No. 12105/1. Hamilton stage, Dresdon, Yates County, New York.	52


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PLATE II (VOL. PL. 20)

EXPLANATION OF PLATE II (20)

Figure *Page*

1-2 *Brevicoceras pompeyense* Flower, n. sp. 26
Holotype; x1, (1) ventral aspect, before sectioning, (2) dorsal aspect. Same specimen as Pl. 1, fig. 1.

3-5 *Exocyrtoceras constrictum* Flower, n. sp. 40
Holotype; x1, (3) ventral, (4) right lateral and (5) dorsal aspects. N. Y. S. M. No. 12152 m/l. Schoharie Grit, Schoharie, Schoharie County, New York.

6-8 *Exocyrtoceras sinuatum* Flower, n. sp. 39
Holotype; x1, (6) ventral, (7) lateral and (8) dorsal aspects. N. Y. S. M. No. 12181/3. Schoharie Grit, Schoharie, Schoharie County, New York.

9-11 *Exocyrtoceras sinuatum* Flower, n. sp. 39
Paratype; x1, (9) ventral, (10) lateral, (11) dorsal aspects. N. Y. S. M. No. 12152p/1. Schoharie Grit, Schoharie, New York.

12-15 *Exocyrtoceras exoticum* Flower, n. sp. 38
Holotype; x1, (12) left lateral, (13) oral, (14) septal and (15) dorsal aspects. P. R. I. No. 5805. Columbus Limestone, Columbus, Ohio.

16 *Micronoceras angulatum* Flower, n. sp. 49
Holotype; x1, ventral aspect. Buffalo Mus. Sci., No. E 8570. Tichenor Limestone, Hamilton stage, Eleven Mile Creek, Darien, New York.

17-22 *Brevicoceras compactum* Flower, n. sp. 30
Holotype; x1, (17) ventral, (18) lateral and (19) dorsal aspects. N. Y. S. M. No. 12070/1. Paratype; x1, (20) ventral, (21) lateral and (22) dorsal aspects. N. Y. S. M. No. 12070/2. Schoharie Grit, Schoharie, New York.

23-25 *Pachtoceras obliquum* Flower, n. sp. 59
Holotype; x1, (23) septal, (24) ventral (?) and (25) lateral aspects. Buffalo Mus. Sci.; Lewis Run Sandstone, Lewis Run, Pennsylvania.

26-27 *Cyrtogomphus curvatus* Flower, n. sp. 44
Holotype; slightly less than x1, (26) lateral aspect, venter on left, (27) ventral aspect before sectioning. Buffalo Mus. Sci., No. E-8570. Tichenor Limestone, Hamilton stage, Cazenovia Creek, Erie County, New York.

28-29 *Cyrtogomphus thedfordensis* Flower, n. sp. 45
Holotype; x1, (28) lateral aspect, dorsum on left, (29) ventral aspect. Buffalo Mus. Sci. Hamilton stage, Thedford, Ontario.


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EXPLANATION OF PLATE III (21)

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8-9	*Acleistoceras jonesi* Flower, n. sp. Holotype; x1, (8) left lateral and (9) dorsal aspects. P. R. I. No. 5811. Cherry Valley Limestone, Hamilton stage, Stockbridge, Madison County, New York.	21
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13	*Bolloceras hartti* Flower, n. sp. Holotype, lateral aspect; x½. Cornell Univ. No. 5362. Ithaca Shale, Ithaca, New York.	63
14-15	*Micronoceras delphicolum* Flower, n. sp. Paratype; x1, a dorso-ventrally crushed living chamber (14) septal and (15) lateral aspects. P. R. I. No. 5807. Delphi member, Skaneateles, Hamilton stage, Delphi Falls, Onondaga County, New York.	46
16-17	*Endoplanoceras gomphus* Flower, n. sp. Holotype; about x.6, (16) ventral aspect, (17) lateral aspect. N. Y. S. M. No. 12138/1. Onondaga Limestone, Bridgewater, Oneida County, New York.	54

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PLATE IV (VOL. PL. 22)

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20. *Turnoceras,* n. sp. 43
Only surface of the specimen exposed, ventro-lateral; x1. N. Y. S. M. No. 12590/1. Schoharie Grit, Schoharie, New York.

21. *Metaphragmoceras dubium* Flower, n. sp. 67
Holotype, lateral aspect; x.6. N. Y. S. M. No. 12314/1. Onondaga Limestone, Leroy, Genesee County, New York.

22-24 *Acleistoceras wellsi* Flower, n. sp. 22
Holotype; slightly larger than x.5, (22) ventral, (23) septal and (24) lateral aspects. P. R. I. No. 5813. Tully Limestone, Tinker's Falls, Onondaga County, New York.

25. *Anglicornus goldringæ* Flower, n. sp. 34
Holotype, ventral aspect; x1. N. Y. S. M. No. 12025/1. Probably Canadaway, from Belmont, Allegany County, New York.

EXPLANATION OF PLATE IV (22)

Figure		Page
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PALAEONTOGRAPHICA AMERICANA

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PALAEONTOGRAPHICA AMERICANA

ILLUSTRATED CONTRIBUTIONS

TO THE

INVERTEBRATE PALEONTOLOGY

OF

AMERICA

VOL. II

NO. 10 : STUDY OF THE PSEUDORTHOCERATIDAE

By

Rousseau H. Flower, Ph. D.

October 28, 1939

Palaeontological Research Institution

Ithaca, New York, U. S. A.

CONTENTS

TEXT FIGURES

STUDY OF THE PSEUDORTHOCERATIDAE

By

Rousseau H. Flower

INTRODUCTION

The present study of the Pseudorthoceratidæ grew out of an investigation of Devonian cephalopods, but to determine the genetic affinities the original scope of the investigation has been considerably extended. The origin of the family is found in orthochoantic Silurian forms. Devonian species are described in detail. The study of Mississippian forms has been hampered by the rarity of Pseudothoeratidæ in the American Mississippian and scarcity of European material. Doubtless the now known forms present only an inkling of what will be learned of the development of the family in this system upon more thorough investigation. Such Pennsylvanian forms as have been investigated have been studied for morphological rather than taxonomic purposes. The Pennsylvanian genera are few in number, and as investigations of others now in progress will add materially to the known species shortly, an intensive taxonomic study has been deemed unnecessary.

The description of the species belonging to a family recognized as recently as was the Pseudorthoceratidæ is almost certainly very incomplete and will doubtless be extensively supplemented and revised. An important part of the present investigation has been a morphological study with particular reference to the deposits of the siphuncle and cameræ with a view toward increasing their taxonomic usefulness. Before such structures can be used taxonomically with any feeling of security it is necessary to understand their structure, origin, ontogeny and function. The structure and ontogeny can be studied direct from well preserved specimens. On the basis of the deposits the tissues which were responsible for their secretion have been reconstructed; moreover, traces of cameral tissues present supporting evidence which is most reassuring. Further, the tracing of the development of the cameral tissues and discussion of the function of the deposits may serve to emphasize that the deposits of the cameræ as well as those of the siphuncle are an integral part of the organism, and are subject to the same cycles of growth which affect other parts of the animal.

The investigation of internal structures is a relatively recent development in the study of cephalopods, and was initiated by Teichert's admirable investigations of the Actinoceroidea. At the present time there is reason to believe that the further study of these structures may offer a solution to the phyletic problems of orthoceracones, particularly the large group of orthochoanitic forms, and that a taxonomic revision based upon such features may result in generic divisions which will permit the wider use of these abundant forms in faunal and stratigraphic investigations.

ACKNOWLEDGMENT

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PART I

MORPHOLOGY OF THE NAUTILOID SHELL WITH SPECIAL REFERENCE TO THE PSEUDORTHOCERATIDAE

GROSS FEATURES OF THE SHELL

THE WALL OF THE CONCH

The exterior of the shell wall of the Pseudorthoceratidæ shows no unusual features. The surface markings are not different from those found in other cephalopods. Addition to the shell occurs very largely at the aperture, and for that reason the form of the aperture is retained on the surface in the form of lines of growth. This is frequently significant, for it reveals that in some instances the hyponomic sinus was present throughout life, while in other instances it was developed only in the late ephebic and gerontic stages; again, it may be absent throughout life.

Thin sections of various fossil Nautiloidea have thus far failed to show differentiation of shell layers in the wall of the conch, but this is doubtless due to alteration by replacement of the original shell material. Three layers are known in *Nautilus*. An outer porcelaneous layer is followed by a prismatic layer which is about three times as thick as the porcelaneous layer. The inner layer consists of a thin nacreous film. Judging from the amount of variation in Recent molluscs in the texture and thickness of the shell layers it is safe to assume that similar variation must have occurred in fossil Nautiloidea.

A constriction of the interior of the gerontic living chamber is an important feature of most orthoceracones. It is suspected that this constriction is produced by a thickening of the inner nacreous film, for that is the only shell layer known to be produced proximad of the tip of the mantle lobe. The location of the gerontic constriction and its form are important specific criteria in orthoceracones.

Other markings of the interior of the shell are concerned with the attachment of the soft parts. *Nautilus* possesses a pair of lateral shell muscles which produce crescent-shaped ridges on the sides of the living chamber. Muscle scars have been noted in a few Paleozoic nautilicones, but have not yet been recognized in orthoceracones. In addition to the muscle scars, *Nautilus* possesses three aponeurotic bands[1], one dorsal and two ventral. The dorsal bands are without a counterpart in fossil Nautiloidea, but the entire area subtended by the ventral bands is represented in fossil forms by a conchial furrow, which is discussed below.

THE SEPTA

The septa are the partitions which characterize most cephalopod shells and serve to distinguish the chambered portion, or phragmocone, from the adoral unchambered portion, the living chamber It has been generally known that the septa are secreted by the posterior surface of the visceral mass. It has been suspected for some time, from the lack of fossil or Recent nautiloid shells showing incomplete septa, that deposition was rapid, but only recently has this been confirmed

1 Miller, A. K., Dunbar, C. O., and Condra, G. E.: *The nautiloid cephalopods of the Pennsylvania system of the mid-continent region*, Nebraska Geol. Surv., ser. 2, Bull. 9, 1933, p. 32.

by direct observation. Pruvot-Fol[2] noted that in *Nautilus* forward progression in the shell is gradual, but that septation is sudden and discontinuous.

Three parts of the septum have been recognized by Teichert[3] (fig. 1). The *free part of the septum* divides the conch into cameræ, and is properly that part of the septum which is not in contact with any other shell structure. Secondly, however, it may become incorporated in the siphuncle. The *mural part* of the septum extends orad of the free part of the septum with which it is continuous, to the next succeeding septum (fig. 1, m.). The point at which the siphon pierces the septum is referred to as the *septal foramen,* and at this point the septum extends apicad around the siphon for some distance. This portion of the septum has long been known as the *septal neck* (fig. 1, n). Upon its form depend the major divisions of the Nautiloidea proposed by Hyatt.[4].

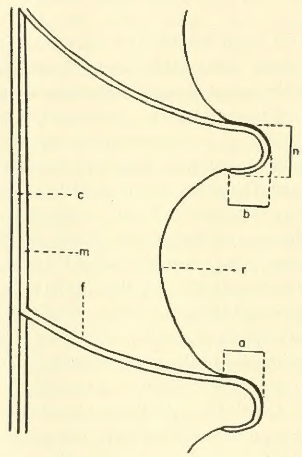


Fig. 1. Essential structural features of the phragmocone: *c*, wall of conch; *m*, mural part of septum; *f*, free part of septum; *n*, septal neck; *b*, brim; *a*, area of adnation; *r*, connecting ring.

LONGITUDINAL FURROWS OF THE INTERIOR OF THE SHELL

THE TWO TYPES OF FURROWS

The internal molds of many cephalopods bear longitudinal carinæ which are the reflections of grooves on the interior of the shell. As carinæ or ridges these have been described by various investigators[5], and have been variously interpreted.

2 Pruvot-Fol, A.: *Rémarques sur le Nautile,* C. R. XIIe Congress International de Zoölogie, Lisbonne, 1935, pp. 1652-1663, Lisboa, 1937.

3 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden,* Paleontographica, Bd. 78, Abt. A., 1933, pp. 117-119, figs. 1-2.

4 Hyatt, A.: *Cephalopoda,* in Zittel-Eastmann Textbook of Paleontology, 1st. ed., vol. 1, 1900, pp. 586-615.

5 Hall, J.: Paleontology of New York, vol. 5, pt. 2, 1879, pp. 240, 248, 250, 278, 287.

Flower[6] pointed out that two distinct types of structure are involved, a continuous ventral "carina", which extends well into the living chamber, and a dorsal "carina" which is a metamerically repeated structure found on the mid-dorsal region of each camera. This is the "false siphuncle" at least in part of various authors. Miller, Dunbar and Condra[7] stated that the structure appeared to be connected with the accumulation of globules of limonite in the upper side of the shell as it lay in the matrix, and considered it an inorganic phenomenon.

It is necessary to distinguish between the dorsal and ventral carinæ. Failure to do so in the past has led to some errors. Hall compared the dorsal furrow of *Dolorthoceras tersum* with the ventral furrow of *Striacoceras typus* (Saemann) (= *Orthoceras marcellense* Hall) and as a result described *D. tersum* upside down. Loomis[8] mistook the dorsal furrow for a marginal siphuncle and as a result described a *Michelinoceras* as a *Bactrites*. The types were broken in such a way that the septum and the true siphuncle were not exposed. Additional material shows that the specimen figured by Loomis as *Bactrites*, sp. mut. *pygmæus* is probably not distinct from his *Orthoceras subulatum* Conrad mut. *pygmæum* Loomis.

The ventral and dorsal furrows are very different in origin, structure and probably in function, and for that reason are best discussed separately. To prevent the possibility of confusing the very different structures it has seemed best to express the fundamental differences between the furrows by giving them rather distinct names. The continuous ventral furrow is here called the CONCHIAL FURROW. The name SEPTAL FURROW is proposed for the dorsal structure.

In every instance in which a check has been possible it has been found that the conchial furrow is in line with the hyponomic sinus and is therefore mid-ventral in position. The septal furrow occurs on the opposite side on the mid-dorsal region. It may be noted further that the cameral deposits are concentrated ventrally, and I have found the three criteria of hyponomic sinus, shell furrow and the orientation of deposits to be reliable criteria for the orientation of the conch. It has been possible to demonstrate in numerous instances that neither the dorsal nor the ventral furrows are connected with the orientation of the conch in the sediments. A circular orthoceracone with cameral deposits concentrated ventrally will normally come to lie with the venter below and the dorsum above. Such specimens alone would suggest an inorganic origin for the furrows. However, by noting in the field the position of the conch in the sediments it has been possible to demonstrate that the orientation of the conch in the sediments has no bearing on the position of the furrows. This discordance has been especially striking in the writer's experience while collecting the abundant orthoceracones which occur in a limestone at the top of the Pompey member of the Devonian (Hamilton group, Skaneateles formation,) of central New York. The discordance is further illustrated by *Euloxoceras* of the Pennsylvalian, which shows furrows on the dorsum

[6] Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont., vol. 22, No. 76, 1936, p. 16.

[7] Miller, A. K., Dunbar, C. O. and Condra, G. E.: *The nautiloid cephalopods of the Pennsylvanian system of the mid-continent region*, Nebraska Geol. Surv., ser. 2, Bull 9, 1933, p. 80.

[8] Loomis, F. B.: *The dwarf fauna of the pyrite layer at the horizon of the Tully limestone in western New York*, New York State Museum Bull. No. 69, 1903, p. 916, pl. 4, figs. 12-13.

and venter, although the strongly compressed shells of this genus are commonly found resting on a lateral surface.

THE CONCHIAL FURROW

The interior of the shell of many cephalopods bears a single mid-ventral conchial furrow. The structure is a widespread feature in the Nautiloidea, although it is rarely seen as a furrow, but is frequently and readily observed as a ridge on the internal mold.

The conchial furrow is often best seen on the phragmocone but in several instances it has been possible to trace it nearly to the aperture of the living chamber. This shows that it is a feature of the inner surface of the wall of the conch, and not of the mural part of the septum. On the phragmocone the mural part of the septum appears to be of uniform thickness and to follow the slight emargination produced by the conchial furrow may be preserved whether separation occurs between shell and matrix, or as sometimes happens, between the wall of the conch and the mural part of the septum.

It is probable that the conchial furrow is to be correlated with the entire area subtended by the pair of ventral aponeurotic bands of *Nautilus*.

Miller, Dunbar and Condra[9] noted that the aponeurotic bands and the area of attachment between them had scarcely any relief, and that traces of the structures could be expected only in perfectly preserved specimens. In mature specimens of *Nautilus* it is often very difficult to determine the exact limits of the aponeurotic bands which are often faint. Also, in some specimens there can be seen faint longitudinal markings which appear to be internal relics of longitudinal shell markings, and which have nothing to do with shell attachment. The presence of such markings makes the recognition of the aponeurotic bands almost impossible in some specimens. However, there is indication that in immature specimens the aponeurotic bands are much clearer and more closely spaced than in the adults. In a specimen in which the whorl has a width of 87 mm. and a height from the impressed zone of 79 mm. the aponeurotic bands subtend a width of about 13 mm. but lie in a longitudinal polished band 25 mm. in width. In an immature individual where the whorl has a width of 45 mm. and a height of 34 mm., the bands are very clearly marked and encompass a width of only 1.5 mm. (pl. 9, fig. 2). The increased clarity of the bands in the early stage may not be constant, as only a single immature individual was available for study. However, it is significant that the bands are very close together in the earlier whorls of *Nautilus*, and present an appearance very similar to the conchial furrow of fossil forms.

The wide distribution of the conchial furrow in Nautiloidea, comprising a series of ellipochoanitic forms ranging from Ordovician to Tertiary, offers further substantiation for the correlation of that structure with the ventral aponeurotic bands of *Nautilus*. It occurs in a wide variety of orthochoanitic genera, both straight and coiled, but appears to be absent in most cyrtochoanitic forms. Among the Cyrtochoanites the Pseudorthoceratidæ are a notable exception. It has been noted in *Dolorthoceras, Adnatoceras, Pseudorthoceras* and *Mooreoceras*. It is present

[9] Miller, A. K., Dunbar, C. O. and Condra, G. E.: *The nautiloid cephalopods of the Pennsylvanian system of the mid-continent region*, Nebraska Geol. Surv., ser. 2, Bull. 9, 1933, p. 32.

in *Euloxoceras*, though it is difficult to distinguish there because of faint longitudinal ridges of the ornament which form longitudinal ridges on the interior. In other genera it is either obscured by the ornament or not preserved on specimens known thus far owing to the coarse texture of the matrix. It is widely present in orthochoanitic orthoceracones, being well developed in *Michelinoceras* and *Geisonoceras*. Thus far I have been unable to detect any trace of the structure in orthochoanitic orthoceracones of the Chazy or Trenton limestones of the Ordovician, but the structure is not confined to forms occurring in the later part of the Paleozoic, for it is well developed on *"Ooceras" perkinsi* Ruedemann of the Chazy limestone, a cyrtochoanitic form of doubtful affinities but possibly related to the Stereoplasmoceratidæ.

Among coiled cephalopods it is of relatively common occurrence, though the genera on which it has thus far been observed make up a rather heterogeneous assemblage. It has been so far observed in *Nephriticeras, Centroceras* and *Tetranodoceras* of the Devonian, in *Metacoceras, Titanoceras, Cœlogasteroceras, Domatoceras* and *Solenocheilus* of the Pennsylvanian, *Cymatoceras* and *Eutrephoceras* of the Cretaceous and *Hercoglossa* of the Eocene.

The genus *Striacoceras* Flower of the Devonian is unique as far as is known at present in possessing a pair of ventro-lateral furrows in addition to the usual mid-ventral furrow (Pl. 8, fig. 13).

The conchial furrow is normally very shallow, and it is not uncommon to find it so obscurely preserved that it cannot be photographed from whitened specimens. It is rather variable within the species, as was shown in a large series of *Striacoceras typus*. The structure has not been observed on any specimens from coarse sandstones, and it appears that a limestone sufficiently fine grained that internal molds from it present a polished surface is the best medium for its preservation. The conchial furrow has been noted in Devonian and Pennsylvanian specimens preserved under such conditions, but under different conditions the same genera and often the same species may show no trace of the structure.

THE SEPTAL FURROW

The septal furrow occupies the mid-dorsal region of the conch. Unlike the conchial furrow it is not continuous, but is repeated on the mural part of each septum including the last. As a consequence, it can be seen on the base of the living chamber, but only on the extreme basal part where the mural part of the last septum is developed. This is sufficient to indicate that the furrow is a structure of the mural part of the septum rather than of the wall of the conch.

The septal furrow is fairly constant in form. It is typically seen as a groove on the interior of the shell and a ridge on the internal mold. It is essentially linear. The adoral end extends nearly to the adoral suture, but is narrowly separated from it in well preserved specimens. The furrow typically extends apicad for the greater part of the length of the camera, always terminating, however, before the free part of the septum is attained. Occasionally it is short, extending barely apicad of the middle of the camera. This condition is typical of *"Orthoceras" pelops* Hall of the Schoharie grit of the Middle Devonian.

Three types of preservation have been found. The first, and commonest, is that discussed above, in which a ridge on the internal mold fits into a groove on the interior of the shell. On such specimens the groove and ridge are regular and present smooth surfaces.

A second type is one in which the condition is reversed, and a ridge on the interior of the shell fits into a groove of the internal mold. In such instances the crest of the ridge and the bottom of the groove are rough, suggesting that there was no original shell surface there to facilitate a smooth separation.

A third type, one which has been observed only in pyritized specimens, is one in which the whole dorsal surface of both the interior of the shell and the internal mold is smooth. The septal furrow is level with the rest of the surface. In most specimens it is outlined by a faint suture. In a few specimens, however, it appears only as a variation in color, evidently a phenomenom of weathering.

Thin cross sections of the conch have so far failed to show any trace of the structure, but its nature can be ascertained both by the preservation of the fossil forms and the existence of a similar structure in *Nautilus*, which has largely escaped notice.

In *Nautilus* it can be clearly seen that this area is one in which the mural part of the septum is not developed. In the first whorl the furrow occupies nearly the entire length of the dorsal wall of the camera, but it becomes shortened rapidly so that in the last half whorl of a mature individual the furrow is confined to the adoral third of the mural part of the septum. The function of this peculiar structure is not known. Obviously it has to do with the structure of the posterior mantle which secretes the septa, but further than that it is not possible to go at present.

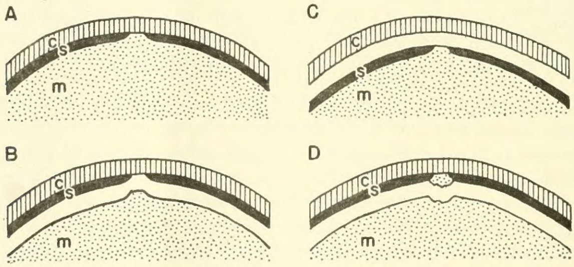


Fig. 2. Diagrammatic sections through the dorsal wall of the conch, showing the septal furrow. *c*, wall of conch; *s*, mural part of septum; *m*, matrix.

A. Normal condition, showing the shell before separation.

B. Separation of matrix from the mural part of the septum results in a ridge on the internal mold and a groove on the interior of the shell.

C. Separation between the mural part of the septum and the wall of the conch produces a smooth surface, sometimes marked by a faint suture, and sometimes perfectly smooth, the septal furrow showing as variation in color due to differential weathering.

D. Separation is largely as in *B*, except that shearing has broken off the protruding portion of the matrix.

Probably an investigation of the structure in *Nautilus* in relation to the soft parts may yield a solution.

The mode of preservation of fossil forms shows that there, as in *Nautilus*, the structure represents a region in which the mural part of the septum is not developed. To demonstrate this it is necessary first to consider the different types of preservation individually. The so-called internal mold is not always a true internal mold in the Nautiloidea, because separation may occur not only between the shell and the matrix, but also between the mural part of the septum and the wall of the conch. This fact has not been generally recognized. Quite commonly an internal mold, particularly when composed of limestone, will show two layers of separation along the phragmocone, with sutures visible at each level. In some specimens from the Cherry Valley limestone weathering was such that it was sometimes possible to separate the mural part of the septum from an apparent internal mold. Occasionally apparent internal molds, when sectioned, show traces of the mural part of the septum.

Typical specimens from the Schoharie grit of the Middle Devonian are true internal molds, all original shell material being dissolved away. In such specimens the matrix rises dorsally to form a well defined carina, showing conclusively that there was no shell material at the level of the inner surface of the mural part of the septum. Such a condition is shown in fig. 2 B.

When the groove is on the internal mold and the carina is on the interior of the shell separation of two kinds may be represented. Probably the commonest condition is that represented in fig. 2 D, in which separation, as before, occurs between the matrix and the mural part of the septum. Fracture has broken the matrix at or centrad of the level of the inside of the mural part of the septum, producing a roughened area. A similar phenomenon may occur with separation between the wall of the conch and the mural part of the septum, but with matrix adhering to the wall of the conch at its separation. This condition, however, has not been conclusively recognized.

In pyritized specimens, in which only one level is represented, separation takes place throughout at the contact of the wall of the conch and the mural part of the septum. The carina which may surround the septal furrow in such instances represents the true termination of the septum (fig. 2 C). Specimens in which the septal furrow appears only as a variation in color, represent the same sort of parting, but the color variation is due to differential weathering of the matrix.

The septal furrow is rather wide-spread among orthoceracones, but is known only sporadically in coiled forms. From the similarity of the structure found in orthoceracones to that of *Nautilus*, it is suspected that the structure is in reality wide-spread if not universal in Nautiloidea. Its apparent absence may be due in part to lack of study, in part to preservation, and in part to the inaccessibility of the dorsum in coiled cephalopods. It is present in all smooth shelled Pseudorthoceratidæ where the preservation is such that it can be reasonably expected. It is unknown in *Cayutoceras* and *Bradfordoceras* which are known only from specimens occuring in coarse grained sandstones and shales, and in *Sceptrites*, which is known only from coarse grained limestones. It is widely present in orthochoanitic orthoceracones of the Silurian and Devonian. It is remarkably well developed in Cincinnatian species of *Ormoceras*, but has thus far not been noted in other Actinoceroidea.

The septal furrow like the conchial furrow will serve as an accurate criterion of the orientation of specimens. Previously the only certain criterion in orthoceracones has been the hyponomic sinus, and too often that was absent. Troedsson[10] figured and described a *normal line* in *Orthoceras regulare* Schlotheim, of the *Orthoceras* limestone of Sweden. Except that the region is very narrowly closed adorally if at all, this is identical with the septal furrow as seen in other orthoceracones. Troedsson regarded the structure as ventral in position. However, the strong similarity with the septal furrow and the apparent lack of any definite conflicting evidence, suggests that it is dorsal here also. It has often been assumed that the siphuncle when eccentric lies ventrad to the center of the conch. That this is not always the case is shown by *Euloxoceras*. Both the septal furrow and the concentration of cameral deposits show that the siphuncle is dorsal.

THE SIPHUNCLE

TERMINOLOGY

The siphuncle is a composite structure consisting of several distinct parts of different origin, and may best be defined as the tube which encases the siphon. Two divisions have been recognized, an *ectosiphuncle* and an *endosiphuncle*. The ectosiphuncle comprises the outer wall of the siphuncle, consisting of the septal necks and the connecting rings in ellipochoanitic cephalopods, and the septal necks alone in holochoanitic cephalopods. The endosiphuncle comprises all structures within, which take on different forms in different groups. The structures are often spoken of as *endosiphuncular deposits*. Since this suggests a counterpart "exosiphuncle deposits" which do not exist, the term siphonal deposits is preferred here. The term has the further advantage of brevity; also it implies the origin of the structures from the siphon.

The term endosiphuncle was first used by Hyatt[11] who said: "Organic deposits in the form of endocones, and taper off at the center into a spire that is sometimes tubular and hollow, or again flattened and elliptical. This is the *endosiphuncle*." Later in the same work the term is used for the central canal of the Actinoceroidea[12].

The term was not more clearly defined until 1906 when Ruedemann[13] revised the morphological terminology as follows: "The ectosiphuncle is the external wall of the siphuncle; the endosiphuncle comprises all structures within the same." The tube which Hyatt apparently had in mind in wording his short definition is not a single structure, but is composed of the endosiphotube and the endosiphocoleon of Ruedemann. Further, as defined and used, the endosiphuncle of Hyatt is not a structure, but the cavity remaining within several calcareous structures.

10 Troedsson, G. T.: *Studies on Baltic fossil cephalopods; I. On the nautiloid genus Orthoceras*, Lunds Univ. Arssk., N. F., Avd. 2, Bd. 27, Nr. 16, 1931, p. 20, pl. 3, fig. 2.

11 Hyatt, A.: *Cephalopoda*, in Zittel-Eastmann Textbook of Paleontology, vol. 1, 1st. ed., 1900, p. 596.

12 *Ibid.*: p. 608.

13 Ruedemann, R.: *Cephalopoda of the Champlain basin*, New York State Museum, Bull. No. 90, 1906, p. 403.

The term was employed by him for the central canal of the Actinoceroidea, as well as for the combined endosiphotube and endosiphocoleon of the Endoceroidea.

Foerste and Teichert[14], and later Teichert[15], have used the terms endosiphuncle and endosiphuncular deposits for the calcareous structures within the siphuncle of Actinoceroidea, which comply with Ruedemann's definition. Ruedemann's usage has been followed in many of the more important works on the structure of cephalopods in recent years and is followed here. The following of Hyatt's usage would lead to several difficulties. The endosiphuncle of the Endoceroidea is a cavity with definite walls which is in part at least a structure distinct from the endocones, and involves the walls of the endosiphocoleon and the endosiphotube. The endosiphuncle of the Actinoceroidea is the cavity within the siphuncle not occupied by annulosiphonate deposits, consisting of the cavity of the central canal in the apical portion, to which is added the cavity occupied by certain unknown but possibly parenchymal tissues in the adoral portion. It has no fixed wall.

STRUCTURE OF THE ECTOSIPHUNCLE

The ectosiphuncle in ellipochoanitic cephalopods is a composite structure, being made up of two distinct parts, the septal neck, and the connecting ring, which are very different in structure and origin. The *septal neck* (fig. 1 n) is essentially a part of the septum with which it is continuous, and identical in structure.

It is largely upon the basis of the form of the septal neck that the major divisions of the Nautiloidea were based. Hyatt[16] first divided the Nautiloidea into the Holochoanoidea and the Ellipochoanoidea. In the Holochoanoidea the septal necks are long, extending at least the length of the camera, and connecting rings are absent. In the Ellipochoanoidea the necks are short and the greater part of the length of the siphuncular segment is made up of the connecting ring. Although these groups have been supplanted, the terms holochoanitic and ellipochoanitic are convenient for descriptive purposes and are often used. Hyatt[17] later divided the Nautiloidea into Holochoanites, Schistochoanites, Orthochoanites, Myxochoanites and Cyrtochoanites. The Holochoanites contain essentially the same forms as did the Holochoanoidea. The Schistochoanites are invalid structurally and need be given no attention here. The Orthochoanites are ellipochoanitic cephalopods characterized by straight septal necks. The Cyrtochoanites are ellipochoanitic forms with recurved septal necks and more or less expanded siphuncular segments. The Myxochoanites constitute a small, highly specialized, group of forms which are orthochoanitic in the early stage and cyrtochoanitic in the later stage.

Foerste and Teichert[18] have differentiated two regions of the septal neck in cyrtochoanitic cephalopods (fig. 1). The apical extension of the septal neck is

14 Foerste, A. F., and Teichert, C.: *The actionceroids of east-central North America*, Denison Univ. Bull., Sci. Lab., Jour., vol. 25, 1930, pp. 201-296, pls. 27-58.

15 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, pp. 111-230, pls. 8-15.

16 Hyatt, A.: *Genera of fossil cephalopods*, Boston Soc. Nat. Hist., Proc., vol. 22, 1883, p. 260.

17 *Ibid.*: 1900.

18 Foerste, A. F. and Teichert, C.: *The actinoceroids of east-central North America*, Denison Univ. Bull., Sci. Lab., Jour., vol. 25, 1930, p. 222.

called the *neck* (fig. 1 n), while the recurved portion is called the *brim* (fig. 1 b). Though these two regions often overlap, the relative development of neck and brim is characteristic of a genus and is a valuable character in all cyrtochoanitic cephalopods.

The *connecting ring* is very different from the septal neck in structure and in origin. It is composed of calcite spicules loosely arranged in stellate patterns in *Nautilus*. Thin sections through the connecting ring in Paleozoic Nautiloidea have thus far failed to show recognizable spicular elements. Replacement may account for this, and the discrepancy may be more apparent than real. In all Paleozoic forms studied the connecting ring appears spongy and porous under high magnification, with the openings clogged with fine organic matter which is at least in part identifiable with the matrix.

The connecting ring is the most fragile of the calcareous structures of the cephalopod shell, and is frequently entirely destroyed. It is not known for any of the Silurian species of *Gigantoceras* Hyatt[19]. Likewise it is consistently absent in *Leurocycloceras* Foerste[20]. It may be that in such forms no spicules were developed or that calcification was slight, and that the spicules were too few and too loosely arranged to be capable of preservation.

In some of the Pseudorthoceratidæ the connecting ring is preserved only in the apical part of the phragmocone where it is strengthened by siphonal deposits. The apical preservation alone might suggest that the connecting ring was developed late in the history of the camera. However, a study of the conditions of preservation shows that there is a very real correlation between the destruction of the connecting ring and the invasion of the siphuncle by sediments. Further, the connecting ring is more often destroyed when the invading matrix is coarse and sandy. Other factors, such as pressure by compaction of the sediments or the transportation and attendant damage of the shell prior to burial are doubtless contributory but are harder to estimate. Although the frequent destruction of the connecting ring in adoral cameræ suggests a delayed development, the study of a considerable series of specimens shows that the extent of destruction is variable within a species and that it is frequently erratic. Further, in the best preserved specimens the connecting ring is retained in the last camera.

The form of the connecting ring is variable. It extends from the outside of the tip of one septal neck apicad to the preceding neck, into which it disappears. In cyrtochoanitic cephalopods an *area of adnation* (fig. 1 a) is frequently developed, where the connecting ring lies in contact with the free part of the adapical septum. Frequently in Actinoceroidea and some other forms the brim of the septal neck is *recumbent*, that is, recurved so sharply that it lies in contact with the free part of the septum, the connecting ring may also lie in contact with the free part of the adoral septum. This feature is not developed in any of the Pseudorthoceratidæ.

19 Hyatt, A.: *Cephalopoda*, in Zittel-Eastmann Textbook of Paleontology, vol. 1, 1st. ed., 1900, p. 608. See also Foerste, A. F., *Notes on cephalopod genera; chiefly coiled Silurian forms*, Denison Univ. Bull., Sci. Lab., Jour., vol. 21, 1925, p. 37.

20 Foerste, A. F.: *A restudy of American orthoconic Silurian cephalopods*, Denison Univ. Bull., Sci. Lab., Jour., vol. 23, 1928, p. 272.

EARLY SIPHUNCULAR STAGES

The condition of the siphuncle in the apical chamber and the adjacent cameræ has been figured and described by Miller, Dunbar and Condra[21], and by Schindewolf[22].

Miller, Dunbar and Condra report the presence of a subspherical apical cæcum which hangs freely within the chamber without touching the apical wall. The septal necks are described as slightly recurved throughout. Schindewolf figures a condition which might be considered on the border line between orthochoanitic and cyrtochoanitic, but fails to differentiate the septal necks and the connecting rings. The apical cæcum is subspherical and very slightly broader than the succeeding siphuncular segments. The first segment of the siphuncle beyond the cæcum is short and appears cyrtochoanitic at a glance. Later segments show a progressive increase in length while the maximum and minimum diameters remain the same. The question arises as to whether the condition of the early siphuncular segments is to be considered as cyrtochoanitic and pointing to a cyrtochoanitic ancestry, or whether the condition is only apparently cyrtochoanitic or cenogenetic. At first glance the earliest siphuncular segment appears to be distinctly convex in outline so as to suggest a cyrtochoanitic rather than an orthochoanitic stage. Close inspection shows that the difference is more apparent than real and that Schindewolf was correct in considering the form orthochoanitic.

The connecting ring is aligned with the outside but not the inside of the septal neck. Consequently there is a faint contraction of the interior of the siphuncle at the septal foramen. In later stages the difference is so slight in proportion to the diameter of the siphuncular segment that it is not apparent (fig. 3a). In the earlier cameræ, however, the siphuncular segment is so small that the contraction is apparent and a cyrtochoanitic appearance results (fig. 3 b). The length of the segment is also significant, as shown in Schindewolf's drawing. In the first three segments there is a marked increase in length, while the maximum and minimum diameters of the interior of the segment remain the same. The increase in length alone does much to reduce the apparent cyrtochoanitic effect.

The effect of size on the apparent cyrtochoanitic condition can be seen by comparing the difference between the small apical end of *Pseudorthoceras* with the larger apical end of *Trematoceras*[23].

Here the early siphuncular segments are twice as wide as those of *Pseudorthoceras* and four times as long. With such an increase of dimensions the difference in thickness between the connecting ring and the septal neck becomes negligible and an unquestionably orthochoanitic outline is produced.

21 Miller, A. K., Dunbar, C. O. and Condra, G. E.: *The nautiloid cephalopods of the Pennsylvanian system in the mid-continent region*, Nebraska Geol. Surv., ser. 2, Bull. 9, 1933, p. 83, pl. 1, figs. 8-9.

22 Schindewolf, O. H.: *Bemerkungen zur Ontogenie der Actinoceren und Endoceren* (Cephal., Nautil.). Neues Jahrb. für Mineralogie etc., Beil.-Bd. 74, Abt. B., 1935, p. 96, fig. 6.

23 Schindewolf, O. H.: *Ibid.*, p. 91, fig. 3.

It may be further pointed out that the development of an orthochoanitic condition following apparently cyrtochoanitic segments in *Pseudorthoceras* would be difficult to explain; it would indicate a change from cyrtochoanitic to orthochoanitic, followed by a reversal of the condition in neanic segments. The development of the orthochoanitic condition seems to have no other explanation than the recapitulation of an ancestral condition. The early cyrtochoanitic effect is mechanical and is the direct result of the small size of the early portion of the conch.

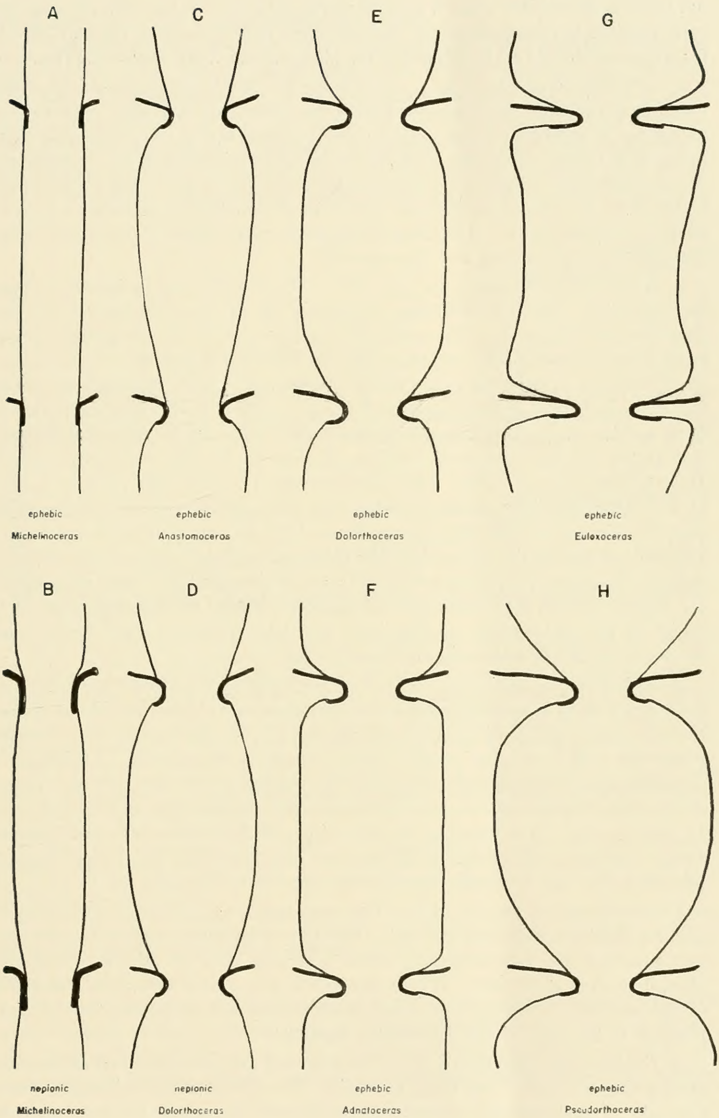
LATER SIPHUNCULAR STAGES

The outline of the siphuncle undergoes a marked ontogenetic progression in the Pseudorthoceratidæ, and the outline of the early stages of the more specialized genera recapitulates the ephebic outlines of earlier and simpler forms from the metanepionic stage onward. It has been found convenient to name the types from genera in which they occur as ephebic characters, and they are referred to as such in the descriptions in the systematic portion of this paper. Smooth shelled genera are selected as types for the various types of outlines, because such forms seem to represent the generalized stock in which siphuncular modification took place, while ornamented or otherwise specialized forms show scarcely any deviation from the types. The application of the names to other families in which the resemblance would be purely homeomorphic is not to be recommended. It is used here largely for brevity.

1. *Michelinoceras Type* (*fig.* 3 *a-b*).—This is not an ephebic feature in any of the Pseudorthoceratidæ which are cyrtochoanitic by definition, but it is found in the early stages. The siphuncle is orthochoanitic, consisting of vertical septal necks and connecting rings which are either cylindrical or very faintly expanded within the cameræ. The interior of the siphuncle may appear to be somewhat contracted at the region of the septal foramen, but this is attributed to the difference in the thickness of the septal necks and the connecting rings, which are aligned externally. The neck is vertical, which is the essential criterion of the orthochoanitic condition, and the outline of the exterior of the siphuncle is essentially cylindrical. The condition is typical of the ephebic segments of *Michelinoceras* Foerste, but is

Fig. 3. Types of siphuncular outlines.

A. *Michelinoceras* type.—Orthochoanitic condition with cylindrical outline.
B. Nepionic *Michelinoceras*.—A false cyrtochoanitic condition of the interior results from the great difference in thickness of neck and connecting ring in proportion to the siphuncle segment.
C. *Anastomoceras*.—A simple cyrtochoanitic condition, with the brim vestigial and no area of adnation.
D. Nepionic *Dolorthoceras*.—The brim and area of adnation are one-half the neck; the connecting ring is slightly and nearly uniformly convex.
E. Ephebic *Dolorthoceras*.—The brim increases and is subequal to the neck; the area of adnation remains one-half the neck. The connecting ring tends to be less curved in the middle of the segment, but is still convex throughout.
F. *Adnatoceras*.—The brim and area of adnation are subequal and slightly greater than the neck. The middle of the segment becomes straight, curvature being confined to the ends.
G. *Euloxoceras*.—The brim and area of adnation increase further. The expansion is confined to the ends of the segment; the middle of each segment becomes faintly concave. Expansion is slightly greater on the venter, shown on the left.
H. *Pseudorthoceras*.—The neck, brim and area of adnation are the same as in *Dolorthoceras*, but the segment becomes markedly convex, varying from pyriform to subglobular.


A
ephebic
Michelinoceras
C
ephebic
Anastomoceras
E
ephebic
Dolorthoceras
G
ephebic
Euloxoceras
B
nepionic
Michelinoceras
D
nepionic
Dolorthoceras
F
ephebic
Adnatoceras
H
ephebic
Pseudorthoceras

not found in the ephebic stage of the Pseudorthoceratidæ. It has been noted in the early portions of *Pseudorthoceras, Dolorthoceras* and *Spyroceras*, the only genera for which sufficiently early portions of the phragmocone are available at present.

2. *Anastomoceras Type* (*fig.* 3 *c*).—This is the first of the cyrtochoanitic types found in the ephebic stage of a member of the Pseudorthoceratidæ. Siphuncular expansion is slight and is due more to the convexity of the connecting ring than to the septal neck. The neck is slightly recurved, but is without the development of a definite brim. There is no area of adnation. This type of structure is characteristic of the ephebic siphuncular segments of *Anastomoceras* Flower, n. gen., of the Lower Devonian. It has been noted in the early stages of *Pseudorthoceras, Dolorthoceras, Spyroceras* and *Mooreoceras*.

3. *Neanic Dolorthoceras Type* (*fig.* 3 *d*).—This is a shade more specialized than the preceding. The brim and area of adnation are developed, subequal, and are about one-half the neck. The outline of the free part of the connecting ring is faintly convex throughout. This is an ephebic feature in the earliest known species of *Dolorthoceras*, including *D. parlenese* (Williams) of the Oriskanian of Maine, and *D. rudis* (Hall) of the Onondaga limestone of New York. The separation of these species into a distinct genus has not seemed advisable in view of the gradation of the ephebic siphuncular outlines of these forms into the typical ephebic *Dolorthoceras* type of outline which characterizes Hamilton and younger species of *Dolorthoceras*. The neanic *Dolorthoceras* type appears to be an ephebic character in *Diagoceras*, although the condition of the area of adnation is not known and the free part of the connecting ring seems to be slightly more convex than is typical. It is present in ephebic *Sceptrites*, and is persistent in *Spyroceras* extending farther orad in that genus than in Hamilton species of *Dolorthoceras*. It is found in the early stages of Hamilton and later *Dolorthoceras, Petryoceras, Mooreoceras, Pseudorthoceras* and *Cayutoceras*.

4. *Dolorthoceras Type* (*fig.* 3 *e*).—The brim and neck are subequal and about twice the area of adnation, for while the brim increases beyond the neanic *Dolorthoceras* stage, the area of adnation remains static. The connecting ring is strongly curved at the ends but is only faintly convex in the middle. This type of structure appears in the ephebic siphuncular segments of *Dolorthoceras, Petryoceras, Palmeroceras, Spyroceras, Geisonoceroides, Cayutoceras, Fusicoceras* and *Cryptorthoceras*. It is found in the early stages of *Pseudorthoceras* and *Mooreoceras*. Indeed, some species of *Mooreoceras* can hardly be said to pass beyond this stage, but may be distinguished by the form of siphonal deposits.

5. *Adnatoceras Type* (*fig.* 3 *f*).—The brim and area of adnation are subequal and are slightly greater than the neck. This form type can be readily distinguished by the form of the connecting ring which is straight over the middle portion and abruptly curved at the ends. It is known only in the ephebic siphuncular segments of *Adnatoceras*. *Palmeroceras* is intermediate between *Adnatoceras* and *Dolorthoceras* in the form of the siphuncular segments.

6. *Euloxoceras Type* (*fig.* 3 *g*).—The brim and the transverse part of the connecting ring are easily three times the neck. The area of adnation is nearly twice the neck. The siphuncular segments are contracted strongly at the ends, and are faintly concave in the middle. This type is found only in ephebic *Euloxoceras*,

the ontogeny of which is unfortunately not known.

7. *Pseudorthoceras Type* (*fig.* 3 *h*).—The brim and neck are subequal as in the *Dolorthoceras* type. The area of adnation is less than the brim and is occasionally vestigial. The free part of the connecting ring is more or less convex, forming siphuncular segments which may vary from pyriform to subglobular in form. This is found in the ephebic segments of *Pseudorthoceras, Mooreoceras, Paraloxoceras, Bergeceras* and *Bradfordoceras*. The development of this type of outline in *Bradfordoceras* is independant of that of the other genera which are closely

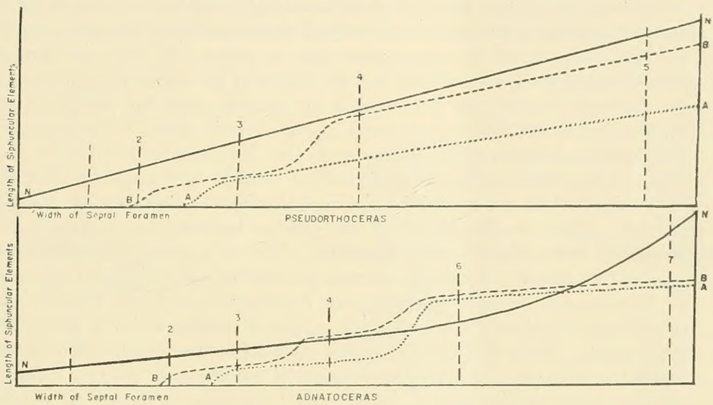


Fig. 4.—Development of brim, neck and area of adnation in *Pseudorthoceras* and *Adnatoceras;* N, length of septal neck; B, length of brim; A, length of area of adnation.

Generic stages repeated in the ontogeny are typically represented at the sections indicated by vertical lines: 1, *Michelinoceras* stage, orthochoanitic; 2, *Anastomoceras* stage, cyrtochoanitic, brim vestigial, area of adnation wanting; 3, Nepionic *Dolorthoceras* stage, brim and area subequal and about one-half the neck; 4, Ephebic *Dolorthoceras* stage, brim and neck subequal, area one-half the neck; 5, Late ephebic condition found in *Pseudorthoceras*.

The development of the *Pseudorthoceras* type of outline from the ephebic *Dolorthoceras* type results in no essential change in the relationship of neck, brim and area of adnation, but only in the increased convexity of the connecting ring. In late ephebic individuals the brim and area are apparently reduced; when measurements are considered the reduction can be seen to be only relative, as shows here.

6, *Adnatoceras* stage, the brim and area are subequal and are greater than the neck; 7, Gerontic *Adnatoceras* condition, the brim and area of adnation become reduced in proportion to the septal neck. However, reduction is apparent rather than real, and is due to the rapid increase in the septal neck.

Pseudorthoceras is based on measurements of *P. knoxense*. The first two stages of *Adnatoceras* are based upon *Dolorthoceras*, sufficiently early stages of *Adnatoceras* being unknown. Stages beyond 2 are known from *A. spissum*.

related to each other.

The first four types follow each other in the order named whenever adequate early stages have been observed (fig. 4). Beyond the *Dolorthoceras* type expansion may occur in either of two ways. In *Adnatoceras* and *Euloxoceras* the segments remain slender in form, expanding at the ends, but becoming first straight and then concave in the middle. The expanded condition is brought about by the increase in the brim and the transverse part of the connecting ring at one end, and the increase of the area of adnation and a free transverse part of the connecting ring on the other end of the segment. In the *Pseudorthoceras* type, on the other hand, the condition of brim, neck and area of adnation remains largely unchanged. The condition found is essentially that of *Dolorthoceras*, but expansion is brought about by the increase convexity of the free part of the connecting ring (fig. 4).

What may be gerontic reversion to an ancestral condition has been noted in *Adnatoceras spissum*, the earliest and simplest representative of the genus known. After the attainment of the *Adnatoceras* type of outline, the brim and area of adnation become gradually reduced, and the outline of the segments become much more uniformly curved, thus producing in the gerontic stage fair replicas of the *Dolorthoceras*, neanic *Dolorthoceras* and *Anastomoceras* types. This reverses the ontogenetic progression and also the evolution. The appearance of similar phenomena in the Actinoceroidea suggests another solution than atavism. Here the earliest stages which are preceded by a small depressed protoconch are broadly expanded. There is no evidence of any relation between the group and any cephalopods with orthochoanitic siphuncles. Yet in a group of Cincinnatian species of *Ormoceras*[24], successive segments pass through generic stages beginning with *Armenoceras*, through *Ormoceras* and *Deiroceras*, and finally attain in segments similar to those of *Leurorthoceras* a type of outline which is practically orthochoanitic. Here it is hardly possible to interpret the simplification of the siphuncular outline to a reversion to an ancestral condition, for such an ancestral condition cannot be demonstrated. Kobayashi[25] noted the similarity between the siphuncular outlines of the Stereoplasmoceratidæ and certain of the Sactoceratidæ, and suggested a common origin of *Sactoceras* and *Stereoplasmoceras* in the genus *Sactorthoceras* Kobayashi. This is opposed not only by the ontogeny of the Actinoceroidea, but also by the fundamental differences in the organization of the siphonal deposits, and Kobayashi's position is hardly tenable.

The reduction of siphuncular expansion in *Actinoceras* itself is well marked, but it is confined to the gerontic portion of the phragmocone, that part secreted during the slight apertural contraction which occurs in the gerontic stage. The simplification of the siphuncle in both the Actinoceroidea and in *Adnatoceras* seems to be a result of an increase in the rate of expansion of the septal foramen. This causes the minimum diameter of the siphuncle to increase more rapidly than the maximum diameter, causing a gradual reduction in the expansion of the siphuncular segment. Attendant modifications of the outline will naturally follow, but no radical changes are initiated; rather the complexities of the outline gradually disappear and the result is one of simplification rather than atavism.

24 The exact generic reference is not beyond question in view of the marked changes in the siphuncular outlines. Doubtless species which have been placed in *Deiroceras* are congeneric, and it is possible that some species referred to *Armenoceras* may also be closely related.

25 Kobayashi, T.: *On the Stereoplasmoceratidæ*, Japanese Jour. Geol. Geogr., vol. 13, No. 3-4, 1936, p. 234.

SIPHONAL DEPOSITS

MORPHOLOGY

Annulosiphonate deposits, the only type of siphonal deposits which is relevant to a discussion of the Pseudorthoceratidæ, consist in their simplest state of small circumferentially complete rings formed within the septal foramen of nautiloid cephalopods. A section through a ring will show that it is made up of lamellæ arranged about a center of deposition which is adjacent to the septal neck.. Hypothetically the simplest ring is the *annulus* (fig. 5A) which is attached by its outer surface or some part of it to the septal neck, while the remainder of the surface, which is free, is everywhere equidistant from the center of deposition. This condition is normally found only in the earliest stage of growth of an annulosiphonate deposit.

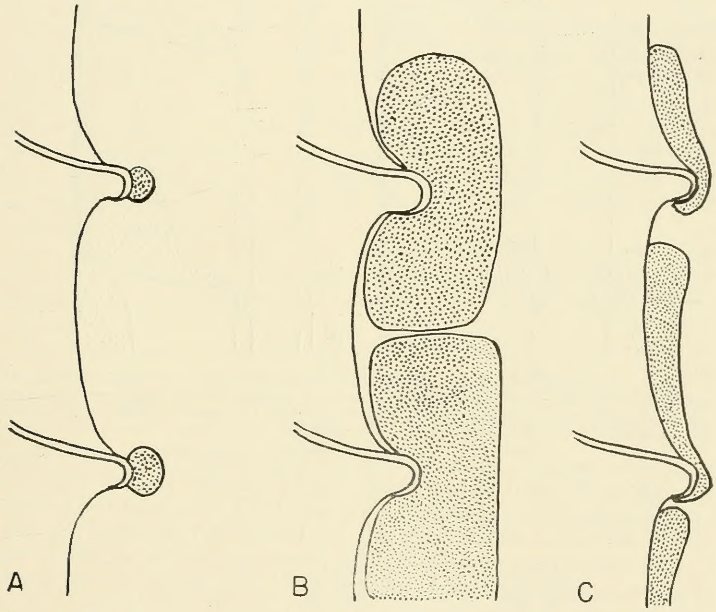


Fig. 5. Types of annulosiphonate siphonal deposits.

A. The annulus.—Free surface regular in growth, equidistant from center of deposition. Developed only against septal neck.

B. Pendant deposits.—Deposit hangs free within the siphuncle, being attached only at the septal necks.

C. Partietal deposits.—Deposit extends along the wall of the siphuncle. Deposits may or may not fuse to form a continuous lining.

Annulosiphonate deposits may vary greatly in form and may be divided into several categories. Teichert[26] proposed to divide the deposits into two groups which he termed *centripetal* and *centrifugal.* While these groups are probably of fundamental importance, the terms which were proposed for them have been found to be somewhat confusing and not entirely descriptive. New terms are proposed here which it is hoped will be simpler and more descriptive.

PENDANT DEPOSITS, which correspond to the centripetal deposits of Teichert, originate from the septal neck and develop markedly inward, constricting the endosiphuncular cavity, often to a remarkable degree. These deposits hang upon the septal necks at which they are formed, and are never in contact with the free part of the connecting ring, but are separated from it by the *perispatium* (fig. 5B).

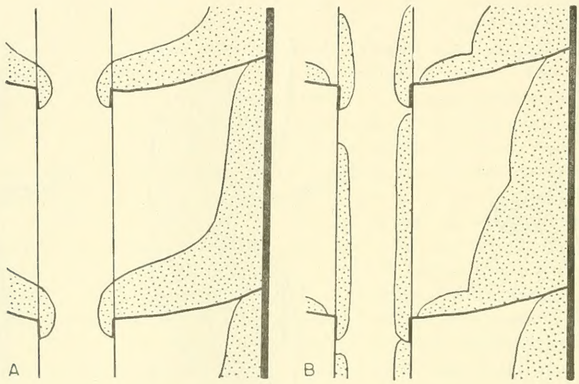


Fig. 6. Diagrammatic sections through phragmocones showing difference between (A) orthoceroid deposits, in which cameral and siphonal deposits develop equally along the connecting ring, and (B) pseudorthoceroid deposits, in which the siphonal deposit develops along the connecting ring independent of cameral structures.

PARIETAL DEPOSITS, which correspond to the centrifugal deposits of Teichert, originate at the septal necks but never develop markedly inward. They grow mainly by the addition of material to the adoral or adapical ends of the deposit, and lie close against the connecting ring. No perispatium is developed (fig. 5C).

Two distinct types of parietal annulosiphonate deposits are recognized here. The first of these, the ORTHOCEROID DEPOSIT (fig. 6A) consists of small annulosiphonate rings which are extended considerably adorally from the septal foramen, but are scarcely produced adapically. The deposit rarely extends half the length of a camera. This is because the extent of the development along the inside of the connecting ring is limited by and commensurate with the development of cameral deposits outside of the ring.

The second type, the PSEUDORTHOCEROID DEPOSIT (fig. 6B) differs from the orthoceroid deposit in appearance, for the adoral extension of the deposits has

[26] Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, p. 127.

proceeded to such an extent that adjacent deposits fuse to form an apparently continuous lining within the siphuncle. The early stages of the pseudorthoceroid deposit resemble the orthoceroid deposits in form, and are probably derived from them. The fundamental change involved in the development of the pseudorthoceroid deposit is the ability of the siphonal deposit to extend along the connecting ring independent of cameral deposits.

ONTOGENY

The development of the annulosiphonate deposits is very different from that of the ectosiphuncle already discussed above. In serially repeated parts ontogeny may work in two ways. First, there is the ontogeny of unalterable serial parts, parts which once secreted must remain unchanged. Here the oldest and earliest member of the series retains the earliest stage in the ontogeny, and in tracing the series from the oldest to the youngest member the ontogeny may be reviewed. This is exemplified in the sutures and siphuncular segments of cephalopods.

Second, there is the ontogeny of serial alterable parts which in one way or another may be modified by growth. Such modification is widespread. It may affect the exoskeletal parts by moulting as in the Arthropoda; it may affect endoskeletal parts which may be modified by resorption or addition of material; it may affect shell structures which may be modified by addition or resorption or by both. In such a series of parts the oldest part which has undergone the most modification shows not the earliest but the latest stage in ontogeny, while the last formed part may show the youngest ontogenetic stage. This is essentially Jackson's[27] principle of localized stages of development.

The siphonal deposits exhibit only the normal series of the ontogenetic progression of alterable parts. The youngest deposit, that nearest the aperture, shows the earliest ontogenetic stage, and as the series is traced apicad older deposits are encountered which show more and more advanced stages. In the Pseudorthoceratidæ three regions of the siphuncle can be recognized on the basis of the developmental stages of the deposits. There is an adoral portion of the siphuncle which has no deposits. This may vary from one to thirty cameræ, and is constant within the growth stage of a species. The number of vacant cameræ is not, however, the same for neanic, ephebic and gerontic individuals.

There follows a region in which deposits can be traced through their various stages of growth as they are traced apicad in the conch from their inception. This is succeeded by a region in which the deposits have attained maturity and do not develop farther.

ANNULOSIPHONATE DEPOSITS OF THE PSEUDORTHOCERATIDÆ

The Pseudorthoceratidæ are characterized by the pseudorthoceroid type of siphonal deposit described above. However, within the family there is considerable variation of the development and structure of the deposits of the siphuncle. Some types hark back to simpler and presumably ancestral annulosiphonate conditions; these are ontogenetic and presumably recapitulatory. Other deviations are clearly cenogenetic, and may affect all stages of growth. The following types seem significant enough to be given names:—

27 Jackson, R. T.: *Localized stages of development in plants and animals*, Boston Soc. Nat. Hist., Mem., vol. 5, 1899, p. 89-153, pl. 16-25.

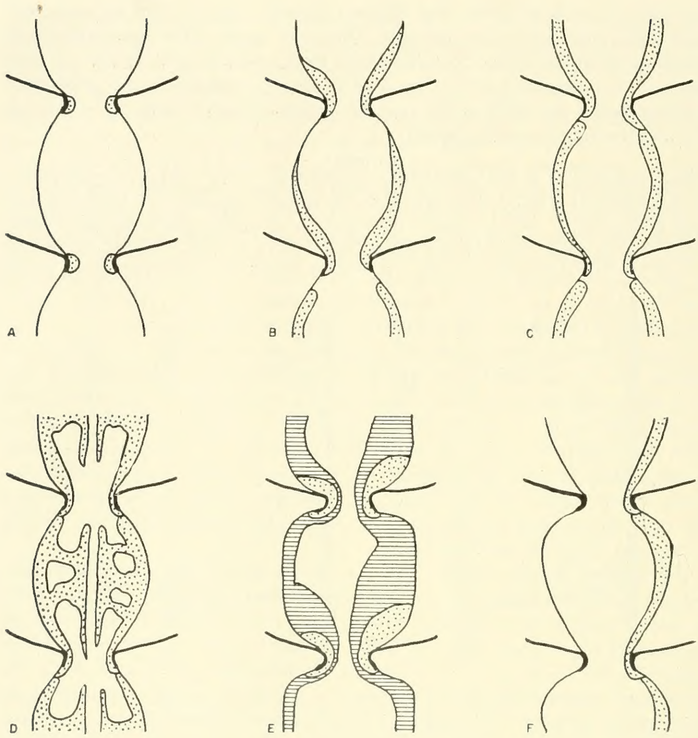


Fig. 7. Types of siphonal deposits of the Pseudorthoceratidæ.
(All sections are vertical, with the venter on the right.)

A. The simple annulus, the earliest stage of annulosiphonate deposits.

B. *Michelinoceras* type, the intermediate stage of siphonal deposits in the Pseudorthoceratidæ. Deposits are extended orad but have not yet fused.

C. *Dolorthoceras* type, in which the deposits have extended farther orad until they have joined to make a continuous lining within the siphuncle. Characteristic of the ephebic stage in the Dolorthoceratinæ.

D. *Anastamoceras* type, a gerontic deposit found only in the genus *Anastamoceras*. A central canal is connected to the *Dolorthoceras* type of deposit by irregular radial pillars.

E. *Cayutoceras* type, confined to the Cayutoceratinæ. Discrete calcareous deposits are enclosed in carbonaceous fused segmental deposits.

F. *Pseudorthoceras* type, in which a continuous lining is formed on the venter before the deposit appears at all on the mid-dorsal region.

1. *The Simple* ANNULUS (fig. 7A).—This, as already mentioned, consists of a simple ring attached by its exterior surface to the septal foramen. The inner surface of the ring is free, and is everywhere equidistant from the center of de-

position, producing a semicircular appearance in section (fig. 5 A). This condition is found in the earliest stages of the siphonal deposits of all annulosiphonate nautiloids, and is suggestive of the common origin of all such forms. Included in the group are the annulosiphonate orthochoanites, the Pseudorthoceratidæ and the Actinoceroidea. At the present time morphological and ontogenetic evidence seems to indicate that the Actinoceroidea may be very distinct from the other groups and that its annulosiphonate deposits may have been developed independently of the others.

2. *The Michelinoceras Type* (fig 7B).—This is essentially the orthoceroid type of parietal deposit so far as the form of the deposit alone is concerned. The deposit is extended considerably orad of the septal neck, but is scarcely extended apically if at all. The interrelation between cameral and siphonal deposits in the orthochoanites fixes this as an ephebic feature there, but in the Pseudorthoceratidæ the siphonal deposits develop over the connecting ring independent of cameral structures, and consequently the condition of discrete annulosiphonate rings is a neanic feature rather than an ephebic one. Its identity in form with the orthoceroid deposit as developed in *Michelinoceras* and its allies is suggestive of the origin of the pseudorthoceroid deposit in the orthoceroid deposit. Inasmuch as the orthoceroid type implies an interrelationship between cameral and siphonal deposits which does not exist here, the term *Michelinoceras* stage is found desirable.

The *Michelinoceras* type of deposit has been noted in the neanic deposits of all Pseudorthoceratidæ for which the ontogeny is known. It is typically developed in the early stages of *Anastomoceras, Dolorthoceras, Spyroceras, Fusicoceras* and *Adnatoceras,* and is somewhat modified although still recognizable in *Pseudorthoceras, Mooreoceras* and *Cayutoceras,* which are specialized.

3. *The Dolorthoceras Type* (fig. 7C).—The end of the adoral extension of the annulosiphonate deposits of the *Michelinoceras* type is attained when adjacent deposits meet, and a continuous lining of segmental origin is formed within the siphuncle. This is the *Dolorthoceras* type which is characteristic of the subfamily Dolorthoceratinæ in the ephebic stage. Though deposits appear first on the venter and are thickest there, the adjacent rings do not fuse to form a continuous lining of the siphuncle on the venter before they appear on the dorsum. The deposit is simple and not differentiated into two distinct layers.

4. *The Anastomoceras Type* (fig. 7D).—This type is derived from the *Dolorthoceras* type which precedes it in development, by the formation of a central core in each segment, apparently about a central vascular tube. The core is connected with the *Dolorthoceras* type of deposit by irregular anastamosing radial processes. This is known only in the genus *Anastomoceras* of the Dolorthoceratinæ, of which it is apparently a gerontic feature.

5. *The Cayutoceras Type* (fig. 7E).—This type is another derivative from the more generalized *Dolorthoceras* type. Here the siphonal deposit has become differentiated into two layers. A primary layer is calcareous and consists of

discrete deposits of the *Michelinoceras* type. This is covered by a carbonaceous outer layer which consists of fused segmental elements essentially of the *Dolorthoceras* type. This type of structure is confined to *Cayutoceras* and *Bradfordoceras* which make up the Cayutoceratinæ. Transitional types connect the *Cayutoceras* type with the *Dolorthoceras* type. The structure is strongly reminiscent of *Westonoceras* of the Upper Ordovician, but the demonstrable relationship of *Cayutoceras* to *Dolorthoceras* shows that the resemblance to *Westonoceras* is merely isomorphic.

6. *The Pseudorthoceras Type* (fig. 7F).—This differs from the *Dolorthoceras* type in the extreme dorso-ventral differentiation of the siphonal deposits. The annuli are incomplete, forming first on the venter. The deposit grows orad from the septal foramen rapidly, while lateral growth is slow. The result is that a complete lining is formed on the venter before the rings are completed dorsally. Further growth of the deposit is brought about mainly by the addition of material to the lateral margins of the calcareous mass, and finally the two edges meet on the mid-dorsal line. This type of development is found in the Pseudorthoceratinæ. The simple annulus and the *Michelinoceras* stage can be recognized in development but owing to the retardation of the secretion on the dorsum the pattern is distorted. Nevertheless the stages can be recognized, appearing first on the venter and only much later on the dorsum.

In the neanic segments of *Pseudorthoceras* a further modification appears. The deposit never becomes completed dorsally. It is suspected, although the evidence cannot be considered conclusive as yet, that this condition becomes an ephebic feature in *Mooreoceras*, at least in part. In *Paraloxoceras* and *Bergoceras* the siphonal deposits become greatly thickened and radial canals are developed in them.

CAMERAL DEPOSITS[28]

ORGANIC AND INORGANIC CAMERAL DEPOSITS

The presence of various calcareous structures within the cameræ of cephalopods has long been recognized, but until recently they have been given little attention. Barrande, Hyatt, Hall and Ruedemann recognized these structures as organic, and Hall[29] discussed them in some detail and offered some speculations as to their origin. However, the majority of paleontologists have preferred to tread on safer ground and to leave alone structures which have no counterpart in any living form and which might after all turn out to be due to the deposition of infiltrated material after the death of the organism.

It remained for Teichert[30] to point out some of the differences between organic and inorganic structures. It is necessary to consider these and additional differ-

[28] These structures have been referred to as intracameral deposits by various authors. Intracameral implies that there are also intercameral or extracameral deposits which it is necessary to differentiate by the use of these prefixes. As there are no such deposits, the use of the prefix seems unnecessary, and its elimination serves to shorten the term and, it is hoped, will tend to produce a less formidable nomenclature than that in general use.

[29] Hall, J.: Paleontology of New York, vol. 5, pt. 2, 1879, pp. 240, 245-9, 250, 256, 279-80.

[30] Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, pp. 181-188.

ences before proceeding to the structure and taxonomic value of organic cameral deposits.

Inorganic deposits, of not only the cameræ but also the siphuncles of cephalopods are often difficult to distinguish from organic structures, but it can be demonstrated that organic and inorganic deposits differ in their mode of occurrence. Organic deposits are formed in accordance with the symmetry and growth of the organism. Inorganic deposits bear no such relation to the shell; they are formed as geodic fillings of cavities, either as complete fillings of hollow cameræ, or as complemental fillings of incomplete internal molds.

Inorganic Deposits.—Within a closed cavity such as a camera which retains its walls and siphuncle intact infiltrated material is deposited evenly and uniformly over the inner surface. The first layers are normally thin and cryptocrystalline. Such layers often resemble the lamellæ of growth of an organic deposit. Successive layers become gradually thicker and of coarser texture, and in the center of the cavity large crystals of calcite can be made out. In section this type of filling may occasionally resemble episeptal and hyposeptal deposits in an advanced stage of growth, but the condition can be recognized as inorganic by the uniform layers formed over the connecting ring. A FALSE PSEUDOSEPTUM[31] may be developed, running from the adoral outer corner of the camera to the central cavity occupied by coarse crystalline material, but not infrequently another similar line may be found running to the central adapical or adoral corner, or both, next to the siphuncle.

The shape of the camera seems to be a factor in the development of the false pseudoseptum. It is best seen in very shallow cameræ. The principles which govern the distribution of such a deposit are those governing the deposition of crystalline material in a hollow cavity. There is only one requirement for this type of structure: that the camera remain closed so that no material in suspension in water can enter. Deposition is chemical and follows saturation. Consequently this type of structure can occur in any closed camera, regardless of its proximity to the living chamber. Not infrequently cameræ containing such organic deposits are found erratically spaced, alternating with cameræ which have become filled with sediment.

The incomplete internal mold depends upon the invasion of sediments which fill the cameræ only in part. Such sediments normally sink to the bottom of the camera, and the uppermost portion remains hollow, later to be filled in with calcite or other mineral substance after the burial of the conch. This calcite, which may often resemble organic deposits, is dependent not on the symmetry of the conch, but upon gravity and the position of the conch in the sediments. The peculiar features of the incomplete internal mold are to be found not only in the cameræ, but also in the siphuncle. The apparent deposit in the siphuncle of *Adnatoceras naplense* Flower, n, sp., is of this type (Pl. 3, fig. 2) the dark matrix occupying the lower part of the siphuncle as it lay in the sediments, while the upper part was originally left vacant and was later filled in by calcite.

31 The term PSEUDOSEPTUM, as shown below, refers to the line along which organic episeptal and hyposeptal deposits of the cameræ meet when well developed.

The condition of the incomplete internal mold of the cameræ may be somewhat different if the invading sediment was introduced through the siphuncle. In such instances the wall of the siphuncle, usually the connecting ring, is broken and is frequently entirely destroyed. If this occurs soon after the death of the organism the sediments may be washed into the cameræ and arrange themselves on the lower side in the same manner as though the break had been in the wall of the conch. If, however, the sediments of the siphuncle have been partially consolidated, further pressure, possibly derived from the weight of overlying accumulating sediments may force the partially solidified material within the siphuncle to invade the cameræ, breaking the connecting rings. This has been observed in a number of orthoceracones from the Richmond of Indiana and Ohio. Teichert[32] has illustrated and described a specimen of *Armenoceras danicum* Teichert in which the invasion of such material seems to have been stopped by some substance which has later been destroyed and which might, as Teichert suggests, indicate that the invading material was blocked by a tissue which later decayed, disappeared, and left a cavity which was finally filled in by infiltrated calcite. As it is evident that tissue must have been present in the cameræ, it is quite possible that its presence at the time when invading sediments entered the conch might account for some of the peculiar phenomena of the relative distribution of sediment and matrix which cannot, or at least up to the present have not been explained in any other way.

Organic Deposits.—The organic deposits can be distinguished from inorganic deposits by several characteristics which indicate that they were formed in accordance with laws governing the growth and bilateral symmetry of the organism as a whole, and are independent of breaks at either end of the shell. The number of cameræ which contain no trace of deposits is constant for the growth stage within the species. Individuals in the same stage of growth will show a constant number of vacant cameræ, but individuals of a species representing different stages of growth are not necessarily comparable. It has been found, however, that in the greater number of orthoceraconic species examined, there is no preceptible variation in this respect between neanic and ephebic individuals, and that gerontic variation is the exception rather than the rule. Tracing deposits apicad from their inception successive growth stages are found, and in the Pseudorthoceratidæ there is a well defined region in which deposits are mature and growth has stopped. In other orthoceracones the mature region is less clearly defined, but a stage is reached in which there is no detectable difference in the amount of deposit in a considerable series of apical cameræ which might not be due to variation in size of the cameræ.

The inner surface of the cameral deposit shows a bilaterally symmetrical pattern, and usually there is a marked concentration of the deposits on the ventral side of the conch. The symmetry of the cameral deposits is in accordance with the symmetry of the conch as a whole, as is shown by correlation with the dorsai

[32] Teichert, C.: *Einige actinoceroide Cephalopoden aus dänischen Diluvialgeschieben und aus dem Gotlandium Skandinaviens,* Meddelelser fra Dansk Geologisk Forening, Bd. 8, hft. 4, 1934, p. 374-380, pl. 8, figs. 1-2.

furrow, the conchial furrow and the aperture.

Furthermore, it has been possible to demonstrate by marking in the field the upper or lower side of the specimen as it lay in the matrix, that the dorso-ventral distribution of the deposit is independent of the position of the conch in the sediments, and is therefore not affected by gravity as is the complemental filling of the incomplete internal mold. Though the accumulation of the greater part of the mass of the cameral deposits on the venter often causes the conch to come to rest with the venter beneath, numerous examples are known in which the conch lay on a dorsal or lateral surface. *Euloxoceras,* because of its compressed form, is commonly found resting on a lateral surface, but the deposits are concentrated ventrally.

Striacoceras typus (Saemann) of the Cherry Valley limestone of the Middle Devonian has been an excellent species in which to study the independence of cameral deposits to the orientation of the conch in the matrix. It is possible to separate large slabs of the limestone along bedding planes, exposing the upper or lower surface, as the case may be, of a prolific cephalopod assemblage. In such slabs (one of which is on exhibition in the New York State Museum and has recently been figured by Miller[33]) when numerous specimens are exposed and the position of the bedding plane is evident, determination of the matter is not difficult.

The complexity of the lobation when considered with its symmetry furnishes additional evidence of the organic nature of cameral deposits. The interior often bears a fine and elaborate pattern which is constant within the species. More general features hold throughout generic or higher groups. In general the four regions of the cameral deposit noted above in *Pseudorthoceras knoxense* seem to hold fairly well throughout all stenosiphonate orthoceracones with mural deposits.

The similarity of the fine texture of the cameral deposits with that of the molluscan shell offers further evidence of the organic nature of the cameral deposits, although not conclusive by itself.

The independence of the cameral deposits from the character of the surrounding sediment shows that the structure is original in the shell and eliminates at least the possibility of geodic filling. Remarkably clear impressions of such deposits are sometimes found on flattened internal molds from the Ithaca shale, in which the original shell material was completely dissolved. Again in the Oriskany sandstone, generally a medium unfavorable for the preservation of fine structural detail, well defined cameral deposits have been found. *Striacoceras typus* shows well developed deposits although differently preserved under different conditions. The species is found not only in the Cherry Valley limestone proper, but in an unnamed argillaceous lens in the limestone at Cherry Valley, and in the soft black shales which are the equivalent of the limestone in eastern New York.

Almost any specimen with deposits preserved will show that the deposits were present before sediments entered the cameræ. Specimens of *Pseudorthoceras knoxense* further show that not only did the deposits precede the breaking of the shell, but that they were a determining factor in the resistance to pressure during

33 Miller, A. K.: *Devonian ammonoids of America*, Geol. Soc. Amer., Special paper, No. 14, 1938, pl. 1.

the consolidation of the sediments. The living chamber is not known for the species. Further, there has been as yet no record of adoral cameræ which contain no deposits. The species is known then, entirely from apical portions of the phragmocone. Such specimens may be broken both adapically and adorally, but flattening is confined to the adoral end. If such a specimen is sectioned, it will be found that the flattening of the cameræ decreases apicad in proportion to the increase in the mass of cameral deposits. The unflattened condition of the apex is due to the added strength which these structures give to the shell.

Perhaps the best criterion of the organic nature of the deposits is that they are not common to all chambered shells but are confined to a relatively small though seemingly heterogeneous group of forms. Furthermore, the form of the deposit is constant within the species. The specific character of the deposits gives them taxonomic value. Cephalopods known to possess cameral deposits may be grouped as follows:—

1. Orthoceracones of the Orthochoanites, Actinoceroidea, Pseudorthoceratidæ and Stereoplasmoceratidæ.

2. Cyrtoceracones derived from orthoceracones of the above groups. This includes *Troostoceras* Foerste and Teichert of the Actinoceroidea, *Sceptrites* Flower, n. gen., of the Pseudorthoceratidæ and such species as "*Oöceras*" *perkinsi* Ruedemann which are evidently cyrtoconic Stereoplasmoceratidæ and are possibly referrable to *Cyrtoönoceras* Kobayashi.

3. Brevicones of several genera. Except for *Poterioceras* McCoy *sensu stricto*, which is probably not closely related to other brevicones, the deposits are vestigial and appear only in the gerontic stage. It is suspected that vestigial gerontic cameral deposits may be widespread among actinosiphonate brevicones, for while they have been thus far observed in only a very few genera, those genera are rather widely distributed and not closely related. Thus far deposits have been noted in *Hexameroceras, Brevicoceras, Herkimeroceras, Acleistoceras* and *Worthenoceras.*

4. The only known occurrence in gyroceracones of any kind is confined to a peculiar Middle Devonian genus, now in process of description, of which *Gomphoceras* (?) *cruciferum* Hall of the Schoharie grit of the Middle Devonian is the only described representative.

Cameral deposits are not known in many early Paleozoic orthochoanitic orthoceracones. They appear to be uniformly absent in orthochoanitic longiconic cyrtoceracones, gyroceracones, and in all nautilicones and trochoceroids. They are not known in the cameræ of Holochoanites. Organic deposits were reported in *Vaginoceras oppletum* of the Chazy limestone, by Ruedemann[34]. The uniform condition of the deposits on the interior of the camera and the obviously erratic development of several false pseudosepta in one camera suggest inorganic structures. At the present time the possibility of a connection between the cameræ

[34] Ruedemann, R.: *Cephalopoda of the Champlain basin*, New York State Museum, Bull. No. 90, 1906, p. 413-415, pl. 4, fig. 3; pl. 5, figs. 1-4; pl. 6, fig. 1; pl. 9, figs. 1-3.

and the organism in Holochoanites seems remote.

It should be noted that aside from the original organic deposits and inorganic deposits mentioned above, there are frequently found irregular patches of calcite in the shell surrounded by sediment, for which neither explanation seems entirely satisfactory. Such patches appear to represent cameral tissue which was present at the time of burial of the conch and the filling of the cameræ by sediments, but was later destroyed and the space which it formerly occupied became filled by inorganic material.

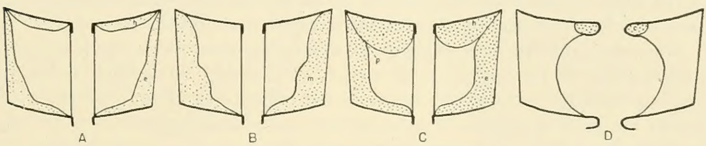


Fig. 8. Longitudinal sections of cameræ illustrating various types of cameral deposits.
A. Early stage in development of episeptal and hyposeptal deposits.
B. Mural deposits, modified episeptal deposits in the absence of hyposeptal deposits.
C. Advanced stage of episeptal and hyposeptal deposits showing the pseudoseptum.
D. The circulus, a specialization of the hyposeptal deposits; *c*, circulus; *e*, episeptal deposits; *h*, hyposeptal deposits; *m*, mural deposits; *p*, pseudoseptum.

MORPHOLOGY

Teichert[35] presented a classification and terminology for the cameral deposits, which is based entirely upon their distribution in the cameræ as seen in longitudinal section. Teichert's terminology is slightly modified and supplemented here. The following types can be recognized:—

1. *Episeptal Deposits* (*fig.* 8*A, C*).—The episeptal deposits, proposed by Teichert, form against the adapical septum of the camera both against the free and mural parts, but do not attain the adoral septum.

2. *Mural Deposits* (*fig.* 8*B*).—These are the cirfumferential deposits of Flower[36]. They are a specialized type of episeptal deposit developed in the absence of hyposeptal deposits. They form mainly against the mural part of the septum, and may encroach on the adoral wall as well as on the adapical free part of the septum.

3. *Hyposeptal Deposits* (*h, fig.* 8*A C*).—Deposits which form against the convex adoral wall of the camera.

4. *The Circulus* (*fig.* 8*D*).—This term is here proposed for the Stutzring of Teichert. It is a specialized hyposeptal deposit formed just outside the septal neck, and tends to strengthen it. The English equivalent of Stutzring is somewhat cumbersome. The term collar was previously proposed by me[37], but it was found undesirable as the same term had been used for the prosiphonate ammonoid necks.

[35] Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, pp. 168-171.
[36] Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont., vol. 22, No. 76, 1939, p. 17.
[37] Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont., vol. 22, No. 76, 1936, p. 17.

The circulus is never developed in the Pseudorthoceratidæ, and is so far known only from the Actinoceroidea. Most of the Pseudorthoceratidæ have mural deposits, but instances are known in which episeptal and hyposeptal deposits are developed. This occurs in *Euloxoceras, Cayutoceras* and in *Adnatoceras ciscoënse* Miller, Dunbar and Condra. *Euloxoceras* is derived from *Adnatoceras* in post-Devonian time, and *A. ciscoënse* is closer to it stratigraphically than to any other known species of *Adnatoceras*. It is suspected that the similarity of the cameral deposits represents a genetic relationship in this instance. *Cayutoceras* is not related to the other two, and the appearance of hyposeptal deposits, in the presence of which mural deposits become episeptal, is entirely independent.

Numerous authors have referred to a *pseudoseptum* within the cameræ of cephalopods. If the term is to be used at all it should be confined to the line running from the outer apical corner of the camera apicad and centrad, which marks the point of contact of episeptal and hyposeptal deposits when both are strongly developed. This line never attains the siphuncle, as the deposits are discrete in the central portion. The term pseudoseptum has been used improperly for a line along which inorganic deposits meet, as well as for limonitic bands which represent the margin of episeptal or mural deposits in the cameræ (fig. 8C).

Teichert noted that deposits were normally heavier on the venter than on the dorsum. Cross sections of the cameræ show this unequal distribution in all forms, but it is especially marked in orthochoanitic forms where the inner surface of the cameral deposits is complexly lobed. The best specimens on which to study this lobation are those which by weathering, exfoliation or dolomitization have lost the shell and the cameral deposits, and which retain the molds of the deposits. Such specimens show a characteristic pattern of lobes, striæ and bosses on the internal mold. The details of the sculpture are of specific value, though more general features may be characteristic of higher groups, and a general pattern can be postulated which will hold for most stenosiphonate cephalopods with mural deposits. The pattern exhibited by *Striacoceras typus* (Saemann) of the Cherry Valley limestone has already been described and illustrated[38].

Hall[39] has figured numerous specimens representing various species from the Schoharie grit of the Middle Devonian of New York, which show similar but not identical phenomena, and among Barrande's illustrations in his Système Silurian du Centre de la Bohème there are examples too numerous to cite.

A similar though somewhat more generalized pattern may be seen in orthoceracones of the Richmond which are referrable to the genus *Ormoceras*.

The mural lobation shows several persistent features which may be summarized as follows.—

1. A persistent *ventral sinus* which will appear as a ridge on exfoliated specimens (fig. 9, v).

[38] Flower, R. H.: *Cherry Valley Cephalopods*. Bull. Amer. Paleont., vol. 22, 1936 p. 310, pl. 24, fig. 3; pl. 25, figs. 3-5, 7.

[39] Hall, J., Paleontology of New York, vol. 5, pt. 2, 1879, pl. 35, figs. 5-6; pl. 81. figs. 1-2; pl. 112, figs. 11-15.

2. *Ventro-lateral Masses.*—These are massive and variously lobed, and flank the ventral sinus. In exfoliated specimens these regions are often quite complexly lobed or pitted on the surface (fig. 9, vl).

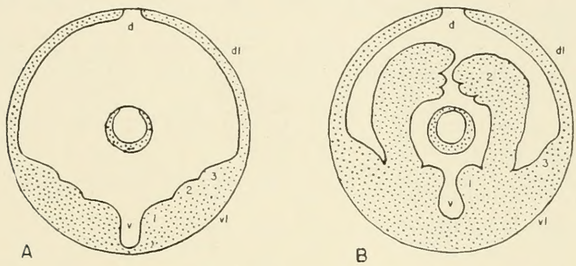


Fig. 9. Cross sections through the cameræ of *Pseudorthoceras*, showing the radial distribution of deposits.

A. Immature deposits.
B. Mature deposits. d, dorsal hiatus; dl, dorso-lateral bands; vl, ventro-lateral masses; v, ventral sinus.
1, 2, and 3, indicate the first, second and third pair of lobes of the ventro-lateral masses.

3. *Dorso-lateral Bands.*—These are relatively thin bands of deposit in comparison to the ventro-lateral masses, and normally present a transversely banded surface in exfoliated specimens. The transition between the dorso-lateral bands and the ventro-lateral masses is usually abrupt, especially in the early stages of the development of the mural deposit, but it is occasionally poorly defined, and in *Ormoceras* the two regions are not well differentiated (fig. 9, dl).

4. *The Dorsal Hiatus.*—This is a small area on the mid-dorsal region, not always extending the length of the mural part of the septum, in which no deposits are laid down. It is, when localized, confined to the adoral portion of the mid-dorsal region of the camera. In position it agrees precisely with the septal furrow, but is a structure of the cameral deposits rather than of the septum (fig. 9, d).

In *Pseudorthoceras knoxense* the ventro-lateral masses are obscurely trilobed in the early stages of development. In the later stages the two outer lobes become obscured, and the inner pair of lobes becomes greatly produced and nearly surrounds the siphuncle (fig. 9 A-B).

It has not been possible to make a detailed study of the lobation of the deposits in any of the Pseudorthoceratidæ except *Pseudorthoceras knoxense*, owing to the limited amount of material available. Dorso-ventral differentiation of the deposits is shown on exfoliated specimens of *Dolorthoceras*, *Adnatoceras*, and *Sceptrites*, and complex sculpture is indicated throughout. In sectioning *D. palmeræ* (Flower and Caster) it was evident that the lobes derived from the ventro-lateral masses nearly surround the siphuncle, as in *Pseudorthoceras*. Exfoliated specimens of Pennsylvanian species of *Mooreoceras* have shown the four main regions noted above. The condition of the lobation of the deposits of *Euloxoceras, Adnatoceras ciscoënse* and *Cayutoceras* is unfortunately unknown, so it is not certain whether the same radial pattern is retained when hyposeptal deposits appear in the Pseudorthoceratidæ.

Investigation of the radial distribution of cameral deposits in other groups of cephalopods is still very incomplete. There is indication of a considerable diversity of structure, but data are at present inadequate for evaluation of the genetic significance of the characters supplied. Quite a distinctive pattern may appear when hyposeptal deposits appear, the main feature of which is a massive mid-ventral deposit. This occurs in *Elrodoceras,* where episeptal and hyposeptal deposits join on the mid-ventral region at a very early stage. In *Leurocycloceras* a similar though more elaborate pattern is developed. *Michelinoceras* (?) *ludlowense* (Miller and Faber) of the Trenton of Kentucky, develops mid-ventral hemispherical bosses on the mural part of the septum, and concentric striæ surround the protuberances. These will be described and illustrated in detail at another time.

ONTOGENY

The deposits of the cameræ, like those of the siphuncle are serially arranged structures and follow the principle of localized stages of development in their growth. All undergo a similar development at a nearly uniform rate until a mature condition is attained. Thus in any species in which deposits are developed the phragmocone may be divided into three regions.—

1. A region of empty cameræ near the living chamber.

2. A region in which deposits are exhibited in successive stages of growth as they are traced apicad.

3. An adapical region, which is increased as the shell grows, in which deposits are mature and undergo no further change. A similar series has been shown for the siphonal deposits. Two main features hold throughout the deposits and are believed to be of fundamental importance:

1. The first trace of cameral deposit is found some distance from the base of the living chamber, and the number of septa between the first trace of deposit and the living chamber is constant for the growth stage within the species. Often this is constant within the species except for the very earliest stages of growth. Certainly it holds for all moderately developed individuals in a considerable number of species.

2. The dorso-ventral differentiation of the cameral deposits varies directly with the distance of the siphuncle from the venter. In species with markedly ventral siphuncles the amount of material secreted against the dorsal and ventral walls may vary only slightly. In species with central siphuncles the dorso-ventral differentiation is more marked, but it reaches its climax in such forms as *Euloxoceras,* in which the siphuncle lies dorsad of the center of the conch. In actinoceroids an additional factor is to be seen, for the dorso-ventral differentiation of the cameral deposit varies inversely with the size of the siphuncle.

MICROSCOPIC STRUCTURE OF CAMERAL DEPOSITS

In general the aragonitic portions of the molluscan shell show in thin section two kinds of markings, lines of growth which represent successive secreting surfaces, and lines oblique, or perpendicular in some sections, which represent the rows of aragonite prisms. Such structures are known in the shells of *Nautilus pompilius*, *Aegoceras planicosta*, and in the guard of *Belemnites*[40].

The organic deposits of the siphuncle and cameræ of *Pseudorthoceras knoxense* retain similar markings under favorable conditions of preservation. Both types of markings have been retained on specimens from the Hazleton Bridge member[41] of the Upper Pennsylvanian of Indiana (Pl. 1, fig. 6). Normally only the lines of growth are preserved, but they may be very clearly shown on silicified specimens.

The fine structure is not in itself diagnostic of the organic nature of the cameral deposits, which is established on other grounds. Such markings in an organic structure are apparently original and indicate that the cameral and siphonal deposits were formed by mantle secretion as are the wall of the conch and the septa.

PART II

SECRETION OF THE SHELL ELEMENTS

TYPES OF SHELL SECRETION

An attack from a physiological point of view may serve to clarify the problems relating to the calcareous deposits of nautiloids under discussion. In all Nautiloidea calcareous material is secreted in three regions:—

1. The secretion of the wall of the conch at the tip of the mantle forming the two outer layers of the shell, and supplemented by the secretion of the thin nacreous layer in a slightly posterior region.

2. The secretion of the septa at the posterior end of the visceral mass.

3. The secretion of the connecting ring by tissues of the siphon.

In orthoceracones two other types of deposit appear:

4. The deposits of the siphuncle, secreted by siphonal tissues.

5. The deposits of the cameræ, secreted by cameral tissues.

On the basis of composition, the shell elements may be divided into two categories, mantle deposits and connecting ring deposits.

[40] Cayeux, M. Y.: *Introduction à l'étude petrographique des roches sédimentaries. Mémoires pour suivre à l'explication de la carte géologique détaile de la France*, Paris, 1931, p. 490-493, pl. 54, figs. 3-6.

[41] Mallot, C. A.: in manuscript.

The connecting ring differs from all other structures of the nautiloid shell in being composed of loosely arranged spicules of calcite. Its origin in *Nautilus* seems to have been given no attention. However a survey of other spicular structures in the animal kingdom shows a mesodermal origin throughout. The silicious spicules of the Porifera are the product of cells in the jellylike layer; the spicules of the Alcyonaria are formed in the mesoglœa. The spicular elements of the skeleton of the Echinodermata are mesodermal, as are the primitive elements of the chordate skeleton. This analogy, one which holds throughout the animal kingdom wherever a study of the soft parts has been made, indicates that the connecting ring of the Nautiloidea may be of mesodermal origin. Further, this is consistent with what can be reconstructed of the tissues of the phragmocone on the basis of a study of calcareous structures and propitiously preserved carbonaceous remnants of tissue. Whether the connecting ring of *Nautilus* is still actually formed within tissue or not, is hardly a determining factor. *Nautilus* is the last survivor of a long line which has had no need of cameral tissue since the close of the Paleozoic, and possibly not since the close of the Ordovician.

Yet in this long interval cameral tissues have not been entirely lost, although they have apparently come to be somewhat modified. Teichert[42] mentions the occurrence of tissue on the adoral side of the camera. Traces of such tissue can be seen in any recently sectioned *Nautilus*; and traces of dendritic structures which appear to have been blood tubes can be made out in them. Unfortunately the origin and physiology of the tissue in *Nautilus* have not been studied, and the very existence of such tissue is but rarely mentioned. Indeed, there appears to have developed among zoölogists a widespread conception of the connecting ring as a structure formed around the siphon, with apparently no tissue outside of it. Parker and Haswell[43] are among the few who have not fallen into this error. Though the connecting ring is not mentioned as such, they state that the siphuncle, here used synonymously with the siphon, has its wall supported by scattered spicules of lime.

Aturia is a significant reminder of the specializations which have come to pass in the Nautilidæ, which are far from being a static group. Miller[44] has recently shown that in *Aturia* there has been a remarkable elongation of both the septal neck and the connecting ring, with the result that for some distance the connecting ring lies close between two septal necks. It appears impossible under such conditions that there could have been any living cameral tissues. Further, the connecting ring is so closely appressed between the two septal necks that its original condition, that is, secretion within a tissue which encloses it, would have been patently impossible.

42 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, pp. 186-188.

43 Parker, T. J. and Haswell, W. A.: A text-book of zoölogy, vol. 1, 1910, p. 776, Macmillan, London.

44 Miller, A. K.: *Beiträge zur Kenntniss tropischamerikanischer Teriiärmollusken;* VI *Some Tertiary nautiloids from Venezuela and Trinidad;* Ecologæ geologicæ Helvetiæ, vol. 30, No. 1, 1937, p. 65-67, text fig. 3, pl. 9, fig. 5.

Nautilus furnishes some evidence which is reassuring such as the presence of cameral tissues and the enclosure of the connecting ring in tissue, but it is hardly a reliable guide in explaining the structures of fossil forms. This is only in part because of the meagre knowledge of *Nautilus* as an organism, the lack of study of features of the conch with special reference to their function, origin and relation to the soft parts, and the contradictory nature of the observations so far recorded. It is very largely because it is by no means as certain as we would like to believe that what holds true for *Nautilus* should hold true for its Paleozoic forebears. For example, the peculiar localization of the retractile fold of the tentacles of *Nautilus* is doubtless a specialization as was suggested by Dean[45], and is hardly a valid basis for the homologization of the tentacles of *Nautilus* with the sucking discs of the Dibranchiata. *Nautilus* is the last survivor of a long line of coiled cephalopods which by reason of their form and mode of life have probably never had need of cameral deposits. Indeed, as will be discussed later, there is some reason to doubt whether such forms are directly descended from orthoceracones with cameral deposits.

In direct contrast to the connecting ring which is endoskeletal and serves to support the siphonal strand within the cameræ, are the mantle secretions. These are aragonitic, showing in thin section lamellæ of growth and vertical, or occasionally oblique markings, indicative of rows of aragonite prisms perpendicular to the surface of secretion. Such structures are formed outside the membranes from which they originate, membranes I propose to designate as mantles, appropriating a term which has originally a considerably broader connotation. In this category fall all of the shell structures except the connecting ring.

The molluscan mantle originates from the ectodermal epithelium of the larva. Morphologically it is the dorsal covering of the primitive mollusc. It is differentiated from the remainder of the ectodermal epithelium mainly by its ability to secrete a shell. This is not constant, for not only are there numerous examples in which the mantle fails to secrete a shell, but there are also numerous instances in which shell material is secreted by the foot, as in the case of the gastropod operculum. Possibly aptychi and anaptychi of cephalopods are similarly formed.

The present discussion is concerned mainly with the physiological aspects of the mantle and its various regions and modes of secretion. It is convenient to designate several significant regions which may be summarized as follows:—

1. The TERMINAL MANTLE which is responsible for the secretion of the wall of the conch.

2. The POSTERIOR MANTLE which is responsible for the secretion of the septa.

3. The SIPHONAL MANTLE which is responsible for the secretion of annulosiphonate deposits within the siphuncle.

4. The CAMERAL MANTLE which is responsible for the secretion of cameral deposits.

45 Dean, B.: *Notes on living Nautilus*, American Naturalist, vol. 35, 1901, pp. 819-837.

Only the cameral and siphonal deposits have a direct bearing on the interpretation of the calcareous deposits formed within the phragmocone. As no such material is secreted within *Nautilus* or any other nautilicone for that matter, all that is known of these mantle surfaces is derived from the calcareous deposits in other groups and whatever analogies can be found with the terminal and posterior mantles.

THE TERMINAL MANTLE

The name terminal mantle is proposed for the portion of the mantle which is responsible for the secretion of the shell wall. It constitutes the margin of the true mantle, and is responsible for the addition of shell material at the aperture. A brief discussion of its rather variable properties may serve as a basis for a knowledge of the secretion of calcareous structures elsewhere in the phragmocone.

The molluscan periostracum is commonly secreted in a terminal groove of the mantle. The main part of the shell, the prismatic layer or layers as the case may be, is commonly secreted by the region of the mantle directly proximad of the terminal groove. The thin nacreous film is secreted over a wider area. In *Nautilus* this layer is very thin. In orthoceracones it is probably this layer which is thickened to form the gerontic constriction of the internal mold, although no orthoceracones sufficiently well preserved to permit a study of the shell wall at this point by means of thin sections have yet been found, and it is therefore not possible to test this suggestion.

The secretion of the shell wall may be continuous, or it may be more or less intermittent. In forms with fine regular growth lines and smooth shells it appears that the terminal mantle was active continuously and at a constant rate throughout the life of the organism.

Periodic alternating stages of rest and secretion are found in *Geisonoceras, sensu stricto.* Here prominent bands ending adorally in slightly elevated areas and containing on their surfaces fine lines of growth, obviously represent the product of a period of secretion.

The acme of periodicity is to be found in coiled forms of the Devonian represented by such forms as *Cophinoceras* Hyatt, *Rhyticeras* Hyatt and *Tetranodoceras* Flower. Here the aperture is produced at the termination of each period of secretion into patterns of frills and spines. During the resting stage the terminal mantle is withdrawn or resorbed, and the next cycle of secretion begins with the addition of material within the tip of the last aperture. Almost identical phenomena are common in the gastropoda.

Ruedemann[46] has shown that in *Orthoceras* cf. *transversum* S. A. Miller, a species which probably falls in the genus *Geisonocerina* Foerste, there is a crowding of growth lines at regular intervals which correspond to the distances between the septa. The writer has noted the same phenomenon in an undescribed *Geisonocerina* from the Onondaga limestone of New York. In the same publication

[46] Ruedemann, R.: *Observations on the mode of life of primitive cephalopods*, Bull. Geol. Soc. Amer., vol. 32, 1921, p. 319-320.

Ruedemann called attention to the synchronization between septa and internal annulations in *Orygoceras,* and between septa and annulations in *Protocycloceras,* and suggested that annulations may have originated on the inside of the shell by resorption. He suggested that this may have been due to the necessity of gaining more room in the living chamber for the voluminous sexual products. The main objection to this hypothesis is that the annulations, even those of *Orygoceras,* are apparently formed at the aperture. Certainly they are found on living chambers of the genus near the aperture and too far forward to have been caused by resorption at the posterior end of the living chamber where the sexual organs are located in *Nautilus.*

The correlation between septa and growth lines of *Geisonocerina* is analagous to the development of annuli in some annulated forms, where in some instances a correlation is possible between septa and annuli. In many instances, however, no such correlation is possible. Annulations are developed independently many times in the Nautiloidea. They are one of the devices which are particularly characteristic of shelled forms which must have led an essentially pelagic existence, though they are not confined to thin shelled forms.

Annulations in most cephalopods are clearly modifications of ornament and shell form, resulting in a corrugation which adds greatly to the strength of the shell without increasing its weight materially. Annulations appear many times in the development of the Nautiloidea alone, and it is not impossible that different physiological and ecological factors may have produced similar results in different lines of descent. The development of annulations in *Spyroceras* is essentially ecological, for *Spyroceras, sensu stricto* was almost certainly pelagic or planktonic as is shown by its reduced deposits of cameræ and siphuncle, and also by its prevalence in strata in which the associated fauna is made up entirely of pelagic forms. The large *Dawsonoceras* of the Silurian is harder to visualise as an active swimmer, but its exceptionally wide range, without any geographic localizations of variations is suggestive of a nektonic rather than a benthonic organism.

THE POSTERIOR MANTLE

The posterior mantle is the surface which is responsible for the formation of the septa. As its name implies, it occupies the posterior surface of the visceral mass as oriented in the typical orthoceracone. Yet the posterior mantle and the septa which it secretes are really dorsal in position with reference to the orientation of the primitive cephalopod. The enteron of the cephalopod forms a U-shaped canal which is indicative of the drawing together of the oral and anal extremities. This has been accompanied by the reduction of the true foot, the homologue of the gastropod foot, to a semi-internal organ, which the original dorsal surface is greatly increased. The vital organs are still dorsal, and correspond in position to the visceral hump of the gastropod. In the gastropod, as secretion of the terminal mantle increases the shell, there is an increase in the length of the visceral mass. In the cephalopod, however, the visceral mass does not increase, but moves forward in the conch, or ventrad, if the primitive orientation is to be retained, while septa are secreted at rhythmic intervals. Only the siphuncle increases materially in length as the shell grows.

It has been suggested that the large siphuncular cavity of certain early Paleozoic cephalopods, particularly the endoceroids and piloceroids, may have served as receptacles for glandular or sexual organs. The main vital organs of the gastropod are confined to the body whorl, while the liver and gonads occupy the spire. Perhaps a comparison between the gastropod spire and the siphuncle of certain early cephalopods is rash, but it is at least very suggestive and tends to support this proposal.

From the complete absence of thin or incomplete septa at the base of the living chamber in nautiloid shells, it would appear that the septum was secreted rapidly, and that short periods of secretion alternate with long periods of inactivity of the posterior mantle. This has recently been corroborated by a study of *Nautilus*[47]. In general there is a definite rhythmic pattern in the formation of the septa. The ratio of the diameter of the conch to the spacing of the cameræ has become an important and extremely useful specific criterion in nautiloids. Usually the septa are slightly farther apart in the neanic stage in proportion to the diameter than in the ephebic stage, while the gerontic stage is marked by very closely spaced septa, usually more or less irregular in arrangement. This is suggestive of a rapid rate of growth of the shell in the neanic stage, and a gradual retardation in the ephebic stage, followed by very marked and often abrupt retardation in the gerontic stage. Such a statement can only be made, however, on the basis of an assumption that the septa are secreted at regular rhythmic time intervals throughout the life of the organism. While there is no direct evidence that this is so, it is consistent with what can be learned of the rate of secretion by the spacing of the growth lines.

Though the spacing of the septa has come to be a useful criterion for specific determination, it is not always a reliable one. Minor and erratic variations are not uncommonly met with, but can usually be recognized as such. The study of a large series of specimens of *Striacoceras typus* (Saemann) of the Cherry Valley limestone has shown that practically all the long-used specific criteria, such as the spacing of the septa, the rate of expansion, and the position of the gerontic features of the conch, may vary markedly within a single species. To what extent this may apply to cephalopods of other horizons and regions is uncertain, and can only be determined by the study of a large series of specimens in each instance, a task which is often impossible owing to practical difficulties in the accumulation of suitable material.

The rhythmic nature of septation has been recognized but no adequate explanation has been offered. The voiding of sexual elements should be periodic and might affect the secretion of the septa; but here we might further expect to find a wide-spread sexual difference owing to the difference in volume of egg and sperm masses. No indication of such differences has been found in the Nautil-

47 Pruvot-Fol, A.: *Remarques sur le Nautile*, C. R. XIIe Congres International de Zoologie, Lisbonne, 1935, pp. 1652-1663, Lisboa, 1937.

oidea with a very few possible exceptions. In the early stages of the Actinoceroidea there may be found such differences which might be attributed to sexual dimorphism as was suggested by Kobayashi[48]. According to his hypothesis forms now regarded as specifically distinct may represent sexes of the same species. Practical difficulties arise in the inability thus far to correlate "species" into pairs, and also the complete absence of one sex, and that presumably the female, in the Cape Calhoun of northern Greenland. Further, in possible sexual forms of brevicones there is some difference in the depth of the cameræ, but this is involved with so many other variations in form that it is hardly significant in itself. Variation of this sort appears to be the exception rather than the rule, and it appears that the explanation of the rhythmic nature of septation must be sought elsewhere.

THE CAMERAL MANTLE

EVIDENCE OF CAMERAL MANTLE

Once it is demonstrated that the deposits within the cameræ are organic in origin, the problem of the mode of their secretion arises. They are formed in closed cameræ, often far from the living chamber; they agree with the nautiloid shell in microscopic structure; they are complexly lobed, the general pattern of the lobation is bilaterally symmetrical and its finer details furnish characters of specific value.

Chemical deposition can be safely eliminated, and has been discussed above in the section dealing with shell morphology. There is no inherent property of the interior of the camera which can explain the specific lobation, nor can it be accounted for on the basis of any property of a hypothetical cameral fluid. The only remaining possibility, the one which is the simplest and the most obvious, particularly in the light of the microscopic structure, is that the deposits must have been formed by a living tissue capable of secreting calcareous material, probably in the form of aragonite. For this tissue, which there will be some occasion to discuss, the term CAMERAL MANTLE is proposed.

Evidence of the tissue itself is only rarely to be met with in nautiloids. Teichert[49] has figured and discussed a specimen of *Armenoceras danicum* Teichert in which invading matrix has broken the connecting rings and has forced its way into the cameræ. Its progress was stopped before the camera was completely filled, apparently by some substance which was later destroyed, for the remainder of the space is occupied by infiltrated calcite. As Teichert suggests, this obstruction must have been caused by a tissue which was still preserved when the conch was buried, but which later decayed, leaving a cavity which was finally filled in by inorganic infiltration. I have observed almost identical phenomena in various specimens and species of *Ormoceras* in the Richmond.

48 Kobayashi, T.: *Contributions to the study of the apical end of the Ordovician nautiloid*, Japanese Jour. Geol., Geogr., vol. 14, Nos. 1-2, 1937, pp. 1-21, pls. 1-2.

49 Teichert, C.: *Einige actinoceroide Cephalopoden aus Dänischen Diluvialgeschieben und aus dem Gotlandium Skandinaviens*, Meddelelser fra Dansk Geologisk Forening, Bd. 8, hefte 4, 1934, p. 374 ff., pl. 8, figs. 1-2.

An even more striking example of the obstruction of invading matrix by cameral tissues is shown in an undescribed species of *Rayonnoceras* from the Chester of Indiana. The conch rested on the ventral or siphonal side. The connecting rings have been destroyed, and sediments from the siphuncle have invaded the cameræ. Further, the wall of the conch is broken on the dorsal side, so that sediments have entered one of the cameræ from above. Gravity would cause the sediment entering from above to mingle with that entering through the siphuncle, but the two are separated by an area of calcite which must, as in Teichert's specimen, indicate the presence of a tissue which was present at the time when the conch was buried and filled with matrix, but which has later been destroyed. This specimen will be described elsewhere in detail.

Further evidence of the cameral mantle may be found in unbroken cameræ. A *Geisonoceras teicherti* Flower, n. sp., (Pl. 7, fig. 8; Pl. 9, fig. 19) from the Onondaga limestone of New York which has been figured by Teichert[50], retains perfect cameræ in the adapical end. Episeptal and hyposeptal deposits are present, and are represented by white calcite. The cavity within the cameræ is occupied by light calcite, but there is a layer adjacent to the organic cameral deposits which is highly carbonaceous (Pl. 9, fig. 19). The carbonaceous material is undoubtedly derived from a tissue, and must represent a structure present within the conch before burial and infiltration occurred. It may or may not be significant that the carbonaceous band occupies the position postulated below for the cameral mantle on physiological and morphological grounds.

FORM OF CAMERAL MANTLE

It is very doubtful whether any of the calcite-filled areas representing the position of the cameral mantle at the time of burial of the conch preserve either its original form or position. Some time doubtless elapsed between the death of the organism and the burial of the shell. Decay had removed the visceral mass and the siphon. The cameræ were open either through the broken connecting ring, the broken wall of the conch or both, and doubtless decay had affected the cameral mantle, separating it from its deposits and altering its original form. There is little in such specimens to indicate regularity of form or position. Only in cameræ which remained closed and in which the probable course of the mantle is indicated by carbonaceous material is there any reason to suppose that either the original form or position has been retained.

Certain inferences can be drawn concerning the original form of the mantle from the nature of the deposits of the cameræ. Gas must have been present in the cameræ, or the orthoceracones could hardly have lived as nekton or plankton as some of them are known to have done. If gas was present in a camera, it must have lain either in a vacuolate inner layer or in a cavity surrounded by the cameral mantle. Vacuolate tissues are generally primitive, as is the vacuolate pseudocœlom of the Nemathelminthes and are not to be expected in such highly

50 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, p. 182, fig. 33; pl. 13, figs. 44, 46.

organized forms as the cephalopods. The cameral mantle must have lain against the concave adapical wall of the camera, both against the free and mural parts of the septum, for episeptal and mural deposits were formed in those regions. It must have lain against the convex adapical wall, at least in those species possessing hyposeptal deposits. Lastly, it must have lain against the outside of the connecting ring in order that an exchange of metabolic materials could take place with the siphon.

The cameral mantle was a secreting tissue, and as such was active metabolically. It required ingredients for its deposits. Such ingredients are unconsolidated; the materials which would constitute a mature deposit such as that of *Pseudorthoceras knoxense* would require a space larger than the camera. Further, were such ingredients present in the cameral mantle, the calcareous materials should so strengthen it that it would be frequently preserved. As has been seen, it is infrequently preserved, and then only poorly. Further, the mantle itself would have required food for nourishment, since it was highly active metabolically, and all of the waste materials could not have been eliminted in the form of calcareous deposits or as gas within the camera; certain substances must have been eliminated through the usual excretory channels. Obviously the mantle must have been connected with the rest of the organism. The only possible connection is through the connecting ring with the tissues of the siphon which join directly to the visceral mass. That such a connection existed is shown by the relationship which obtains between cameral and siphonal deposits, and by the vascular system of the Actinoceroidea, which admits of no other interpretation. The presence of an apparently rather solid connecting ring has seemed a serious obstacle to the acceptance of such a belief. An exchange of materials might take place by osmosis through a permeable connecting ring. However, it may be that there is a much more direct and simpler connection. The connecting ring of *Nautilus* is composed of loosely placed spicules of calcite, arranged in stellate patterns and held together by organic matter. All thin sections of connecting rings of fossil forms which I have examined show a spongy texture, and often the cavities of the connecting ring are clogged with fine invading sediments. It seems probable that the pores of the connecting ring were large enough to permit capillaries to pass directly through the ring into the cameral mantle. The vascular system of the siphon in its primitive condition was made up of numerous fine tubes in a parenchymous tissue. There are no radial tubes in any of the Pseudorthoceratidæ except *Paraloxoceras* which were large enough to be preserved embedded in calcareous deposits. The Actinoceroidea alone have a complex system of radial canals, and this group is admittedly highly specialized. Most orthochoanitic forms show no vascular structure. Only in one small group of forms is there even a trace of a central canal. The capillary vessels which passed through the connecting ring doubtless continued without modification into the cameral mantle.

ORIGIN OF THE CAMERAL MANTLE

Another problem which must rest to some extent upon conjecture is the origin of the cameral mantle. There are two possibilities: an origin by lateral proliferation from the siphonal strand, and an origin from the posterior mantle at the time when the animal moves forward in the conch. The evidence seems to favor the latter possibility. Though cameral deposits generally appear some distance from the living chamber, a few instances are known in which well defined deposits are present, though small, in the last camera, next to the base of the living chamber. It seems improbable, though it is not impossible since nothing is known of the time required for the formation of new cameræ in fossil nautiloids, that a functional mantle could have been produced so readily from the siphon. Nor does a hypothesis of an origin of the mantle from the siphon explain why episeptal deposits normally precede hyposeptal deposits in their appearance. Further evidence of the origin of the cameral mantle from the posterior mantle is found in the striking similarity between the septal furrow and the dorsal hiatus. Two distinct calcareous deposits, the septum and the cameral deposit, are characterized by small mid-dorsal areas where secretion does not take place; further, these areas lie adjacent to one another. This suggests more strongly than any other bit of evidence that the tissue which secreted the cameral deposits and that which secreted the septa were one and the same, and that the cameral mantle is developed from the posterior mantle which is separated from the visceral mass and left behind as it moves forward in the conch, the new septum being secreted by a fresh layer of cells.

As the visceral mass moves forward, a new segment of the siphon is formed. The tissue which is to develop into the cameral mantle is in direct contact with it, and the two were doubtless supplied by the same blood vessels (fig. 10A).

A question arises as to whether the part of the cameral mantle lying against the connecting ring is an outgrowth of the sloughed off posterior mantle or whether it is derived from the siphonal strand. One fact seems significant, though it has been consistently overlooked. The connecting ring is spicular, thereby differing from all other shell structures. Spicular deposits elsewhere in the animal kingdom are mesodermal without exception, save when they appear in the mesoglœa or the jelly-layer which precedes the mesoglœa in primitive forms. There is no information available concerning the formation of the connecting ring in either Recent or fossil cephalopods, but by analogy it should also be of mesodermal origin. It is recognized that reasoning by analogy may lead to erroneous conclusions; but in this instance there is little else to serve as guidance, and an analogy is employed which has been found to hold not in one instance, but in all instances, in which it can be applied and checked by a study of the soft parts of Recent forms.

If the connecting ring was secreted inside the tissue, the strand of siphonal tissue passing orad from the bud of the cameral mantle may have formed a part of the cameral mantle, and would not have been entirely incorporated in the siphon. The spicules of calcite were placed about the fine blood vessels which had preceded them in development (fig. 10B).

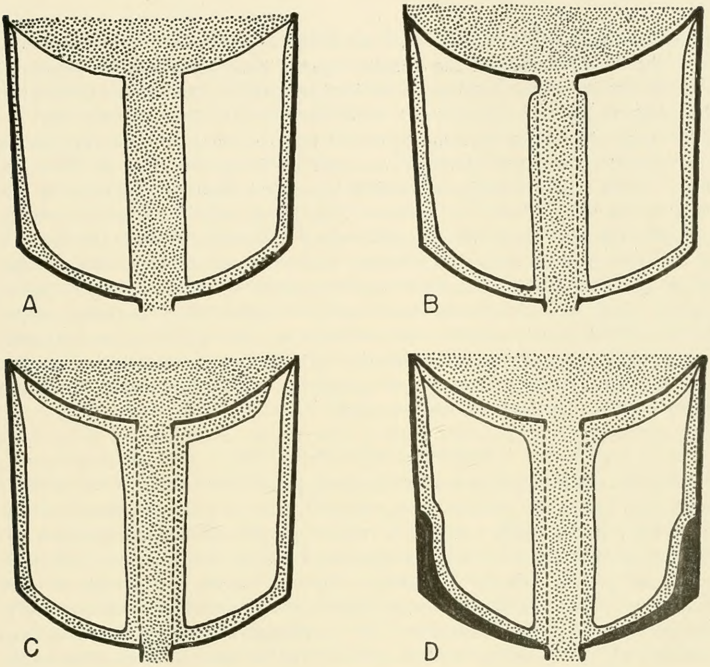


Fig. 10. Growth stages of the cameral mantle. (Tissues indicated by stippling; mantle secretions by black; connecting ring by dotted line).
A. The visceral mass has moved forward in the conch previous to the formation of a new septum, leaving behind the sloughed off posterior mantle, and a large siphonal strand.
B. The new septum is secreted by the new secreting surface. The connecting ring is formed within the siphonal strand.
C. The mantle tissue of the siphonal strand extends adorally, coming into position for the secretion of hyposeptal deposits.
D. The growth of the mantle is completed, forming a complete lining for the camera. Episeptal deposits are being secreted.

The cameral mantle is already in position for the secretion of episeptal deposits and for communication with the rest of the organism through the connecting ring. It remains for the mantle to extend anteriorly from about the siphuncle, over the convex side of the newly formed septum, thereby coming into position for the secretion of the hyposeptal deposits (fig. 10C-D). This is doubtless the explanation of the fact noted by Teichert that the hyposeptal deposit normally follows the episeptal deposit in its appearance in a camera. A large number of species never develop the hyposeptal deposits at all. This fact leads to the question as to whether in such forms the cameral mantle actually extends over the adoral surface of the camera. In the Pseudorthoceratidæ hyposeptal deposits are developed in *Adnatoceras ciscoënse* (Miller, Dunbar and Condra) in *Euloxoceras*, and in *Cayutoceras*. *Cayutoceras* is only distantly related to the other two, while there is reason to believe that *Euloxoceras* must have sprung from *Adnatoceras* in post-Devonian, and possibly Pennsylvanian time. We have, then, in the family Pseudorthoceratidæ hyposeptal deposits appearing in two isolated instances. Were the absence of hyposeptal deposits connected with the failure of the adoral part of the cameral mantle to develop, it would be necessary to conclude that the break thus formed had been closed twice independently. More examples of the isolated loss and reappearance of the hyposeptal deposit can be found in the Actinoceroidea, and the distribution is somewhat erratic in the orthochoanites, where as yet we have no clear guide to the phylogeny except the cameral and siphonal deposits. The evidence seems to indicate that the hyposeptal portion of the cameral mantle was present throughout, but that it was not always active as a secreting surface.

GROWTH OF THE CAMERAL MANTLE

Once the cameral mantle has been formed, the further tracing of its development rests upon safer ground. It is essentially that of any other tissue. It has just been traced through a period of regional growth without any apparent differentiation of tissues other than the elements of the circulatory system which must have been present from the beginning. After the mantle is so developed as to completely or nearly completely line the camera, the cells in various regions begin to undergo functional modifications. The secreting surfaces begin to develop; doubtless also the secretion of gas is a function of the inner surface of the mantle. Growth of the tissue does not cease when secretion begins; rather it continues very much as before. The surface of the mantle becomes greater, while by reason of the deposits, the areal extent of the camera is typically lessened. This is compensated for by a folding of the mantle, accompanied by regional differentiation in the rate of secretion. In this way the characteristic lobes and "ornamentation" of the interior of the deposit is developed. At length differentiation in the rate of secretion has become so great that secretion is going on only in a few isolated areas, on the crests of a few lobes of the deposit, as on the middle pair of ventro-lateral lobes of *Pseudorthoceras*, while it has ceased in other areas.

The final cessation of deposition appears to be the logical conclusion of a retardation of growth which at first is apparent only in certain areas, as upon the dorso-lateral bands or the ventral sinus. The apparent acceleration in other areas is probably only relative. In the Actinoceroidea and the orthochoanites the retardation is apparently functional, as is the cessation of deposition. The siphonal and cameral tissues are not separated, and the cessation of deposition can only be explained on the basis of a physiological change in the cameral mantle. The continuous lining of the siphuncle of the Pseudorthoceratidæ, Stereoplasmoceratidæ and Troedssonoceratidæ presents another problem. Does this lining serve to sever the connection between the siphonal and cameral tissues and thereby control the amount of calcareous material secreted within a given camera? Or is it the deposition of material around the siphon in regions in which no exchange of metabolic materials is taking place? The fact that cessation of deposition in other groups is apparently to be attributed to physiological causes[51] would favor the latter possibility, but it is by no means conclusive. Fortunately for the solution of the problem there is some direct evidence. In the apical segments of *Pseudorthoceras* there is typically a region in which the siphonal deposit is incomplete; that is, it is not closed on the dorsum, and a connection between the cameral and siphonal tissues is never completely broken. In more adorally located cameræ, the deposit is completed dorsally and the cameral mantle is cut off from the remainder of the organism. A comparison of the two regions shows that the cameral deposits are markedly heavier where the siphonal deposit is incomplete; indeed, they practically fill the cameræ, leaving only small interstices among the various lobes, and present a sharp contrast to the relatively slight development in slightly more adoral segments, which is too marked to be accounted for by the normal ontogenetic progression which is to be found in cameræ with immature deposits. Further, the closure of the dorsal wall of the siphonal deposit is indicative of a mature condition. This indicates that in the Pseudorthoceratidæ the closure of the siphonal wall is the controlling factor in determining the amount of stereoplasm which is secreted within the camera. From this it is concluded that the physiological relationship between the siphonal and cameral deposits is different in the Pseudorthoceratidæ from that in the Actinoceroidea or "Orthoceratidæ". What condition obtains in the Stereoplasmoceratidæ and Troedssonoceratidæ is as yet uncertain, but can doubtless be ascertained by further study of the groups.

THE SIPHONAL MANTLE

The annulosiphonate[52] siphonal deposits were secreted by the surface of the siphon, which is here called the *siphonal mantle.* Teichert[53] suggested that the annulosiphonate deposits of the Actinoceroidea may represent the gradual calcification of siphonal tissues. This conclusion is opposed by the form of the deposits, their microscopic structure and evidence of a mantle surface. Annulosiphonate

[51] It has not been possible to demonstrate beyond all possible doubt that the cameral deposits in such forms completely cease to develop. Growth is reduced to a negligible quantity in the apical cameræ, apparently because of the axial gradient, as is shown below in connection with the discussion of the relation of cameral and siphonal deposits.

[52] The present discussion is concerned only with annulosiphonate deposits. It is not certain whether actinosiphonate deposits are formed within or outside of the siphonal tissues. The deposits of the endoceroids and ellesmeroceroids, are not considered, for while they are probably mantle secretions also, they are very different in structure and were probably derived independently.

[53] Teichert, C.,: *Structures and phylogeny of actinoceroid cephalopods,* Amer. Jour. Sci., ser. 5, vol. 29, 1935, p. 11.

deposits make their appearance at the septal neck, the only point at which the surface of the composite tissues of the phragmocone lies within the siphuncle. Elsewhere the connecting ring is formed within the wall of the siphonal strand, so that part of the original strand lies within the camera rather than in the siphuncle. The fine structure of the siphonal deposits of *Pseudorthoceras knoxense* shows that they were similar to the aragonitic shells known to be secreted by the surface of a membrane. No siphonal deposits in actinoceroids have been found which show more internal structure than fine growth lines, but all available specimens are pseudomorphs of calcite or other material, and recrystallization has usually proceeded to such an extent that the retention of the original fine structure cannot be expected. The same loss of structure can be seen in many specimens of *Pseudorthoceras,* and it is only rarely that traces of the rows of aragonite prisms are preserved.

On the basis of the form of the siphonal deposits it might appear that the Actinoceroidea and other annulosiphonate orthoceracones represent a genetic line. The deposits of the Actinoceroidea are pendant; those of orthochoanites and their derivatives are parietal. Differentiation occurs upon the modification of a simple type, the annulus, which is common to the earliest ontogenetic stages of both types of deposit. A phylogenetic relation is suggested. Yet the ontogeny of the Actinoceroidea is such as to suggest that a relationship with other annulosiphonate cephalopods may be more apparent than real, and that Teichert's suggestion of a relationship with the Endoceroidea, made originally upon the basis of ephebic characters, appears to offer the most nearly adequate solution for the placing of these singular forms in a tenable relationship with other cephalopods.

But even without a demonstrable relationship, it seems highly improbable that such strikingly similar structures as the annulosiphonate deposits of the Actinoceroidea and those of the stenosiphonate cephalopods could have evolved from structures of totally different origin. Occasionally exceptional specimens of the

Fig. 11.—Form of deposits of the phragmocone, relation of secreting surfaces, and supposed genetic relationship of the main types.

Geisonoceras.—Continuous secreting surface.

Dawsonoceras.—Hyposeptal deposits lost.

Orthoceras brucense.—Siphonal deposits lost.

Striacoceras.—Siphonal and hyposeptal deposits lost.

Virgoceras, a pseudorthoceroid.—Hyposeptal deposits absent; siphonal deposits delayed in appearance, develop rapidly.

Harrisoceras.—Siphonal deposits appear early, lying in contact with ectosiphuncle only at septal neck. Central canal developed gerontically, showing in apical end. Episeptal deposits appear after siphonal deposits, hyposeptal deposits apear still later or may be absent.

Actinoceras.—Time relationship of appearance of deposits as in *Harrisoceras.* Deposits pendant, practically filling siphuncle except for radial canal system. The apical siphuncular segment shows the perispatial deposit.

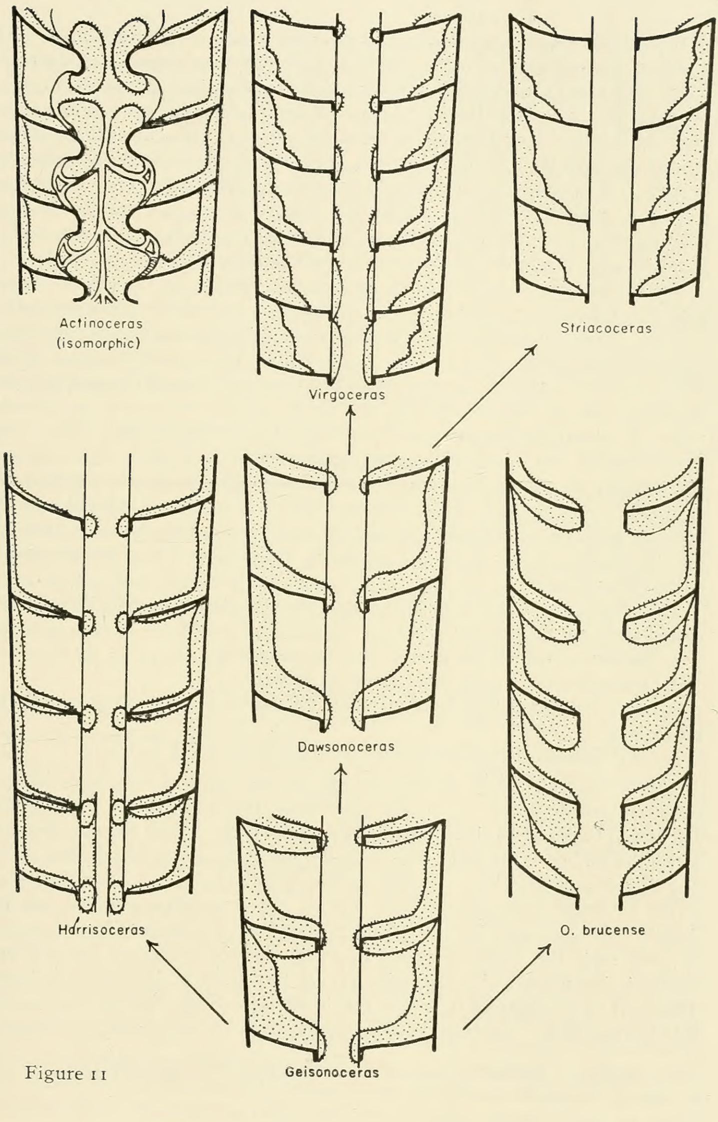

Actinoceras
(isomorphic)
Virgoceras
Striacoceras
Dawsonoceras
Harrisoceras
O. brucense
Geisonoceras

Figure 11

Actinoceroidea may show evidence of a siphonal mantle. Teichert[54] has figured a section through several radial canals of *Cyrtonybyoceras barrandei* Teichert, which shows two carbonaceous layers separated by calcite which may be organic or inorganic. The inner layer I take to represent the wall of the vascular tube, probably slightly calcified during the life of the organism. The outer layer, which is separated from the inner one by calcite, lies at the margin of the annulosiphonate deposits. It is suggestive of a mantle surface, originally continuous, which has come to be complexly lobed and folded until it comes to form a sheath for the vascular system. The outer carbonaceous layer should not appear if only the gradual calcification of siphonal tissues produced the deposit.

The siphonal and cameral mantles behave very similarly and as will be shown presently, the two are doubtless closely related, both structurally and functionally. In both, secretion begins at a definite stage in development and this can be estimated in relation to the growth of the conch by the distance from the base of the living chamber to the first trace of deposits. Both cameral and siphonal deposits appear at a definite distance from the base of the living chamber up to the gerontic stage. In gerontic individuals the deposits may approach somewhat closer to the living chamber, but are usually thinner when completely formed. It is not certain whether the adoral extension of deposits in the gerontic stage is widespread or whether it is confined to the Actinoceroidea. In both siphonal and cameral deposits deposition is gradual, extending over a considerable period of time, so that the developmental stages of the deposits extend over a considerable length of the phragmocone.

The growth stages of the siphonal mantle are very similar to those already discussed above for the cameral mantle:—

1. Regional growth of the mantle from its rudiments.
2. Development of a generalized secreting surface.
3. Local variation in the rate of secretion accompanied by folding and growth of the mantle.
4. Final attainment of a mature condition and cessation of secretion.

The first stage, that of regional growth, is accomplished when the siphonal strand is developed, which must occur previous to the formation of a new camera. Deposition begins at localized areas, at the septal neck. This is the only point at which the surface of the tissue lies within the siphuncle as was pointed out above. The deposit grows, and the secreting surface is increased. As a necessary result of the formation of annulosiphonate deposits, the endosiphuncular cavity is reduced. Reduction may be relatively slight as in most orthochoanites, or it may be great as in the Actinoceroidea. In either case the surface of the siphonal mantle is increased, and invagination occurs to a more or less marked extent. This must be accompanied by a reduction in the mass of the siphonal tissue, probably by resorption. The blood vessels remain, which are represented by the endo-

54 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A., 1933, pl. 12, fig. 39.

siphuncular vascular system of the Actinoceroidea. Other tissue is reduced, and in the Actinoceroidea is almost completely eliminated. What this tissue could have been can hardly be determined. It was certainly parenchymous and generalized; it is just possible that it may have been glandular and that the large siphuncles of the Actinoceroidea may have served for the storage of food.

The end of siphonal deposition is rarely abrupt, but may be brought about in various ways. In most Actinoceroidea deposition continues until further resorpaion of tissue is impossible. In most Orthochoanites there can be seen the same gradual decrease in rate of growth that can be found in the cameral deposits. In the Pseudorthoceratidæ a definite mature condition is attained which is not as easily explained; apparently the siphonal deposits attain maturity without the same gradual decrease in rate of deposition which is found in the Orthochoanites, and which suggests the axial gradient as a possible physiological explanation. All that can be said with certainty is that the appearance of a definite mature condition is reached when the deposits effectively isolate the cameræ.

RELATION OF CAMERAL AND SIPHONAL MANTLES

TYPES OF SECRETION PATTERNS

Among the known annulosiphonate and related nautiloids several groups can be distinguished on the basis of the relations which obtain between the cameral and siphonal deposits if considered in terms of the surfaces of the deposits and the variations in the development of secreting surfaces within the phragmocone. It is evident that some of these groups are genetic, for they form compact units of restricted range. It is too early as yet to say that others are genetic, but they at least serve to clarify the relationships which hold between the tissues and deposits of the phragmocone.

GROUP OF GEISONOCERAS, SENSU STRICTO

First to be considered is a group in which the development of cameral and siphonal deposits is such that there is a single active secreting surface in the phragmocone which is continuous from one camera to the next (fig. 11). In all other groups the secreting surface, and therefore the outline of the deposits, is discontinuous, in one way or another. The development of episeptal and hyposeptal deposits against the outside of the connecting ring and the development of the *Michelinoceras* type of deposit against the inside of the connecting ring are strictly commensurate, so that the surface of the growing deposit, which is the surface of active secretion within the phragmocone, is continuous from its beginning in relatively adoral cameræ, to its termination in the apical part of the phragmocone if not in the apical part of the shell. The beginning of deposition in any given camera is dependant upon the development of the secreting surface of the cameral mantle as outlined above. The cause of the cessation of deposition is more obscure. There is apparently no definite region in which deposition ceases entirely as in the Pseudorthoceratidæ, or if there is one it has not been possible to detect it. In the Pseudorthoceratidæ there are three well delimited areas, one of no secretion, one of developing secretion, and one of mature secretion, and the bound-

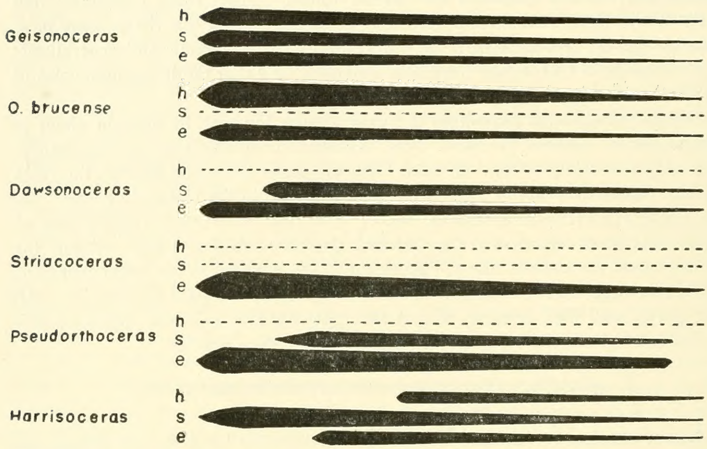


Fig. 12.—Diagramatic representation of the essential relations between various secretions in the phragmocone, showing their relative appearance, rate of growth, and cessation of growth; *h*, hyposeptal deposits; *s*, siphonal deposits; *e*, episeptal deposits.

Geisonoceras.—All three deposits are uniform and form a single secreting surface. The relative time of appearance may be variable; siphonal deposits sometimes appearing slightly after the other two.

Orthoceras brucense.—Siphonal deposits are completely lost; hyposeptal deposits develop more rapidly then episeptal deposits.

Dawsonoceras.—Hyposeptal deposits are lost. Siphonal deposits normally follow episeptal deposits, which are here modified to mural deposits.

Striacoceras.—Only the episeptal deposit develops, which is here mural in form.

Pseudorthoceras.—Hyposeptal deposits are typically absent. Episeptal deposits appear and complete a considerable part of their growth before siphonal deposits appear. Completion of the siphonal deposit isolates the camera, and therefore stops the growth of the cameral deposit.

Harrisoceras.—Siphonal deposits appear first and are well developed before deposits in the cameræ appear. Hyposeptal deposits normally follow episeptal deposits, but may be entirely wanting.

aries of these areas move forward in the phragmocone in an orderly procession as the shell grows at the aperture and more cameræ are added at the base of the living chamber. Accordingly the region of no secretion and the region of immature deposits are uniform, but not mathematically constant, throughout the life of the organism, and the region of mature deposits is constantly being increased in extent. In the group under discussion, however, there appears to be no sharply defined boundary between regions of mature and immature deposits. In fact, it is questionable whether there is a region in which deposition has entirely ceased. It appears that deposition is rapid in the early stages, as is shown by the considerable advance in the volume of deposits in a series of adoral cameræ. A marked contrast is afforded by the imperceptible difference in the volume of deposits in a series of adapical cameræ, indicating that deposition there is very slow. Further, in tracing a series of cameræ from the inception of cameral deposits apicad, the difference in volume of the deposits of adjacent cameræ becomes progressively less as the apex is approached. Any control which may exist over deposition in the cameræ is strictly physiological, and is not aided by any structural device. The gradual decrease in the rate of deposition as a series of cameræ is traced apicad indicates that the controlling factor is the axial gradient. The tissues of the phragmocone which are nearest the metabolically active visceral mass are the ones which receive the most nourishment from the blood stream of the siphon, and the amount of nourishment and the speed of development in any camera varies inversely with the distance from the living chamber.

This type of structure is wide-spread in orthochoanitic orthoceracones, though it is far from including all forms. It occurs in the genotypes of *Michelinoceras* Foerste and *Geisonoceras* Hyatt; it is present in some but not all *Protokionoceras*. The type of structure is well developed in forms of Middle Silurian age and persists at least into the Middle Devonian. It is a generalized type of structure and a simple one, but it is apparently not primitive on purely stratigraphic grounds, for the structures have not been observed in Chazy or Trenton Orthochoanites, in spite of careful examination of numerous individuals and a considerable number of species with these particular features in mind.

It should be emphasized that this type of structure runs across genera as recognized on the basis of ornament, and does not include all species placed in those genera. But there is little variation in the structural pattern, and the group seems to be rather well limited stratigraphically, suggesting that it may represent a closely knit genetic group, and that the internal structures are more reliable guides to genetic relationship than the surface ornamentation.

The other types differ from the above in that the continuous secreting surface is interrupted in some way, and there are a number of different ways in which it has been done.

GROUP OF "ORTHOCERAS" BRUCENSE

In this group siphonal deposits are lost (figs. 11, 12). Episeptal deposits are present but are relatively thin, while the greater part of the space within the camera is filled by the massive hyposeptal deposits. The forms thus far known to fall into this group are relatively slender species, with deep cameræ. The form of the interior of the cameral deposits is rather characteristic, being marked by many radial furrows and concentric lines of growth. This type of surface, which will be described and illustrated in detail at another time, seems sufficient to warrant the recognition of this group. Another singular feature is the characteristic absence of the connecting ring in all specimens so far studied. Its outline can be seen only where it is surrounded by cameral deposits, and the consistency of this type of preservation in various formations and types of sediments leads to the belief that the connecting ring must have been either entirely absent, or else that its spicular elements were so poorly integrated that it will not hold together after the destruction of the tissue which contained them.

The group is wide-ranging, but not over common at any one horizon or locality. It is represented in the Laurel, Liston Creek, Racine and Guelph of the Middle Silurian. Species of this horizon are commonly more or less strongly banded or annulated, and in this group fall species which have been placed in *Cycloceras*, *Leurocycloceras* and *Geisonoceras* by Foerste. The presence of the group in the Helderbergian is doubtful, though *O. paucicameratum* Hall is a likely suspect. It is well represented in the Schoharie grit of the Middle Devonian, and it appears again in the St. Louis limestone of the Mississippian of Indiana.

GROUP OF DAWSONOCERAS

This group is derived from the group of *Geisonoceras* by the loss of the hyposeptal deposits, thereby forming a break in the continuity of the secreting surface in each camera. The episeptal deposits are modified into mural deposits in the absence of hyposeptal deposits, and generally preceded the siphonal annulosiphonate deposits in appearance. This type of structure is well exemplified in the genus *Dawsonoceras*. It is present also in smooth shelled orthoceracones.

GROUP OF STRIACOCERAS

In this group, as in the group of *Orthoceras brucense* the siphonal deposits have been lost, but hyposeptal deposits are absent also, and the episeptal deposits are modified into mural deposits and are generally massive (figs. 11, 12). To what extent this is a genetic group is uncertain. It is possible that it may have originated from several lines of descent at different times. As a stage in the reduction and localization of the deposits of the phragmocone it might be derived from the group of *O. brucense*, from the group of *Dawsonoceras*, or independently from the group of *Geisonoceras*. Members of this group differ from that of *O. brucense*, which is characterized by slender forms with deep cameræ and no preserved connecting ring. It is more probably derived largely if not entirely from the group of *Dawsonoceras*. Some smooth orthoceracones formerly included in *Michelinoceras* and *Geisonoceras* fall here, as well as species of *Kionoceras* and *Protokionoceras*, and also *Striacoceras*, from which the group takes its name.

THE PSEUDORTHOCEROIDS

This group contains not only the Pseudorthoceratidæ but also their orthochoanitic forbears which agree with them in the form of the siphonal and cameral deposits. Here the continuity of the secreting surface is broken, but the siphonal deposits are preserved and put in a late appearance (fig. 12). The main modifications have to do with the time of appearance and speed of development of the various deposits. Cameral deposits appear first, and come to be fairly well developed before siphonal deposits appear. When the siphonal deposits are established, however, they grow with unusual rapidity, and in a series of from six to nine siphuncular segments the entire development from the young to the mature siphonal deposits can be traced. The type of structure has been discussed so extensively in the first section of this paper, that its repetition here is unnecessary. It will suffice to point out that originally discrete segments of the annulosiphonate deposit fuse to form a complete sheath about the siphon. The direct result of this is the isolation of the cameral tissue, and with the source of metabolic materials removed, the secretion of further calcareous material in the cameræ becomes physically impossible. As has already been stated, the marked contrast of cameral deposits in the neanic region of *Pseudorthoceras* in which the siphonal deposit is not completed dorsally and the adoral regions in which it is normally closed shows that the siphonal deposits control the extent of cameral deposits, and that the completion of the siphonal deposits is not delayed until the cameral deposits attain a mature condition; rather they determine what shall constitute maturity in this particular instance.

This group is apparently monophyletic, and is represented in the Silurian by the orthochoanitic forbears of the Pseudorthoceratidæ, from which the Pseudorthoceratidæ are derived in the Devonian. It is derived from the *Geisonoceras* type by the general, though not universal loss of hyposeptal deposits, and by the specializations in the time of appearance and rate of growth of cameral and siphonal deposits, as well as by the development of siphonal deposits over the connecting ring independent of cameral structures.

Hyposeptal deposits reappear in several members of the group. They are found in *Euloxoceras*, in *Adnatoceras ciscoënse* (Miller, Dunbar and Condra) and in *Cayutoceras*.

Before leaving this group it should be noted that the development of siphonal deposits to control the deposition of cameral deposits is apparently an advantageous structure. It is attained independently in the Stereoplasmoceratidæ and Troedssonoceratidæ of the Ordovician which are not annulosiphonate in origin and are not related to the Pseudorthoceratidæ. Further, it is a structure which is only gradually perfected in the Pseudorthoceratidæ, as is shown by the progressive thinning which can be traced from Silurian orthochoanitic forms to Pennsylvanian species of *Pseudorthoceras* and *Mooreoceras*.

GROUP OF HARRISOCERAS

Still another group is differentiated by an acceleration of the development of siphonal over cameral deposits. This is a small group for which the generic name *Harrisoceras* has been proposed[55] (figs. 11, 12).

Annulosiphonate deposits are large and symmetrical or nearly so. Hyposeptal deposits are thin when present and greatly delayed in their appearance. A central canal develops gerontically. The significant feature of the group is the confinement of the siphonal deposits to the septal neck as in the Actinoceroidea. They never become massive enough to develop a recognizable perispatium, but their size and shape suggest the pendant deposits of the Actinoceroidea, though without ever departing far from the simple annulus in form. The group contains thus far only the genus *Harrisoceras* which is world wide in distribution in the Middle Silurian, and is thus far known in America only from strata of Clinton age. Typical *Harrisoceras* is smooth externally. Identical internal structure has been found in species with cancellate ornament which would formerly have been placed in *Protokionoceras*.

[55] Flower, R. H.: *Harrisoceras, a new structural type of orthochoanitic nautiloid*, Journal of Paleontology, vol. 13, No. 5, 1939, pp. 473-480, pl. 49.

THE ACTINOCEROIDEA

The Actinoceroidea may be taken as representing another group closely similar to that of *Harrisoceras*, but representing an isomorphic rather than a genetic relationship. The siphonal deposits are massive and usually outstrip the cameral deposits in development. The relative appearance of the cameral and siphonal deposits is variable. In Cincinnatian species of *Ormoceras* the appearance of siphonal deposits is greatly delayed, and such deposits are present only in the extreme apical end, while cameral deposits make their appearance at the usual distance of about twelve cameræ from the base of the living chamber. In the Actinoceratidæ and Armenoceratidæ cameral and siphonal deposits may appear simultaneously, or siphonal deposits may precede cameral deposits in appearance. The growth relations in such instances are identical with those of *Harrisoceras* (fig. 12).

The essential characteristics of the Actinoceroidea have to do with the specialization of the siphonal vascular system and the attendant modification of the siphonal deposits. The presence of a perispatium alone is diagnostic, and it is the presence of this empty space inside the connecting ring which is responsible for the pendant nature of the deposits. Although the deposits of *Harrisoceras* appear to be pendant, hanging within the siphuncle from the septal necks, they never develop far enough to show whether a true functional perispatium is developed in that genus. The nature of tissue in the perispatium remains in doubt. Teichert considered it a space in which blood could accumulate near the connecting ring, a sort of hæmocœl, so that osmotic exchange of materials could take place between the cameral and siphonal tissues. This does not appear to take into consideration the mesodermal nature of the connecting ring or the high degree of specialization which is represented by the siphonal vascular system of the Actinoceroidea.

The primitive condition of the siphon must have been one of generalized parenchymous tissue with numerous fine blood tubes in a rather irregular arrangement. The Actinoceroidea represent a specialization by reduction and simplification of the numerous fine tubes to an orderly and regular system of large tubes. Yet the cameral tissue is probably a primitive feature even though cameral deposits probably are not, and the blood vessels which nourish it must pass through the connecting ring as fine capillaries. For this reason the reduction of the blood tubes of the siphon must remain internal; peripherally the capillary condition must remain in order that the blood tubes may pass through the connecting ring into the cameral tissue. Doubtless the perispatium was originally occupied by a tissue in which rapid division of the blood tubes was taking place, as is suggested further by the observable divisions of the radial canals as they approach the perispatia in many forms. There are still complex problems involved in the interpretation of the siphonal vascular system, but it is not necessary to discuss them further at this time. It will suffice to point out that the central canals are known elsewhere only in the gerontic stages of two unrelated genera, *Harrisoceras* of the Orthochoanites, and *Anastomoceras* of the Pseudorthoceratidæ.

The Pseudorthoceratidæ owe their development to the ability of the siphonal tissues to sever their connection with cameral tissues, being cut off from them by deposits which act as a valve. It was thought that the development of such structures as radial canals should be impossible in the family, yet in *Paraloxoceras,* obviously a derivative of *Mooreoceras,* a simple series of radial canals is retained throughout life. No perispatium, however, is evident.

It might be possible to regard all annulosiphonate cephalopods as originating from a common type. The idea is intriguing, but closer study will show that some insurmountable obstacles are encountered. First of all, it is impossible to correlate the Actinoceroidea with any other types on the basis of the siphonal structures. The siphuncular outline varies sufficiently within the group that it might be possible to accept such a hypothesis as that already proposed by Kobayashi[56] who regarded the Sactoceratidæ as the ancestral radicle of the Actinoceroidea, deriving from the Orthochoanites through such a form as *Sactorthoceras* Kobayashi, and regarding it as a not distant relative of the Stereoplasmoceratidæ. The other members of the Actinoceroidea might be derived from the Sactoceratidæ. This is opposed not only by the evidence of the siphonal vascular system and the structure of the deposits, which were not considered at all in building up that hypothesis, but by the stratigraphic evidence which shows that the oldest Actinoceroidea are those which possess large and markedly cyrtochoanitic siphuncles. Further, many of the older species which have been referred to *Ormoceras, Sactoceras* or *Deiroceras* are not Actinoceroidea at all, but are cyrtochoanites of rather doubtful affinities which should possibly be referred to the Stereoplasmoceratidæ.[57]

The earliest stages of the Actinoceroidea as recently reported by Kobayashi and the present author,[59] agree in the form of the protoconch and the condition of the beginning of the siphuncle, but the initial chamber itself is not very revealing. The possibilities for variation in form of an initial chamber are definitely limited. Kobayashi saw a possible clew in the central position of the siphuncle, but the value of such an interpretation as a basis for major divisions of Nautiloidea into Ventrosiphonata and Centrosiphonata is questionable. Rather it seems that a quite different division based on the presence or absence of an apical cæcum is more significant, and such divisions will coincide exactly with the Stenosiphonata and Eurysiphonata proposed by Teichert on the basis of the septal necks.

[56] Kobayashi, T.: *On the Stereoplasmoceratidæ,* Japanese Jour. Geol., Geogr., vol. 13, 1936, p. 234.

[57] The study of these forms will be dealt with elsewhere. I have in mind particularly species from the Chazyan of the Mingan Islands recently referred to *Deiroceras,* particularly *Deiroceras diffidens* (Billings) which is closely related to "*Loxoceras*" *moniliforme* Ruedemann and "*Oöceras*" *perkinsi* Ruedemann of the Chazyan of the Champlain basin.

[58] Kobayashi, T.: *Contributions to the study of the apical end of the Ordovician nautiloid,* Japanese Jour. Geol., Geogr., vol. 14, Nos. 1-2, 1937, p. 1-21, pls. 1-2.

[59] Flower, R. H.: *Early stages of Actinoceras* (Abstract), Geol. Soc. Amer., Proc. for 1937, 1938, p. 277.

GENERAL CLASSIFICATION OF ORTHOCERACONES

From the above evidence, which will be set forth in more detail elsewhere, it appears that the Actinoceroidea cannot be regarded as related to the annulosiphonate Orthochoanites, though striking resemblances occur. It is not even possible to trace the forms back to a common annulosiphonate ancestor, but it is necessary to conclude that annulosiphonate structure has evolved independently in these two instances. The orthochoanitic annulosiphonata however appear to represent a genetic group, of which the Pseudorthoceratidæ form a part.

Further, it can be seen that the groups outlined above may serve as major taxonomic divisions for the orthochoanitic orthoceracones. Perhaps one group will have to be added for orthoceracones which lack cameral and siphonal deposits completely. The study of a considerable number of specimens representing various species of Trenton and Chazy orthochoanitic orthoceracones have led to the conclusion that cameral and siphonal deposits must have been absent in such forms.

The present classification of orthochoanitic orthoceracones is that of Hyatt (1900) and is based upon the ornament. At that time it was not suspected that there were cyrtochoanitic orthoceracones similarly ornamented. At the present time it is possible to point to one or more cyrtochoanitic isomorphs of orthochoanitic genera with the exception of *Dawsonoceras*, as is shown by the table at the end of this chapter. In the past it was considered adequate to know the ornamentation of an orthoceracone to refer it to a genus. Now it is known that the ornament alone is not trustworhy, but that at least the outline of the siphuncle must be known as well. From this it naturally follows that all similarly ornamented orthoceracones are not necessarily members of the same genetic group, but at first there seemed no better criterion available. One is now furnished in the patterns of the deposits of the phragmocone. Its use will be complicated by the fact that it cannot be employed for the identification of fragments representing adoral portions of the phragmocone in which such deposits are normally absent, or for flattened specimens or living chambers. Practical difficulties will tend to restrict its use. The task of ascertaining the internal deposits of the type species of established and long used "ornament genera" is in itself no small undertaking. There is already some indication that families and genera remodeled on such a basis will not only bring the classification into closer accord with the phylogeny, which is the constant aim of such revision, but that the restricted generic groups will become useful in unraveling the stratigraphic and paleogeographical problems of the Paleozoic. If as has been generally supposed, the cephalopods were more motile that most other shelled forms, they should be the first to invade new areas following the breaking down of land barriers.

DISTRIBUTION OF ORNAMENT TYPES IN ORTHOCERACONES

I. Transverse liræ and striæ

A. Orthochoanitic	B. Cyrtochoanitic
Harrisoceras	Pseudorthoceratidæ
Orthoceras brucense	*Dolorthoceras*
Geisonoceras	*Diagoceras*
Leurocycloceras	Actinoceroidea
	Elrodoceras
	Ormoceras (*pars*)

II. Annulations and transverse ornament

A. Orthochoanitic	B. Cyrtochoanitic.
Orthoceras brucense	Pseudorthoceratidæ
Brachycycloceras	*Geisonoceroides*
"*Cycloceras*"	*?Neocycloceras*
	Stereoplasmoceratidæ
	Tofangoceras
	Tofangocerina
	Incertæ sedis
	Eskimoceras

III. Annulations and longitudinal ornament

A. Orthochoanitic	B. Cyrtochoanitic
Metaspyroceras	Pseudorthoceratidæ
Ordovicion and Silurian	*Spyroceras*
species referred to	Incertæ sedis
"*Spyroceras*"	Group of "*Spyroceras*"
	clintoni

IV. Longitudinal ridges

A. Orthochoanitic	B. Cyrtochoanitic
Geisonoceras	
Harrisoceras	Troedssonoceratidæ
Virgoceras	*Troedssonoceras*
Kionoceras	Pseudorthoceratidæ
	Euloxoceras
	Mooreoceras (*pars*)
	Actinoceroidea
	Deiroceras

V. Cancellate "*Protokionoceras*" ornament

A. Orthochoanitic	B. Cyrtochoanitic
Harrisoceras	Pseudorthoceratidæ
Geisonoceras	*Palmeroceras*
Striacoceras	Actinoceroidea
Virgoceras	*Deiroceras*
Protokionoceras	

EXCRETORY ASPECTS OF SHELL SECRETION

It is generally conceded that such secretions as fall under the general category of shells may have been originally excretory in function, serving to eliminate mineral wastes from the system of the organism. This has been applied by various investigators to the molluscan shell, the arthropod exoskeleton and to the tests of various of the Protozoa. In the Arthropoda moulting and the secretion of a new exoskeleton are cyclic activities which recur at regular intervals. In the Crustacea, which have remained generalized in many respects, moulting continues throughout the life of the organism and serves to eliminate waste material to such an extent that the only true excretory organ is the small anteriorly situated green gland. The Insecta represent a specialized case, for moulting ceases when the wings are developed. Here the Malphigian tubules are present and serve as specialized excretory organs to meet a new need.

The secretion of septa at rhythmic intervals doubtless served the cephalopod just as the secretion of a new carapace served the crustacean. A problem of some interest and importance is found in the variations in the secretion of the septa throughout life. Are these variations in the secretion of the septa, in the growth of the shell, or in both? The septa are normally rather widely spaced in the neanic portion, slightly more closely spaced in proportion to the diameter in the ephebic portion, and very closely and sometimes rather irregularly spaced in the gerontic portion of the phragmocone. The wide spacing of neanic septa is probably indicative of a rapid growth of both the visceral mass and the shell wall. Relatively rapid growth is a common feature in organisms at this stage. In the ephebic portion the normal specific pattern is attained, which is held over the greater part of the phragmocone with astonishingly little variation. The approach of the gerontic condition is usually abrupt. This may indicate one of three things:—

1. A more frequent secretion of septa in old age, due to more rapid accumulation of minerals in the organism. It is generally held, however, that such accumulations are a feature of a gerontic condition only because completed growth has caused the normal channels for the elimination of waste to be functionally closed.

2. A slowing up in the rate of secretion of the shell wall, accompanied by its thickening. If this were all, it would appear that the gerontic septa should be subject to the same thickening which affects the shell wall.

3. It seems more probable that the slowing up of growth is due to the cessation of the growth of the soft parts of the organism. Calcareous materials accumulate in the system as before, but with a retardation in the rate of growth, there is less need than before of a periodic forward migration in the conch. Consequently though septa are formed at the same rhythmic intervals as before, less material is added to the aperture and forward migrations in the conch become less extensive.

Brevicones present a rather special case. The contraction of the aperture inhibits further growth of the soft parts of the organism, and the form of the contracted aperture is essentially an ephebic rather than a gerontic feature. When the contraction of the aperture begins, the secretion of septa at a normal rate will necessarily result in a compression of the visceral mass which would have to have some such compensation as resorption would offer. However, proportions show that if the length of the living chamber does not vary materially, the beginning of the contraction of the cameræ and of the aperture occurs at the same time. Further, the degree of contraction of the cameræ can be correlated with that of the aperture. In forms with slightly contracted apertures such as *Acleistoceras* or *Amphicyrtoceras*, the ephebic contraction of the cameræ is slight, while it is a prominent feature where the aperture is more completely and gradually closed, as in *Hexameroceras*.

In brevicones the gerontic features may be summarized as follows:—

(1) Thickening of the shell wall interiorly before the aperture.

(2.) Secretion of material by the posterior mantle. This forms the impressed zone of Hall. Unfortunately that term is better known in connection with coiled cephalopods through the works of Hyatt, so the term BASAL ZONE has been proposed for the structure of brevicones.[60] This is a gerontic feature. It consists in the thickening of the final septum, both in its mural and free portions. Often an "ornamented" radial pattern is formed. This has been little studied, but appears to be constant within a species and may be useful taxonomically when it has been given more attention.

(3.) The deposits of the siphuncle. Foerste has noted upon several occasions that the occurrence of actinosiphonate structure is highly variable in several specimens of the same species. I have found such deposits confined to individuals showing some other trace of gerontic features, but not in immature or early ephebic individuals. This may well account for the variability within generic and higher groups, particularly since brevicones are so rare that in many instances species are known from only a few individuals.

ACTINOSIPHONATE STRUCTURE

A problem which remains for further investigation is the physiological and structural significance of actinosiphonate deposits. The fine structure is unknown. As practically all specimens which show actinosiphonate deposits are pseudomorphs, it is doubtful whether a study of thin sections would yield any significant result. However, propitiously preserved material may someday serve to show whether the actinosiphonate deposit is laid down within the tissues, or whether it is formed by a siphonal mantle as are the annulosiphonate deposits. The deposits of *Diestoceras* of the Ordovician, one of the oldest actinosiphonate genera, are concentrated at the septal foramina, and suggest an annulosiphonate origin. In other forms, such as *Herkimeroceras* and *Neumatoceras* the deposits appear to be continuous from segment to segment.

Actinosiphonate deposits are almost certainly polyphyletic. They occur in a group of Lower Devonian orthoceracones represented by *Jovellania* and its allies. Though these are classed as orthoceracones, the living chambers and apertures appear to be unknown; at least they have not been figured. They are widely present in brevicones, though apparently rather erratic in distribution among them. How much this is due to inadequate study, to the examination of early ephebic specimens, or to lack of material, it is not possible to say. Actinosiphonate structure appears again in trochoceroids but seems to be confined to forms which have a more or less contracted aperture. Again it is to be found in a few cyrtoceracones and gyroceracones with contracted apertures which are not generally classed as breviconic or trochoceroid. While some of these forms are possibly strongly curved derivatives of the true brevicones, others apparently are not, but are derived from other coiled forms.

The function of actinosiphonate deposits seems to have been so far unmentioned by all authors. It is a peculiar type of deposit: one which exhibits the poorest possible economy of space, and economy of space is usually desirable. It could

60 Flower, R. H.: *Devonian brevicones of New York and adjacent areas*, Palæontographica Americana, vol. 2, No. 9, 1938, p. 171.

scarcely have been hydrostatic, for it could hardly have affected the orientation. Further, hydrostatic deposits are more massive and compact. Rather, it shows the features of an old age deposit, one formed in the interstices of the siphuncle, if not of the siphon, which were not needed for other purposes. Such interstices would be found among the radially arranged tubes of the siphonal vascular system which radiate to the connecting ring and supply the cameræ with air. In this way it is possible to account for the radial pattern, and also for the peculiar form of the deposits which differ so strikingly from the other types which are found in nautiloids.

MODE OF LIFE AND ECOLOGICAL SIGNIFICANCE OF SIPHONAL AND CAMERAL DEPOSITS

PROBABILITY OF GAS IN CAMERÆ

The mode of life of fossil cephalopods, and particularly of orthoceracones, is still a matter of conjecture. However a consideration of the ecological significance of the cameral and siphonal deposits brings new evidence to bear upon the solution of the problem, and permits the checking and modification of previous hypotheses.

Probably the greatest obstacle to the understanding of the mode of life of Paleozoic cephalopods is uncertainty as to whether gas was present in the cameræ of such forms. Gas has been assumed to be both present and absent by various authors. Dunbar[61] assumed that gas must be absent on the basis of the horizontal mode of life indicated by the color bands, yet postulated a nektonic existence. Teichert[62] has assumed the presence of gas and has presented a very convincing hypothesis of the probable hydrostatic relations on a quantitative basis.

Although *Nautilus* is known to contain gas in its cameræ it does not necessarily follow that gas was present in the cameræ of primitive forms. Indeed, it has been postulated that the development of coiling was the result of the appearance of gas in an orthoconic shell and the attendant elevation of the apex. However, it is evident that the appearance of gas will not account for such a progressively coiled series as that illustrated by Schindewolf[63] from *Rhynchorthoceras* through *Ancistroceras* and *Lituites* to *Cyclolituites* where coiling appears at the apex.

Although the origin of cameral gas is unknown, it is perfectly possible that even the earliest cephalopods may have secreted gas in the cameræ. Among the earliest cephalopods there are numerous cyrtoconic forms which are rapidly expanding and breviconic rather than longiconic. The shortness of the shell and the wide aperture suggest crawling forms which carried the shell with the apex directed upward. This, as has been shown, is the primitive orientation. The cameræ of such forms are exceedingly shallow, and gas would not have had a sufficiently buoyant effect to interfere with a benthonic mode of life. Further,

61 Dunbar, C. O.: *Phases of cephalopod adaptation*, in Organic adaptation to environment, Yale Univ. Press, 1924, p. 191.

62 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A., 1933, pp. 186-200.

63 Schindewolf, O. H.: Paleontologie, Entwecklungslehre und Genetik, Berlin, 1936, p. 36-38.

the color bands, though not known for these particular cyrtoceracones, suggest that cyrtoconic shells were held in this position in life.

In the case of orthoceraconic forms, however, two possibilities exist. The shells may have been dragged along the bottom by benthonic organisms, or the shells may have been held more or less suspended either in crawling or swimming forms. If we assume a continued benthonic existence, the orthoceraconic form suggests a normally horizontal position of the conch. Among the Gastropoda many forms show a similar development, but the dragging along the sea bottom of a long heavy shell of such a form as *Cerithium giganteum* would considerably handicap movement. Shells dragged in this manner might, as Dunbar[64] suggested for orthoceracones, might show signs of wear on the ventral side, and it is possible that lack of such evidence in orthoceracones may be due to poor preservation of the shell surface, as in *Actinoceras.* However, granting that gas was present in the cameræ, it is conceivable that the weight of the shell was so lessened that it was approximately equal to the weight of the water it displaced. Under such conditions the shell would have ceased to be a handicap in movement and it would have become light enough to preclude wear of the shell as the animal crept over the sea floor.

Accompanying the increase in the length of the shell there is an increase in the depth of the cameræ. This implies, though it does not require that the buoyant effect of the phragmocone was increased. One would here bear in mind that it is not altogether certain that the entire cavity of the cameræ was occupied by gas; the available space in the cameræ may have been only partially occupied by gas and variability of the extent of gas secretion is quite possible. An increase of buoyancy would result in a shift of the center of gravity orad, and a shift of the center of buoyancy apicad. As a result the shell would tend to occupy a horizontal position, as Dunbar suggested. Dunbar argued that since the color bands of orthoceracones indicate a horizontal position, and since gas in the cameræ would necessitate a vertical position, that gas must have been absent. However, the deposits of the phragmocone are developed only adapically, and would therefore tend to weigh down the apex of the shell. The addition of such deposits to an orthoceracone containing gas in the cameræ would cause the center of gravity to move apicad until it lay near enough to the center of the shell that a horizontal position is possible. Furthermore, in such an orthoceracone the buoyant effect of the gas would not be entirely counteracted by the weight of the deposits, but gas would still have enough lifting power to lessen the weight of the organism materially, and might even permit a pelagic or planktonic existence.

Furthermore, gas would be necessary to an orthoceracone which lived with its shell in a vertical position. Such a condition was suggested by Foerste[65] on

[64] Dunbar, C. O.: *Phases of cephalopod adaptation,* in Organic adaptation to environment, Yale Univ. Press, 1924, p. 191.

[65] Foerste, A. F.: *The color patterns of fossil cephalopods and brachiopods, with notes on gastropods and pelecypods,* Michigan Univ., Mus. of Pal., Contrib., vol. 3, 1930, p. 140.

the basis of color bands which encompass the shell in *Orthoceras pellucidum* Barrande. As is shown in the discussion of the color bands below, this condition may be more widespread than has generally been supposed.

EVIDENCE OF GAS IN THE CAMERÆ

The deposits within the phragmocone are in themselves evidence of an active mode of life of orthoceracones which would hardly have been possible were the cameræ not occupied by gas. They quite obviously served two distinct functions.

Ventral concentration supplied a stabilizing device which tended to orient the conch with the venter beneath. That this device is ecological in its significance is shown by its formation in several different ways in different genetic lines. In the Endoceroidea the stabilizing effect is produced by deposits in the form of endocones within the large ventral siphuncle. In the Actinoceratidæ and most other Actinoceroidea the heavy annulosiphonate deposits practically fill the large ventral siphuncle, and cameral deposits, though doubtless contributory, were of minor importance. However, when the siphuncle becomes small, or when it is removed from the venter as in the Sactoceratidæ of the Actinoceroidea, the cameral deposits become both heavier and more markedly concentrated on the venter. The cameral deposits of the Pseudorthoceratidæ and the Orthochoanites are the essential stabilizing organs, and the small siphonal deposits may be reduced, highly modified for other than hydrostatic functions, or may be altogether wanting.

The second feature of the deposits of the phragmocone which is significant ecologically is their apical concentration. This serves a double function. First, it weighs down the apex, counteracting the buoyant effect of the gas in the cameræ sufficiently to permit a horizontal mode of life. Second, the weighted apex is essential for the arrowlike flight of the organism in hyponomic swimming.

The ecological importance of the apical concentration of the deposits of the phragmocone is shown by the number of ways in which it has been developed in different genetic lines. In the Endoceroidea the siphonal deposits of endocones alone serve to weigh down the apex. It is not generally recognized to what extent the development of endocones is confined to the apical part of the shell. The author has collected a specimen of *Endoceras proteiforme* Hall which attains a diameter of about seven inches at the base of the living chamber. The first trace of endocones is found more than three feet apicad. Assuming a constant rate of expansion, this would imply a maximum length of about two and a half feet of siphuncle filled with deposits in the form of endocones, while the adoral three feet, followed by a living chamber of unknown length, contains no accessory calcareous materials. Further, in many Endoceroidea the so-called nepionic bulb will add materially to the weight of the apex as soon as deposition begins within the siphuncle.

In the Actinoceroidea the siphuncle is also filled with calcareous deposits, but here the deposits are in the form of annulosiphonate rings rather than endocones. Cameral deposits are contributory, but come to be important only in the Sactoceratidæ, where the siphuncle is too small to be very important hydrostatically.

In stenosiphonate orthoceracones the siphuncle and cameral deposits may both serve to weigh the apex, but usually the cameral deposits, being much more massive, are the more significant of the two as balancing factors.

The apex is again weighted in the Dibranchiata, but in an entirely new way. The mantle has grown over the shell, and the addition of material to the outside of the shell forms an apical guard on the outside of the phragmocone.

ECOLOGICAL EVIDENCE

That at least some of the orthoceraconic cephalopods had sufficient gas in the cameræ to make possible a planktonic existence is shown convincingly by the fact that orthoceracones appear as regular members of plankton faunas. They are in fact, the first cephalopods to appear in such associations. It is quite evident that a cephalopod with an external shell could not have made up a part of a plankton association had the cameræ not been occupied by gas. That the cephalopods were an integral part of such faunules and were not carried into those environments as dead shells is shown by the absence of conspecific forms in contemporaneous benthonic facies. Air filled orthoceracones should be capable of transportation from planktonic to nonplanktonic facies. Such shells might be carried until breakage or solution liberated the gas within the phragmocone. That no planktonic Naples species are known from the Ithaca suggests that any shells that may have been thus transported were broken too badly to be recognizable.

Ruedemann[66] has found orthoceracones in the Silurian graptolite shales of the Prince of Wales Island. It is not surprising that the orthoceracones of such an association are characterized by types of ornament and shell corrugation which have long been considered diagnostic of the genera *Spyroceras* and *Kionoceras*. It is not surprising that these, the first cephalopods to occur in such an association, belong to a group, ecological rather than taxonomic, in which the shell wall has been so modified as to result in a structure of minimum weight and maximum strength. Smooth orthoceracones have since been found in Silurian graptolite shales of Belgium. The flattened condition of the specimens and the destruction of internal structure makes impossible a study of their genetic relationships.

In the Devonian of New York orthoceracones are abundant in plankton associations. Here again the shells are usually flattened and generic identification is largely impossible. Orthoceracones occur in the Union Springs member of the Marcellus, at the base of the Hamilton stage. Small thin shelled species of *Spyroceras*, such as *S. idmon* and *S. lima* are known largely if not entirely from highly carbonaceous shales of the Hamilton in which the other faunal elements are definitely known to be planktonic. In the Upper Devonian smooth orthocera-

66 Ruedemann, R.: *Paleozoic plankton faunas of North America*, Geol. Soc. Amer., Mem. 2, 1934, p. 34.

cones, sometimes of considerable size, occur in the Geneseo shale[67]. Small forms occur in the Genundewa limestone, which owes its limy condition to the presence of the planktonic *Styliolina*. In higher strata orthoceracones occur commonly in the Middlesex and Rhinestreet shales. Orthoceracones have not been generally recognized in these formations in the past, and have been apparently confused with *Bactrites* which occurs in the same horizons and associations. *Bactrites* can be distinguished by its more slender form, even in the flattened state.

COLOR BANDS AS CRITERIA OF THE MODE OF LIFE

Color bands should serve as an excellent test for the position of the conch of the orthoceracone in life, and further, it should be possible to correlate the color bands of a species with its siphonal and cameral deposits and thereby check the ecological importance of the deposits of the phragmocone. In one instance, that of the Trenton orthoceracones described by Ruedemann, it is known that color bands were confined to one side of the shell, indicating a horizontal mode of life, and that deposits are developed within the phragmocones of the several species concerned. In other instances, as is shown below, the color bands are much less reliable.

Color bands which were confined to one side of the shell were first reported by Ruedemann[68], who pointed out that this indicated that the shell was held in a horizontal position during life. He suggested a benthonic mode of life on the grounds that the long straight conch could hardly have been carried horizontally in swimming.

Dunbar[69] accepted the idea of the horizontal mode of life on the basis of color bands but rejected the benthonic mode of life on the basis of the absence of wear on the ventral side of the shell. The argument is a legitimate one, but conditions of preservation may destroy such evidence. Ventral wear should be best developed on a shell which has heavy deposits, such as an *Actinoceras*. An *Actinoceras* which retains much of the surface is exceptional. The shell wall is usually recrystallzied and it only rarely separates from the rock at the shell surface, and then only in small patches. Again, if gas is present in the cameræ of even a form with heavy deposits, the weight would be greatly lessened, and friction would be reduced.

Foerste[70] studied the color bands of orthoceracones and came to the conclusion that the color patterns of ellipochoanitic orthoceracones were ventral while those of holochoanites were dorsal. From this he concluded that the ellipochoanitic cephalopods must have occupied a horizontal position with the venter upward. However, a close examination will show that the evidence of the color bands which has been so widely accepted is not always reliable.

67 The author has collected flattened portions of phragmocones up to two inches in width from the Geneseo as developed in the vicinity of Ithaca.

68 Ruedemann, R.: *Observations on the mode of life of primitive cephalopods*, Bull. Geol. Soc. Amer., vol. 32, 1921, p. 315-317.

69 Dunbar, C. O.: *Phases of cephalopod adaptation*, in Organic adaptation to environment, Yale Univ., Press, 1924, pp. 191, 197.

70 Foerste, A. F.: *The color bands of fossil cephalopods and brachiopods, with notes on gastropods and pelecypods*, Univ. of Michigan, Mus. of Geol., Contrib., vol. 3, No. 6, 1930, pp. 109-150, 5 pls.; *The cephalopods of the Hölandet area*, Skr. ut. av. Det. Norske Videnskaps-Akademie i Oslo I Nat.-Naturv. Klasse, No. 4, 1932, pp. 149-150.

Form and Orientation of Color Bands.—Color bands may be divided into three great groups on the basis of their form: the diagonal zigzag bands typified by *Orthoceras anguliferum* d'Archiac and de Verneuil, the longitudinal bands found in *Orthoceras trusitum* Hall of the Trenton, and the transverse bands typified by *O. dunbari* Foerste of the Pennsylvanian. The diagonal zigzag pattern is bilaterally symmetrical and is doubtless oriented in regard to the symmetry of the conch. The specimens of *Orthoceras anguliferum alpense* which Foerste figured show no trace of the aperture, the position of the siphuncle, cameral deposits or the furrows of the interior. There is no means of determining whether they are dorsal or ventral in position. A *Hedstromoceras* with color bands shows them only on the siphonal side which may be ventral. The only orthoceracone in which the color bands are indisputably ventral is a *Mooreoceras* collected and described by Mr. Richard Schweers[71], in which diagonal color bands are present on the ventral side as shown by the conchial furrow.

The longitudinal color bands reported by Ruedemann[72] in Trenton orthoceracones are unquestionably confined to one side of the shell. Ruedemann points out that the orthoceracone is not perfectly straight, but that the side bearing color bands is faintly convex. This would seem to support Foerste's proposal that the color bands are ventral, but it is not known whether the curvature is endogastric or exogastic. Thus far specimens retaining color bands have failed to show deposits within the phragmocone, and the furrows of the interior of the shell are either originally absent or not preserved. Consequently there is no sure criterion of orientation. Mural deposits are present in the cameræ in the species concerned. Although the deposits are not definitely known to be concentrated on the venter, it is reasonably safe to assume that they are, for the ventral concentration has been found to be universal wherever orientation can be checked.

The transverse bands are known from only two species, *O. dunbari* Foerste of the Pennsylvanian, and *"Orthoceras," sp.* Flower and Caster of the Conewango of the Upper Devonian. In neither is there any means whereby it is possible to determine the relation of the color bands to the dorso-ventral plane. The transverse black bands in *O. dunbari* end laterally in densely black areas. The dorsal condition is not known. A thick black unmarked band has been noted in *Geisonoceroides woodæ*, of the Hamilton shales of New York where it is dorsal. The venter is too poorly preserved to show color markings. However, there is a suggestive resemblance between the black band of this form and those of *O. dunbari*. It is possible that in such species the dorsum may have been uniformly dark and the venter transversely banded.

Preservation of Color Bands.—Color bands are only rarely preserved on orthoceracones, and require special conditions for preservation. The Stafford lime-

71 Unfortunately still unpublished.

72 Ruedemann, R.: Paleontological contributions from the New York State Museum, 4. *On color bands in Orthoceras*, New York State Mus., Bull. Nos. 227-228, 1919, pp. 79-88.

stone which contains orthoceracones showing faint traces of color bands, the Trenton limestone in which color bands are not uncommonly preserved and the Alpena limestone are similar in texture, fracture and mode of preservation of the cephalopods.

In typical specimens the distribution of color bands depends upon the distribution of calcite in the shell. This was recognized for Trenton specimens by Ruedemann. Calcite is commonly present against the side of the shell which lay uppermost, and is the complemental filling of the incomplete internal mold. In the Trenton orthoceracones good color bands can be seen where the dorsum lay uppermost. Where a lateral surface is uppermost the gradual lateral disappearance of color bands can be seen. Such a specimen has been figured by Ruedemann[73]. Only rarely are specimens found in the Trenton in which the color bands are not confined to the side of the shell occupied by calcite. In such instances they are not actually preserved as color bands but are indicated by elevated and depressed bands on the surface of the shell due to differential weathering.

Ruedemann considered the inorganic factors in the orientation of color bands and was able to show in spite of them that the color bands were originally present on only one side of the shell. Other investigators have not taken the inorganic factors into account. The pattern of *Orthoceras anguliferum alpense* Foerste is bilaterally symmetrical, but the center of symmetry of the pattern does not lie in the center of the preserved part of the pattern. This shows that other factors besides the original distribution of the pattern determine the present alignment of the pattern on the shell. It is not surprising, therefore, to find that the two specimens figured by Foerste the color bands are present only on the side which contains calcite.

Calcite occurs on the ventral side of the *Mooreoceras* cited above as having ventral color markings. From what has been said above it follows that the present orientation of the color bands on these specimens need not be the complete original pattern. It is quite possible that diagonal color bands may have extended originally completely around the shell of orthoceracones as they did in cyrtoceracones.

The longitudinal color bands of Trenton orthoceracones indicate a horizontal mode of life. This is also suggested by the transverse bands which give way to a dense black dorsal area, though here the matter is not beyond dispute. Diagonal color bands are not conclusive, but probably extended completely around the shell, suggesting a vertical rather than a horizontal mode of life. A vertical mode of life is further suggested by *Orthoceras pelucidum* var. *contrahens* Barrande, of the Silurian of Bohemia, which possesses longitudinal bands which pass entirely around the shell. This alone would suggest that the mode of life is not the same in all orthoceracones.

73 Ruedemann, R.: Paleontological contributions from the New York State Museum, 4. *On color bands in Orthoceras,* New York State Museum, Bull. Nos. 227-228, 1919, fig. 23.

Most specimens which preserve color bands fail to show any of the internal features of the shell. For this reason it is often not possible to identify a specimen showing color bands with a species in a more typical condition of preservation. Consequently most forms which possess color bands are described as "species" of "*Orthoceras*." With the generic and specific identification uncertain, all that such specimens tell us is that some orthoceracones had color markings on one side of the shell, while in others the color bands may have extended around the shell. This is not very satisfactory.

Only in one instance has it been possible to establish a correlation between color bands and the deposits of the phragmocone. The orthoceracones of the Trenton limestone which show traces of color bands represent several allied species. Preservation of the interior is rare, but a few specimens are known which show that the siphuncle is small, orthochoanitic and subcentral, showing that the species should be placed in the genus *Michelinoceras*. Mural deposits are known to be present in the cameræ. Both deposits and the color bands suggest a horizontal mode of life. The ventral concentration of the cameral deposits is not yet known here. It may be assumed however, from that fact that cameral deposits are not known which do not show ventral concentration. Likewise the dorsal position of the color bands is an assumption, but it is difficult to see how any other condition could have held.

In the specimen of *Mooreoceras* mentioned above, on the other hand, the diagonal color bands are known to be ventral. Deposits are known to be concentrated ventrally, making possible a horizontal mode of life with the venter down, but not with the venter up. It is therefore necessary to conclude that the present distribution of the color bands represents only a part of the original pattern. The color bands may have passed entirely around the shell originally, and may have been preserved only against the side which lay uppermost and which was filled in by calcite. Such a color pattern would seem to imply a vertical position for the shell in life, and the deposits indicate a horizontal position with the venter down. Two possible explanations for the discrepancy suggest themselves. Nothing is known of the condition of the color bands on the dorsum which may have been much darker than those on the venter. Again, the original color pattern may be preserved only as a negative. The calcite which represents the shell is normally white. The relatively insoluble melanin pigments which make up the color bands may have prevented the entry of discoloring minerals in originally dark areas, while originally light areas may be discolored and darkened by them. In this way the original relationship may be reversed. That something of that sort has happened in the *Mooreoceras* under discussion is suggested by the appearance of color bands on the inside of the shell.

The possibilities of error in the interpretation of color bands are so great that they can hardly be considered reliable indicators of the mode of life of orthoceracones. When the evidence of the color bands agrees with that of the deposits of the phragmocone in indicating a horizontal mode of life, such a conclusion is safe, but too often there is either a grave discrepancy or complete inability to compare the two lines of evidence in a species. In cases of discrepancy, it appears that the deposits are the more reliable guides.

GENERAL CONCLUSIONS AND OUTLOOK

From the ecological and structural evidence it is fairly clear that gas must have been present in at least the majority of orthoceracones. This may have been a condition inherited from the earliest cyrtoconic cephalopods. Changes of several sorts have come about in the history of the cephalopods in which the presence of gas and the hydrostatic relationship may have been significant. A crawling ancestoral form with a short cyrtoconic erect chambered shell has been postulated. In such forms the cameræ are so shallow that the buoyant effect of the gas could hardly compensate for the weight of the camera walls. However, very shallow cameræ are essentially an early Paleozoic feature. Elongation of the shell and elongation of the cameræ may have gone hand in hand. This would result in increased buoyancy of the apex of the animal. However, cameral tissues are probably a primitive feature, even though deposition of cameral deposits is not. Quite probably the beginning of septation was marked by a split in the posterior mantle forming a cameral mantle connected with the siphonal strand between the septal necks. This is suggested by the obvious retention of cameral tissues and the development of gerontic deposits is brevicones, where such features were not only characteristic of the gerontic stage, but were excretory in function, at a time when the normal elimination of calcareous material from the system by the normal processes of shell growth and septation was no longer possible.

The development of the contracted aperture of the brevicone is probably associated with a floating mode of life which followed the increase in buoyancy of the phragmocone. Such forms have light shells, often very thin in proportion to the size of the conch as a whole. Deposits formed within the phragmocone are gerontic features, and are never massive, as are the deposits of orthoceracones which are useful to the organism by virtue of their weight.

Orthoceracones may have developed at several different times in different ways, and the present indications of the wide gaps separating the Holochoanites, Actinoceroidea and stenosiphonate orthoceracones suggest something of the sort. Three possible modes of life must be considered for the orthoceracones: 1. The orthoceracone may have developed from the primitive cyrtoconic type by elongation of the shell, elongation of the cameræ, increased buoyancy of the phragmocone which was counteracted by the building of apical deposits in one of several possible ways which have been enumerated above. This produces a horizontal potentially nektonic form. 2. Again, it is possible that the elongation of the cameræ may have been accompanied by a reduction in the amount of gas, and that some cephalopods may have lived benthonic lives with the shell held horizontally, with little or no gas in the cameræ. 3. Again, some forms may have developed gas without compensating deposits, and may have lived with the shell in a vertical position, as is suggested by some color bands and the absence of deposits in some forms. If it can be demonstrated that color bands occur on all sides of an orthoceracone which lacks cameral and siphonal deposits, this condition would seem to be demonstrated; at present it is only a possibility.

To add to the complexity, it is possible that one or more of the three possible types of orthoceracones may have been derived from either of the other two. This seems a hopelessly complicated picture, but in dealing with possibilities which are not yet capable of proof or dismissal, it must be considered.

It might be pointed out that flattened orthoceracones which were unquestionably benthonic and were probably derived from more active ancestors, have very shallow cameræ. This is found in the Tripteroceratidæ, particularly *Allumetoceras,* and in the Gonioceratidæ. It is difficult to explain why shallow cameræ should develop in forms which by their flattened form were obviously crawlers, unless it was a return to the condition postulated as ancestral, in which the cameræ were so shallow that the buoyant effects of the gas within them did not compensate for the weight of the cameræ walls.

The other great development of the Nautiloidea is coiling. It is now known that coiling may be initiated at the apex of the shell and spread anteriorly. It is still highly probable on the basis of ontogeny, that the gradual and uniform increase in shell curvature postulated by Hyatt may also have occurred. In the series of gradual increase in curvature it is possible that increased buoyancy of the apex may have played a part; in the other series it could not, and if a single explanation is to be postulated for coiling it can not be found in a response to environmental conditions.

It would probably be simplest to think of the orthoceracone, the brevicone and the coiled cephalopod as three different responses to the development of buoyant phragmocones, in only one of which did the tissues of the phragmocone develop into lime secreting organs to any considerable extent. However, the true condition was doubtless much more complex, being complicated by possible series of uncoiling, by return of nautilicones to benthos as trochoceroids, return to brevicones to benthos as trochoceroids, and by complex interrelations in the three possible ecological group of orthoceracones; gas filled forms with apical deposits living horizontally, gas filled forms living vertically, and horizontally living forms with little or no gas, and what gas there was localized anteriorly. However, this is entering a field of conjecture which we are not as yet equipped to test thoroughly and in such fields it is well not to venture too far.

PART III

TAXONOMY

A REVIEW OF THE CYRTOCHOANITES

Hyatt[74] originally divided the nautiloid cephalopods into two orders, the Holochoanoidea and the Ellipochoanoidea. In the first group were included forms in which the wall of the siphuncle is formed by long septal necks, and in the second group were placed forms in which the necks are short and the greater part of the wall of the siphuncular segment is formed by the connecting ring. Later Hyatt[75] replaced the order Ellipochoanoidea by four orders: Orthochoanites, Cyrtochoanites, Schistochoanites and Myxochoanites, and changed the term Holochoanoidea to Holochoanites for the sake of uniformity.

The Schistochoanites comprise a small group of little understood early Paleozoic forms. The Myxochoanites, likewise a small group, are aberrant forms. Miller[76] has shown reason to believe that they are derived from the Oncoceratidæ of the Cyrtochoanites.

In the Orthochoanites were included forms in which the siphuncular segments were cylindrical or nearly so, consisting of straight septal necks and connecting rings. In the Cyrtochoanites, on the other hand, were placed forms in which the septal necks are recurved, and the segments of the siphuncle are more or less expanded in the cameræ. It may be pointed out here that the validity of the Orthochoanites and Cyrtochoanites has not been substantiated by recent findings, for there are numerous gradations between the groups. Some species of *Stereoplasmoceras* Grabau[77] could be placed in either group, though on the whole the group appears to be cyrtochoanitic rather than orthochoanitic. In the Actinoceroidea gerontic siphuncular segments of three genera, *Ormoceras* Stokes, *Paractinoceras* Hyatt and *Leurorthoceras* Foerste become slender and cannot be distinguished from orthochoanitic forms. Many orthochoanitic forms possess slightly inflated siphuncular segments and may be considered as border line cases. The Pseudorthoceratidæ, as is shown below is a cyrtochoanitic family of orthochoanitic origin, and is apparently unrelated to other cyrtochoanitic groups.

74 Hyatt, A.: *Genera of fossil cephalopods*, Proc. Boston Soc. Nat. Hist., vol. 22, 1884, p. 266.

75 Hyatt, A.: *Cephalopoda* in Zittel-Eastman Textbook of Paleontology, 1st. ed., vol. 1, 1900, p. 514 ff., reprinted in later editions.

76 Miller, A. K.: *The myxochoanitic cephalopods*, Univ. of Iowa Studies, Studies in Natural History, vol. 14, No. 4, 1932.

77 See Kobayashi, T.: *On the Stereoplasmoceratidæ*, Japanese Jour. Geol., Geogr., vol. 13, Nos. 3-4, 1936, pp. 229-242, pl. 26.

Hyatt[78] divided the Cyrtochoanites into two suborders on the basis or organic deposits within the siphuncle. The first of these groups, the Annulosiphonata, is characterized by deposits which form calcareous rings at each septal neck. The other group, the Actinosiphonata, comprises forms in which the calcareous deposits of the siphuncle consist of discrete vertical lamellæ arranged in a radial pattern so that the lamellæ converge toward the center. Hyatt believed that the two types of structure were of independent origin, and he included in each group families and genera which were without any known siphonal deposits and which he regarded as primitive.

Three families were placed in the Annulosiphonata. The first of these, the Loxoceratidæ, contained two genera, and was erected for forms with nummuloidal siphuncles which were either empty or contained an "irregular deposit." Unfortunately the genotype of *Loxoceras* McCoy is so little known that no species can be referred to the genus with certainty. Hyatt's statement concerning the presence of irregular deposits appears to be an assumption. Neither the genus nor the family can be used until the structure of the genotype has been studied.

The second family, the Uranoceratidæ of Hyatt, contains gyroceracones and nautilicones with empty nummuloidal siphuncles. The genera *Uranoceras* Hyatt and *Gigantoceras* Hyatt were originally referred to the family. These and related genera have been studied by Foerste[79] who showed that the siphuncle of *Uranoceras* is definitely cyrtochoanitic. The necks are recumbent; the free part of the connecting ring is essentially cylindrical, but there is a broad area of adnation. Foreste's figures do not clearly differentiate between the septal neck and the connecting ring, but the two together are recumbent, appearing as projections inside the siphuncle, and they are curved slightly apicad, so that when the free part of the connecting ring is destroyed, they resemble orthochoanitic septal necks. This is precisely the condition which is found in all of the Silurian specimens and species referred by Foerste to *Gigantoceras*. Unfortunately no specimens of any of the species discussed by Foerste have been found which retain the connecting rings. Foerste did not see the possibility of a cyrtochoanitic condition of *Gigantoceras*, and suggested that the genus be placed in the Orthochoanites.

The third family, the Actinoceratidæ of Hyatt, with some slight modification has become the superfamily Actinoceroidea Foerste and Teichert[80]. The group has received careful study by Foerste and Teichert, and later by Teichert[81].

78 Hyatt, A.: *Cephalopoda*, in Zittel-Eastman Textbook of Paleontology, 1st. ed., vol. 1, 1900, p. 527 ff.

79 Foerste, A. F.: *Notes on cephalopod genera; chiefly coiled Silurian forms*, Denison Univ. Bull., Sci. Lab., Jour., vol. 21, 1925, pp. 28ff., pls. 1-24.

80 Foerste, A. F. and Teichert, C.: *The Actinoceroids of east-central North America*, Denison Univ. Bull. Sci. Lab., Jour., vol. 25, 1930, pp. 201-296, pls. 27-59.

81 Teichert, C.: *Der Bau der actinoceroiden Cephalopoden*, Paleontographica, Bd. 78, Abt. A, 1933, pp. 111-234, pls. 8-15, 50 text figs.

The superfamily Actinoceroidea contains numerous genera described since Hyatt's day, largely due to division of Hyatt's genera. Teichert[82] has shown that the genus *Discosorus* Hall differs fundamentally from the Actinoceroidea in the structure of the siphonal deposits, and has set it apart with its allies *Stokesoceras* Foerste and *Endodiscosorus* Teichert in the family Discosoridæ.

The Actinoceroidea remain the only group originally placed in the Annulosiphonata of the Cyrtochoanites which can still be confidently considered as included under that group.

Aside from the Actinoceroidea the Pseudorthoceratidæ appear to be the only group of cephalopods which is cyrtochoanitic and annulosiphonate. On the other hand, annulosiphonate structure is prevalent in many orthochoanitic genera, particularly those of the Silurian. Whether annulosiphonate structure is sufficient to warrant the recognition of the Annulosiphonata as a taxonomic group is very doubtful, though in some instances at least the annulosiphonate deposits serve as a more reliable guide to phylogeny than does the outline of the siphuncle. The present study deals with the Pseudorthoceratidæ, an annulosiphonate family of cyrtochoanitic aspect which appears to have an origin in orthochoanitic annulosiphonate forms, the change in the siphuncular outline taking place between Middle Silurian and Lower Devonian time.

THE PSEUDORTHOCERATIDÆ

The family Pseudorthoceratidæ Flower and Caster[83] was referred to the Annulosiphonata of the Cyrtochoanites largely as a receptacle to contain forms customarily assigned to the uncertain Loxoceratidæ. The family Sactoceratidæ was previously proposed by Troedsson[84] for the same purpose, but cannot be used in that way because *Sactoceras* is a true actinoceroid, and the family was placed in the Actinoceroidea by Foerste and Teichert[85].

In the Pseudorthoceratidæ were included five late Paleozoic genera of cyrtochoanitic orthoceracones. The siphuncles were regarded as either empty or lined with a continuous lamellar deposit. The segments of the siphuncle are variously expanded, but never wider than long. The statement, in the original designation of the family, that the connecting rings do not attain the preceding septa is both erroneous and misleading. The word septum was used here in reference to the

[82] Teichert, C.: *On the systematic position of the genus Discosorus Hall and related genera*, Amer. Mus. Novitates, No. 512, 1931, 11 pp., 9 figs.

[83] Flower, R. H. and Caster, K. E.: *The stratigraphy and paleontology of northwestern Pennsylvania*, Pt. II, Paleontology, Sec. A: *The cephalopod fauna of the Conewango series of the Upper Devonian in New York and Pennsylvania*, Bull. American Paleontology, vol. 22, No. 75, 1935, p. 29.

[84] Troedsson, G. T.: *On the Middle and Upper Ordovician faunas of northern Greenland*, I. Cephalopods. Judilaeumsekspeditionen Nord om Grönland 1920-23, Nr. 3, 1926, p. 79. (Reprinted in Meddelelser om Grönland, Bd. 71, 1929.)

[85] *Ibid.*: p. 208.

free part of the septum as contrasted with the septal neck. Further, the adnate condition of the connecting ring in *Adnatoceras ciscoënse* (Miller, Dunbar and Condra)[86] was overlooked.

At the time of the original description of the family the nature of the deposits of the siphuncle was not clearly understood, nor was it known whether the Pseudorthoceratidæ were in any related to the Actinoceroidea. The study of Devonian orthoceracones has brought to light numerous forms belonging to the Pseudorthoceratidæ and representing both new and old genera. It is largely upon the basis of this material that a morphological and systematic revision of the family is based. The family is redescribed as follows:—

The Pseudorthoceratidæ contain largely orthoceracones, with slightly exogastric cyrtoconic apices, although two specialized genera attain a cyrtochoanitic form and one is breviconic. The earliest stages of the siphuncle are slender and orthochoanitic. Later segments are definitely expanded and cyrtochoanitic, though rarely wider than long. The necks are short, their length averaging less than one-seventh the length of the segment. The brims are variously developed, but are never recumbent. Siphonal deposits are annulosiphonate and parietal, consisting of rings formed at the septal foramina, extended adorally. When well developed, the segmental deposits fuse to form a continuous lining within the siphuncle. Deposits of the cameræ are mainly mural, although episeptal and hyposeptal deposits occur in a few specialized forms.

The genera of the Pseudorthoceratidæ fall into three subfamilies as listed below. (Generic characters are shown diagrammatically in fig. 21).—

- Dolorthoceratinæ Flower, n. subf.
  - Anastomoceras Flower, n. gen.
  - Diagoceras Flower, 1936
  - Dolorthoceras Miller, 1931
  - Spyroceras Hyatt, 1884
  - Geisonoceroides Flower, n. gen.
  - Petryoceras Flower, n. gen.
  - Palmeroceras Flower, 1936
  - Cryptorthoceras Flower, n. gen.
  - Sceptrites Flower, n. gen.
  - Fusicoceras Flower, n. gen.
  - Adnatoceras Flower, n. gen.
  - Euloxoceras Miller, Dunbar and Condra, 1933
- Pseudorthoceratinæ Flower, n. subf.
  - Pseudorthoceras Girty, 1910
  - Mooreoceras Miller, Dunbar and Condra, 1933
  - Paraloxoceras Flower, n. gen.
  - Bergoceras Flower, n. gen.

86 Miller, A. K., Dunbar, C. O. and Condra, G. E.: *The nautiloid cephalopods of the Pennsylvanian system of the mid-continent region*, Nebraska Geol. Surv., ser. 2, Bull. No. 9, 1933, p. 96, pl. 1, fig. 1.

Cayutoceratinæ Flower, n. subf.
Cayutoceras Flower, n. gen.
Bradfordoceras Flower and Caster, 1935.

No deposits are known within the siphuncles of *Palmeroceras, Diagoceras, Geisonoceroides, Sceptrites* or *Cryptorthoceras*. However, the deposits are developed only in the adapical portion of the phragmocone, and apical portions of species of these genera have not as yet been obtained in a good enough state of preservation to show internal structure. These genera are placed in the Pseudorthoceratidæ on the basis of the similarity of the outline of the siphuncle with *Dolorthoceras* and *Adnatoceras*, from which they are set apart by variations in the form of the conch and the ornamentation of the exterior.

The Pseudorthoceratidæ comprise the only group of cyrtochoanitic orthoceracones known in the Devonian of America with the exception of a few species of *Ormoceras* Stokes and related forms. In the Devonian of Europe a few actinosiphonate orthoceracones occur, such as *Laumontoceras* Foerste, *Jovellania* Bayle, *Tripleuroceras* Hyatt[87], but these lack the generalized features of section and form which characterize Devonian Pseudorthoceratidæ. The family Pseudorthoceratidæ is known to range from the Lower Devonian into the Permian[88].

Ancestral forms are found in the Silurian, and the lower boundary of the family has been drawn rather arbitrarily at the appearance of cyrtochoanitic siphuncular outlines. Two changes are involved: a change in the mode of growth of the annulosiphonate deposits, and a change from orthochoanitic to cyrtochoanitic siphuncular outline. The change in the mode of growth of the deposits has been noted in Middle Silurian species which have been regarded as ancestral. Here the annulosiphonate deposits grow orad over the connecting ring independent of the growth of cameral deposits, and finally fuse to form a complete lining within the siphuncle. This is the pseudorthoceroid type of siphonal deposit. By definition only cyrtochoanitic forms are placed in the Pseudorthoceratidæ. The abrupt appearance of cyrtochoanitic siphuncular segments in the Lower Devonian may be more apparent than real. As yet no members of the genetic stock are known intermediate in age between the Middle Silurian orthochoanitic forms and the Devonian cyrtochoanitic forms. There is very little information available concerning the internal structure of Upper Silurian orthoceracones. It is quite probable that when Upper Silurian orthoceracones are better known, intermediate stages between the orthochoanitic and cyrtochoanitic outline will be found in orthoceracones with pseudorthoceroid deposits. This is suggested by the gradual change in the ontogeny of the Pseudorthoceratidæ and also by the gradual nature of the change of outline in other groups of orthoceracones.

87 Foerste, A. F.: *Actinosiphonate, trochoceroid and other cephalopods*, Dennison Univ. Bull., Sci. Lab., Jour., vol. 21, 1929, pp. 305-311.

88 I am indebted to Dr. Curt Teichert, *fide litt.*, for information on the occurrence of *Pseudorthoceras* in the Fossil Cliff limestone of the Irwin River district of Australia, considered of Lower Artinskian age.

Three subfamilies may be recognized within the Pseudorthoceratidæ. Transitional features may be seen at certain points, but the groups are apparently of genetic significance and serve to clarify the relationships existing within the family.

The DOLORTHOCERTINÆ are characterized by siphonal deposits which show little dorso-ventral differentiation, in short, of the *Dolorthoceras* type. A continuous ring is formed at the septal foramen before adjacent segments fuse to form a continuous ventral lining. The siphuncular outline is slender, the segments are never as wide as long and are generally more or less barrel-shaped. The genera included in this group are listed above. This is a generalized group from which the others are derived, and it is not surprising that it is the oldest, appearing in the Lower Devonian and persisting into the Pennsylvanian.

The PSEUDORTHOCERINÆ are characterized by the fusion of adjacent segmental deposits on the venter before any trace of siphonal deposit appears on the dorsum. The segments of the siphuncle are broader than in the Dolorthoceratinæ, and are fusiform to subspherical. *Pseudorthoceras* and *Mooreoceras* form the nucleus of the family. *Paraloxoceras* develops radial canals, and is a derivative of *Mooreoceras*. *Bergoceras* is a cyrtoconic derivative of *Paraloxoceras* in which the dorso-ventral differentiation in the growth of the siphonal deposits seems to be lost. It is included tentatively in the Pseudorthoceratinæ, although as pointed out elsewhere, it is possible that *Paraloxoceras* and *Bergoceras* may eventually be set off in another subfamily when more material has been studied than is available as present.

The CAYUTOCERATINÆ are characterized by the development of a double deposit, consisting of discrete calcareous annulosiphonate deposits covered by a carbonaceous deposit which appears to be continuous when fully developed, but which is actually composed of fused segmental elements. This group is confined to the Upper Devonian where it is represented by *Cayutoceras* and *Bradfordoceras*.

The essential characters of the genera of the Pseudorthoceratidæ are given in the table below.

GENETIC CHARACTERS IN THE PSEUDORTHOCERATIDÆ

	I	II	III	IV	V	VI	VII	VIII
Anastomoceras	1,2	1	1:0:0	1	1-2	1	1	1
Diagoceras	(1)	2	2:1:1	1-2	2	1	1	1
Dolorthoceras	1	2-3	2:2:1	1-2	1-2	1	1	1
Spyroceras	1	2-3	2:1:1	1-2	1-2	1	2+5	1
Sceptrites	(1)	2	2:1:1	3	1	3	?	?
Palmeroceras	(1)	3-4	2:2:2	1	1	1	3+4	?
Geisonoceroides	(1)	3	2:2:1	1	1	1	2+4	?
Petryoceras	1	3	2:2·1	1-2	1-2	1	6	1
Cryptorthoceras	(1)	3-4	2:1:1	2	2	2	1	?
Fusicoceras	1	3	2:2:1	4	4	4	1	?
Adnatoceras	1	4	2:2:2	1-2	1-2	1	1	1-2
Euloxoceras	1	5	2:3:3	3	3	1	1-3-5	2
Pseudorthoceras	3	6	2:1:1	1	1	1	1	1
Mooreoceras	3	6	2:1:1	1-2	1-2	1	1-(5?)	1
Paraloxoceras	3*	6	2:2:2	2	2	1	1	1
Bergoceras	3*	6	2:2:2	2	2	3	1	1
Cayutoceras	4	3	2:1:1	1	1	1	1	1
Bradfordoceras	4	6	2:1:1	2	2	1	1	1

Key to table of generic characters:—

I. Siphonal deposits
   1. Dolorthoceras type
   2. Anastomoceras type
   3. Pseudorthoceras type
   4. Cayutoceras type
   ( ) denotes assumption, evidence lacking
   * denotes development of connecting rings

II. Siphuncular outline
   1. Anastomoceras type
   2. neanic Dolorthoceras type
   3. ephebic Dolorthoceras type
   4. Adnatoceras type
   5. Euloxoceras type
   6. Pseudorthoceras type
   Hyphenated forms have intermediate ephebic type of siphuncular outline.

III. Ratio of length measurement of neck: brim: connecting ring.
   Numerical value approximate, intended to show ratio among various genera as well as within genus; hence 2:2:2 indicates equal development of neck, brim, and area, with neck equal to that designated as 2 elsewhere.

IV. Section of conch
   1. circular
   2. depressed
   3. compressed
   4. subtriangular, depressed, dorsum flattened.

V. Position of siphuncle
   1. central
   2. ventrad of center
   3. dorsad of center
   4. close to ventral margin

VI. Form of conch
   1. orthoceracone
   2. orthoceracone with contracted aperture
   3. cyrtoceracone
   4. brevicone

VII. Surface
   1. smooth, or with lines of growth
   2. annuli
   3. longitudinal ribs
   4. transverse liræ and striæ
   5. longitudinal liræ and striæ
   6. transverse bands or zigzag liræ
   Commas indicate specific variations of ornament in the genus; plus signs indicate patterns.

VIII. Cameral deposits.
   1. mural
   2. episeptal and hyposeptal

CHECK LIST OF THE KNOWN PSEUDORTHOCERATIDÆ

Subfamily DOLORTHOCERATINAE Flower, n. subf.

Anastomoceras Flower, n. gen.

A. mirabile Flower, n. sp.

A. rudis (Hall)

A. (?) longicameratum (Hall)

Diagoceras Flower
- D. aptum (Hall)
- D. tullium Flower, n. sp.

Dolorthoceras Miller
- D. parlenense (Williams)
- D. rudicula (Hall)
- D. telamon (Hall)
- D. tersum (Hall)
- D. exile (Hall)
- D. revertum Flower, n. sp.
- D. (?) bebryx (Hall)
- D. solitarium Flower, n. sp.
- D. elegans Flower, n. sp.
- D. (?) cayuga (Hall)
- D. palmeræ (Flower and Caster)
- D. cf. icarus (Hall)
- D. sp. (Salem limestone)
- D. goldfussianum (de Koninck)
- D. circulare Miller
- D. (?) dubium Miller, Dunbar and Condra

Spyroceras Hyatt
- S. (?)* multicinctum (Hall)
- S. (?) thoas (Hall)
- S. (?) geneva (Clarke)
- S. (?) incarceratum (Clarke)
- S. (?) staffordense (Clarke)
- S. crotalum (Hall)
- S. nuntium (Hall)
- S. cælamen (Hall)
- S. (?) nuntioides (Clarke)
- S. (?) rudens (Hall)
- S. (?) thestor (Hall)
- S. (?) idmon (Hall)
- S. (?) lima (Hall)
- S. oppletum Flower, n. sp.
- S. (?) pertextum (Hall)

Palmeroceras Flower
- P. fustis (Hall)

* In view of the broad usage of *Spyroceras* in the past, all species for which the siphuncular outline is unknown are referred to the genus with doubt. As pointed out elsewhere in this paper there is nothing to indicate any other generic possibility, and the reference of these species to *Spyroceras* is a fairly safe assumption.

Geisonoceroides Flower, n. gen.
G. woodæ Flower, n. sp.
G. cylindricum Flower, n. sp.
G. aulax (Hall)
G. anguis (Hall)
Petryoceras Flower, n. gen.
P. thyestes (Hall)
P. atreus (Hall)
Adnatoceras Flower, n. gen.
A. spissum (Hall)
A. wellsi Flower, n. sp.
A. cooperi Flower, n. sp.
A. cryptum Flower, n. sp.
A. naplense Flower, n. sp.
A. clarkei Flower, n. sp.
A. cf. neglectum (de Koninck)
A. ciscoënse (Miller, Dunbar and Condra)
Euloxoceras Miller, Dunbar and Condra
E. greeni Miller, Dunbar and Condra
E. milleri Flower, n. sp.
Cryptorthoceras Flower, n. gen.
C. productum Flower, n. sp.
Sceptrites Flower, n. gen.
S. sceptrum (Hall)
S. carteri Flower
S. claviformis Flower, n. sp.
S. obliquus Flower, n. sp.
Fusicoceras Flower, n. gen.
F. eriense Flower, n. sp.

Subfamily PSEUDORTHOCERATINAE Flower, n. subf.

Pseudorthoceras Girty
P. senecum Flower, n. sp.
P. anomalum Flower, n. sp.
P. knoxense (McChesney)
Mooreoceras Miller, Dunbar and Condra
M. ruedemanni Flower, n. sp.
M. bradfordoides Flower, n. sp.
M., sp. (Salem limestone)
M. (?) indianense (Hall)
M. chouteauense (Swallow)
M. cliftonense Miller and Furnish
M. (?) pettisense Miller and Furnish
M. (?) hindei (Foord)

M. normale Miller, Dunbar and Condra
M. normale var. angusticameratum Miller, Dunbar and Condra
M. tuba Miller, Dunbar and Condra
M. bakeri Miller, Dunbar and Condra
M. conradi Newell
Paraloxoceras Flower, n. gen.
P. konincki Flower, n. sp.
Bergoceras Flower, n. gen.
Bergoceras antilope (de Koninck)
Subfamily CAYUTOCERATINAE Flower, n. subf.
Cayutoceras Flower, n. gen.
C. casteri Flower, n. sp.
Bradfordoceras Flower and Caster
B. transversum Flower and Caster
B. multicameratum Flower and Caster
B. consortale (Hall)
B. hector (Hall)
B. ignotum Flower and Caster
B. gomphoides Flower and Caster
B. sinuosum Flower and Caster
B. expositum (Hall)
B. moderatum Flower, n. sp.
B. giganteum Flower, n. sp.
B. fusiforme Flower, n. sp.

SPECIFIC CHARACTERS

The specific characters are derived largely from the proportions of the conch. Certain methods of expressing the proportions have been found convenient.

Rate of expansion.—This may be expressed in two ways. The apical angle may be measured, or the rate of expansion in a known length may be given. The author has found the apical angle rather cumbersome, and it is further undesirable because the rate may vary from one part of the conch to another. Measurements are taken, whenever possible in multiples of 10 mm. lengths. Larger units are desirable particularly where the differences are small.

Curvature and depth of septum.—The depth of the septum is considered here in relation to its diameter. Another method frequently employed is the expression of the curvature of the septum as a portion of an arc of a circle. This has been found cumbersome and there is a considerable possibility of error.

Curvature of sutures.—Sutures are only slightly modified in Nautiloidea. Obliquity is sometimes expressed as an angle made by the plane of the suture with a transverse plane. Sinuosity is expressed in terms of lobes and saddles as elsewhere in the Cephalopoda.

Depth of cameræ.—It has been found convenient to consider the depth of cameræ in connection with the diameter of the conch. This has been conventionally expressed in terms of the number of cameræ in a length equal to the diameter of the conch, the number of cameræ being measured apicad (never orad) of the point at which the diameter is taken. As the proportion may vary among various parts of the conch it is best to give actual measurements rather than proportions. Further, in conchs which are not circular in section it is necessary to specify whether the dorso-ventral or transverse diameters are used.

Gerontic cameræ are usually markedly contracted, and their relation to the diameter is therefore very different from that found in the rest of the conch. The position of the gerontic cameræ in relation to the diameter is often important in fixing the size of the species.

Siphuncle.—The diameter and position of the siphuncle are measured at the septal foramen, *i.e.* the passage of the siphuncle through the septum. In cyrtochoanitic forms it is necessary to know the relationship of the maximum and minimum diameters of the segments and also its length. As proportions vary from one part of the phragmocone to another, it is desirable that the diameter of the conch be stated for the region at which the measurements of the siphuncle are taken.

The relative length of the septal neck, the brim and the area of adnation supply important characters which are discussed in connection with the types of siphuncle outlines.

Living chamber.—Immature living chambers furnish no information other than the length in relation to the basal diameter and the condition of the aperture. The mature living chamber may have different proportions. The rate of expansion is normally greatly reduced, and in some forms, as in the species of *Geisonoceroides* the aperture may contract very slightly orad. The interior of the shell is normally thickened, constricting the interior, usually just orad of the middle. The position, form and extent of the constriction are important specific characters. The lobation of the aperture is expressed in terms of crests and sinuses. The mid-ventral sinus, which is often the only one developed corresponds in position with the hyponome and is known as the *hyponomic sinus.*

Variability of the proportions of the early part of the conch from one region to another and the relation of the proportions of the mature living chamber to a definite size make it necessary that the proportions be expressed in terms of actual measurements in most cases. This results in rather unwieldy descriptions, but what is lost in brevity is gained in accuracy.

SYSTEMATIC DESCRIPTIONS

SUBFAMILY DOLORTHOCERATINÆ FLOWER, N. SUBFAM.

(For a graphic tabular presentation of the genera see text fig. 21)

The subfamily Dolorthoceratinæ constitute simple Pseudorthoceratidæ characterized by the development of a complete annulus before the segmental deposits of the siphon fuse on the venter. The siphuncular segments vary from the scarcely cyrtochoanitic condition found in *Anastomoceras,* and the complex cyrtochoanitic segments of *Euloxoceras*. The segments are uniformly slender, never wider than long, and with the expansion usually more or less localized near the ends of the segment.

As a linear arrangement is essentially artificial, the genera below are arranged in a somewhat empirical sequence.

I. Externally simple forms
   Anastomoceras
   Diagoceras
   Dolorthoceras

II. Ornamented derivatives of Dolorthoceras
   Spyroceras
   Palmeroceras
   Geisonoceroides
   Petryoceras

III. Form deviations
   Sceptrites
   Cryptorthoceras
   Fusicoceras

IV. Internal specialization; increase in siphuncular expansion
   Adnatoceras
   Euloxoceras

Genus ANASTOMOCERAS Flower, n. gen.

Genotype.—*Anastomoceras mirabile* Flower.

This genus contains orthoceracones of circular section and straight transverse sutures. The central siphuncle is cyrtochoanitic but the segments are slender as in *Dolorthoceras*. The brims are less than half the necks, and are sometimes obscure, the greater part of the expansion of the siphuncle being due to the connecting ring rather than the neck. The segments may be variously shaped; in the genotype they are fusiform with the diameter increasing rapidly from the necks to a point orad of the middle, and decreasing more gradually to the preceding septum. In *A. rudis* (Hall) the segment is more cylindrical. The connecting ring joins the preceding septum within the neck, so that there is no area of adnation.

The deposits within the siphuncle are pseudorthoceroid. In the early stage the deposits are somewhat thicker over the septal necks than are those of other genera of this family. There is some dorso-ventral differentiation in the development of the deposits, but it is slight. The gerontic deposits consist of irregular anastomosing processes connecting the continuous pseudorthoceroid deposit with a central tube which occupies the middle of each segment and surrounds the central canal. This tube is not continued through the septal foramen (text fig. 3, p. 21, figs. 13-14).

Discussion.—The genus is unique among the Pseudorthoceratidæ in the gerontic development of the deposits; it appears that siphonal secretion is uncontrolled, and that the excess material is deposited in portions of the siphuncle which are not otherwise needed.

The outline of the segments of the siphuncle is adequate for the identification of the genus. The necks are less recurved than is typical of the neanic *Dolorthoceras* type of outline, and no area of adnation is developed.

The only species which are known to belong to this genus are from the Helderbergian of New York. The genotype *A. mirabile* Flower, n. sp. and *A. rudis* (Hall) are described below. A third species, *Orthoceras longicameratum* Hall[89]

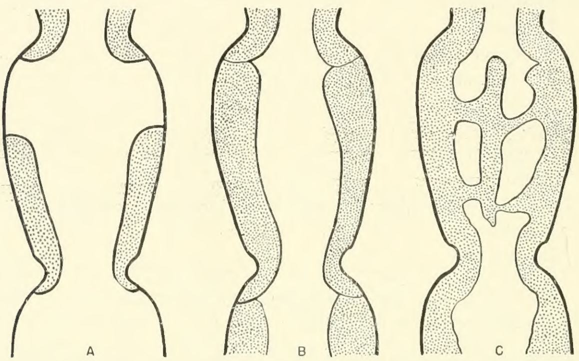


Fig. 13. Development of siphonal deposits in *Anastomoceras*. The sections are dorso-ventral and show the complete absence of dorso-ventral differentiation in the development of the deposits.

A. Siphonal deposits have formed as complete rings at the septal foramina and have developed orad along the connecting ring forming the *Michelinoceras* type of deposits.

B. Further growth of the deposits orad has resulted in the fusion of adjacent deposits to form a continuous lining within the siphuncle. This is the pseudorthoceroid type of deposit. The equal development of the deposit on dorsum and venter result in the *Dolorthoceras* type of deposit.

C. Further deposition results in a central core which is attached to the pseudorthoceroid deposit of B by irregular radial pillars. The section shown is not quite central, and fails to show the perforation of the central core which allowed the main blood vessels to run the length of the siphuncle.

from the same general locality and horizon, will probably prove to be an *Anastomoceras* when better known. Only one of the three figured types shows the siphuncle. Its segments are consistent in outline with the other *Anastomoceras* as far as can be determined from the original illustration. I have not been able to ascertain the location of the types.

89 Hall, J.: Paleontology of New York, vol. 3, 1861, p. 343, pl. 70, fig. 1, *non* pl. 71. figs. 1, 5.

Anastomoceras mirabile Flower, n. sp.

Plate 5, figures 1, 4-7

This species is represented by a single specimen which has been somewhat flattened by pressure. The preserved portion of the conch reveals an expansion of from 20 to 21 mm. in a length of 15 mm., which indicates an unusually slender conch in its undistorted condition. The section appears to have been originally circular. The cameræ and sutures are not well preserved save that one suture at the adapertural end of the specimen shows a transverse and straight course. The depth of the cameræ is known from the segments of the siphuncle; there are two and one-fourth cameræ in a length equal to a horizontal or greater diameter of 20 mm. The siphuncle is large in proportion to the diameter of the conch. Where the diameter of the conch in its crushed condition is 20 mm. at its greatest, the siphuncle is 4 mm. in diameter at its passage through the septum, and expands to 6 mm. within the camera. The length of the segment is 10 mm. The segments are elongated and slightly pyriform, the greatest diameter lying orad of the center of the segment. The necks are long, one-fifth the length of the segment, and bear obscure brims which are about one-third the necks.

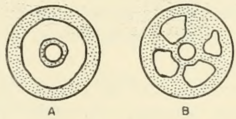


Fig. 14. Diagrammatic cross sections through the siphuncle of *Anastomoceras*.
A. Near end of segment, showing prolongation of end of sheath of central canal.
B. At middle of segment, showing radial processes connecting the sheath with the dolorthoceroid deposit.

The deposits within the siphuncle at once set this genus apart from all others. In the adapertural end of the specimen two cameræ show in section annulosiphonate rings so prolonged adorally as to form a continuous lining within the siphuncle. The deposits retain signs of their segmental origin throughout, and are slightly swollen at the adoral end (Pl. 5, fig. 6). Apicad of these segments the structure is lost by distortion in the holotype, but it is clear in the two apical segments. In a longitudinal section which does not quite attain the center, an apparently central core is present in the middle of each segment. The core does not pass through the septal necks but terminates close to them. It is connected with the pseudorthoceroid deposit by irregular radial anastomosing processes. These structures appear to be uniform in texture with the original deposit. The spaces between are represented by clearer calcareous material. A cross section, (fig. 14,) shows that the "central core" is a part of the wall of a hollow cylinder, apparently the wall of a central canal, which is slightly depressed in section and filled with matrix. Obscure traces of the anastomosing processes can also be seen in this section, together with the infiltrated material between them.

The living chamber, aperture and ornament are unknown.

Discussion.—Even in its poor state of preservation this species can be readily distinguished from all others by its slender section, deep cameræ and relatively large siphuncle. Externally, it might be confused with *Michelinoceras pauciseptum* (Hall) which occurs in the same horizon, but that species has an orthochoanitic siphuncle which is considerably smaller in proportion to the diameter of the conch and its cameræ are deeper.

Type.—Holotype: Pal. Res. Inst., No. 5870.

Occurrence.—From the Helderbergian near the Indian Ladder, Albany County, New York. From the lithology it appears that the specimen is from one of the more calcareous layers of the New Scotland.

Anastomoceras rudis (Hall)

Plate 5, figures 2-3; Plate 7, figure 12

Orthoceras rudis Hall, 1861, Paleontology of New York, vol. 3, p. 346, pl. 72, fig. 4.

This is an orthoceracone which sometimes attains a diameter of 40 mm. in an undistorted state. The section is circular and the rate of expansion is about 3 mm. in a length of 40 mm. The sutures are straight and transverse. There are three cameræ in a length equal to the adapertural diameter. The septa are about one-fifth the diameter of the conch in depth, being 5 mm. deep where the diameter is 27 mm. The siphuncle is central in position and is 3 mm. in diameter where the diameter of the conch is 29 mm.

The siphuncle is poorly preserved, and the connecting rings are usually absent. Where the depth of the cameræ is 6 mm., the septal necks are .8 mm. in length and are bent back at an angle of about 110 degrees and only slightly curved. The brim is about half the neck. The connecting rings are partially preserved in one specimen in conjunction with deposits, and join the septum at the apical end of the camera with no area of adnation. The outline of the siphuncle is known for several weathered and partly crushed specimens which are hardly adequate for measurement of the expansion. It appears that the outline is roughly like that of *Dolorthoceras*, and there is no trace of the fusiform condition of *Anastomoceras mirabile*. The deposits within the siphuncle are pseudorthoceroid. Only an early stage of development has been seen within the species. The first trace of deposits is seen at the sixteenth septal neck from the living chamber. Here the deposit is small, present only on one side, which is assumed to be the venter, and is equally developed orad and apicad of its center. Another specimen shows a more advanced condition. Here the deposit has not increased apicad or centrad, but is extended orad for half the length of the camera. The deposits are thick at the septal necks, decreasing the diameter of the septal foramen by about one-half. A trace of circumferential deposits can be seen in a camera in this specimen.

The living chamber is incompletely known. A fragment with a diameter at the base of 34 mm. is 68 mm. in length. The aperture and surface of the shell are unknown.

Discussion.—The holotype consists of a flattened portion of the phragmocone which is not suitable for either the proportions of the conch or the structure of the siphuncle. On the basis of the proportions, however, it has been possible to refer to this species a number of better preserved specimens upon which the above description is based. In view of the variation of proportions due to distortion, which has more or less affected every specimen examined, it is not possible to use any finer divisions in distinguishing species from the Lower Devonian of New York.

The outline of the septal necks and the absence of an area of adnation are typical of *Anastomoceras*. The deposits of the siphuncle show some peculiar features, but as a corresponding stage of *Anastomoceras mirable* is not available for comparison and there is no justification for the erection of a new genus for the reception of this species.

Type.—Holotype: New York State Mus., No. 12401/1. Hypotypes: Pal. Res. Inst., Nos. 5872, 5873, 5874.

Occurrence.—The holotype is from the "Central portion of the Lower Helderberg group [Helderbergian; Lower Devonian]: Schoharie," which is the New Scotland limestone. The species seems to be widespread, as among the specimens examined there are several from the Helderberg escarpment in Albany County and others from near Catskill, New York.

Genus DIAGOCERAS Flower

Genotype.—*Orthoceras aptum* Hall.
Diagoceras Flower, 1936, Bull. Amer. Paleont., vol. 22, No. 76, p. 23.

This genus contains orthoceracones of circular or depressed section with markedly oblique sutures which slope adaperturally on the dorsum. The septa are oblique and very shallow as in *Mooreoceras*. The siphuncle is located about half way between the center of the conch and the ventral wall, and is markedly eccentric in the neanic stage of the genotype, the earliest stage observed. The neck is well developed, the brim is rudimentary and the free part of the connecting ring is faintly and nearly uniformly convex throughout its length. The poor preservation of all specimens examined leaves some doubt as to the condition of the area of adnation. It appears to be equal to the brim. No deposits are known within the siphuncle. Deposits within the cameræ are mural and are normally well developed.

Discussion.—The neanic *Dolorthoceras* type of segment is probably represented in the ephebic segments of this genus, but doubt concerning the area of adnation made it seem inadvisable to call this the *Diagoceras* type. It appears that *Diagoceras* is derived from primitive species of *Dolorthoceras* in which this type of segment was an ephebic feature. Such forms may be found when better material of Onondaga and Schoharie orthoceracones has been studied.

The slender outline of the siphuncular segments of *Diagoceras* led to its inclusion in the Orthoceratidæ. Further study has indicated that its relations are now probably with *Anastomoceras* and *Dolorthoceras* of the Pseudorthoceratidæ. Only two species are known. The first, the genotype, has been recently described, and no new information has been obtained since this redescription.[90] The species is known only from the Cherry Valley limestone. A new species from the Tully limestone is described below.

The markedly oblique sutures and the condition of the siphuncle will serve to separate this genus from all others of the Pseudorthoceratidæ. Externally it somewhat resembles *Mooreoceras,* from which it can be distinguished by the segments of the siphuncle.

Diagoceras tullium Flower, n. sp.
Plate 4, figure 7

Conch orthoceraconic, circular in section, with no trace of the slightest depression. The rate of expansion is between 2.5 mm. and 3 mm., in a length of 20 mm., with no gerontic decrease up to a diameter of 233 mm. The sutures are markedly oblique, sloping adaperturally on the dorsum. Where the diameter of the conch is 21 mm. at the dorsal portion of the suture, the ventral portion lies 7 mm. apical, so that the obliquity is one-third the diameter of the conch at that point, or equal to the depth of two cameræ. The septum has not been observed. There are five cameræ in a length equal to the adapertural diameter of 5 mm., the measurement being taken at the dorsal extent of the suture. This proportion is found in a much younger stage of *D. aptum,* but the cameræ are closer, and shallower at a corresponding diameter in that species, as the increase in the depth of the cameræ of *aptum* is slower than in *tullium.*

The position and structure of the siphuncle are unknown. The base of the living chamber is 21 mm. in diameter. The length of the living chamber is unknown as are the characters of the aperture. The external mold reveals no trace of fine surface markings such as occur in *D. aptum.*

Discussion.—This species is known only from the holotype which represents a portion of a phragmocone and the base of the living chamber. The species differs from *D. aptum* in the circular section, the slightly greater rate of expansion, the more rapid increase in the depth of the cameræ, and by the much more oblique sutures.

Type.—Holotype: Pal. Res. Inst., No. 5875.

Occurrence.—From a loose block of the Tully limestone along the railroad track on the east shore of Cayuga Lake, about five miles north of Ithaca, New York. Judged by the associated fauna it is from the Apulia member of the Tully limestone. Collected by the author.

90 Flower, R. H.: *Ibid.,* p. 23, pl. 1, figs. 5-8; pl. 2, fig. 1.

Genus **DOLORTHOCERAS** Miller

Genotype.—*Dolorthoceras circulare* Miller.

Dolorthoceras Miller, 1931, Am. Jour. Sci., ser. 5, vol. 22, p. 419; Miller, Dunbar, and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 94.

In *Dolorthoceras,* as here restricted, are placed smooth orthoceracones of circular or slightly depressed section. The sutures vary from straight and transverse to slightly oblique and sinuous. The siphuncle is central in the early stages, but becomes slightly ventrad of the center in the ephebic stage of most species, though in a few it remains subcentral throughout life. The segments of the siphuncle are orthochoanitic at the earliest stage observed. Later segments show the *Anastomoceras* stage, the neanic *Dolorthoceras* stage, and the ephebic segments are of the *Dolorthoceras* stage. The neck and brim are normally equal or nearly so. The area of adnation ceases to develop beyond the nepionic *Dolorthoceras* stage, so that in the normal adult segment it is one-half the brim, or may be even more reduced. The deposits of the siphuncle first appear as simple annuli. These develop into the *Michelinoceras* type of deposit and then into the *Dolorthoceras* type. The deposit is normally completed around the septal foramen before the fusion of adjacent deposits takes place along the venter, but in one fragment of undetermined relationship, the fusion of successive segmental deposits has been noted along the venter before the deposit appears dorsally.

Deposits within the cameræ are mural and are heavier on the venter than on the dorsum.

The aperture has been observed only in certain of the Hamilton species. A hyponomic sinus is present, and the aperture may be trilobed. One of the lobes is slightly deeper than the others and probably represents the hyponomic sinus. The surface of the conch may bear transverse striæ or only fine lines of growth.

Discussion.—The choice of *D. circulare* as a genotype is rather unfortunate, inasmuch as the presence and form of deposits within the siphuncle are unknown. The description of the species was based upon a single rather badly weathered specimen. As the species is from the Karakoram Mountains of Asia, it seems unlikely that more material can be obtained for a study of the internal structure. On the basis of the present evidence it is impossible to detect any important difference between the genotype and the Devonian species here referred to *Dolorthoceras* except the presence of deposits in most Devonian species. Experience has shown that it is unwise to assume the absence of deposits within the phragmocone of a species of the basis of a single specimen, particularly when the specimen is fragmentary. Should *D. circulare* prove upon further study to lack deposits or to possess deposits of a different sort, a new name will have to be proposed for the Devonian species here included. However, the long ranges of other smooth shelled genera of the Pseudorthoceratidæ, *Adnatoceras, Pseudorthoceras* and *Mooreoceras,* which also persist from the Devonian into the Pennsylvanian, make it seem probable that *Dolorthoceras* may also have a similarly extensive geological range.

In *Dolorthoceras* are included species with both the neanic and ephebic *Dolorthoceras* types of siphuncular outline in the mature stage. Species which retain the neanic *Dolorthoceras* outline throughout life are the oldest, and are not known to extend into the Erian of the Middle Devonian. Gradation is such that a separation of such species into a distinct genus would only result in confusion.

The stratigraphic range of the known species of *Dolorthoceras* may be summarized as follows:—

LOWER DEVONIAN

The Moose River sandstone of Maine, which is of Oriskanian age, contains *Dolorthoceras parlenense* (Williams). The species is described below.

MIDDLE DEVONIAN

Ulsterian.—No species from the Schoharie grit have as yet been recognized as members of this genus, owing to the absence of well preserved siphuncles. *Orthoceras rudicula* Hall[91] of the Onondaga limestone of New York apparently belongs in *Dolorthoceras*. Hall's illustration of the siphuncle suggests the neanic *Dolorthoceras* type of outline, but is not clear enough to permit a conclusive statement.

Erian.—In the Hamilton of central New York, *D. tersum* (Hall), *D. telamon* (Hall) and *D. exile* (Hall) are fairly common. It is still doubtful as to just what *Orthoceras bebryx* is, but it is certain that a large species of *Dolorthoceras* has been included. The only *Dolorthoceras* from western New York so far recognized is *D. revertum* Flower, n. sp., in which the siphuncle is eccentric at an early stage and becomes central ephebically. *Dolorthoceras* has not as yet been recognized from the Hamilton of Ontario or Maryland.

UPPER DEVONIAN

Senecan.—The Tully limestone has yielded but one typical *Dolorthoceras*, *D. solitarium* Flower, n. sp. The Ithaca has yielded only flattened specimens, and generic identification is largely impossible. A few specimens have shown *Dolorthoceras*-like siphuncular outlines, but these have been unidentifiable specifically. They are large forms previously referred to *D.* (?) *cayuga* (Hall). *Dolorthoceras elegans* Flower, n. sp. occurs in the Cashaqua shale of the Naples fauna.

Higher beds.—The only *Dolorthoceras* known from higher strata of the Devonian of New York is *D. palmeræ* (Flower and Caster). The horizon of this species is uncertain. It may be Conneaut or Conewango.

MISSISSIPPIAN

A specimen from the Rockford limestone, Lower Mississippian, of Indiana, *Dolorthoceras* cf. *icarus* (Hall) is typical of the genus. No other species have as yet been recognized as typical *Dolorthoceras* from the Mississippian of America. It is possible that several of the species referred to *Mooreoceras* by Miller and

91 *Ibid.*: pl. 92, fig. 1.

Furnish[92] may prove to be *Dolorthoceras* when the siphuncular outline and siphuncular deposits have been made known. At the present time only the septal necks are known for some of the species which are not sufficient to form a basis for generic determination.

Of the orthoceracones of the Mississippian of Belgium described and illustrated by De Koninck, only one can be recognized as a *Dolorthoceras* from the descriptions and illustrations. This is *Dolorthoceras goldfussianum* de Koninck[93] of the Visé limestone.

PENNSYLVANIAN

The genotype, *Dolorthoceras circulare* Miller is from the Pennsylvanian of the Karakoram Mountains of Asia. *Dolorthoceras ciscoënse* Miller, Dunbar and Condra[94] of the Cisco formation of Texas is removed to *Adnatoceras* on the basis of the siphuncular outline. *D.* (?) *dubium* Miller, Dunbar and Condra[95] of the Weeping Water limestone, basal Shawnee of Nebraska as indicated in the original description is doubtfully referred to the genus owing to the poor preservation of the holotype, which is the only known representative of the species.

Key to American Devonian species of Dolorthoceras

A. Siphuncular segments not passing beyond the neanic *Dolorthoceras* stage
  B. Size small; rate of expansion about 1 mm. in 10 mm. ———— *parlenense*
  BB. Size larger; rate of expansion at least 3 mm. in 10 mm. ———— *rudicula*
AA. Siphuncular segments attaining ephebic *Dolorthoceras* stage
  C. Small species; maximum diameter attained 30 mm.
    D. Siphuncle subcentral throughout.
      E. 5 cameræ in length equal to adoral diameter; septum 1/5 diameter in depth.
        F. Length: width siphuncular segments 3:2; rate expansion 3 mm. in 10 mm.; base mature living chamber beyond 16 mm. ———— *solitarium*
        FF. Length: width siphuncular segments 2:1; rate of expansion 4 mm. in 10 mm.; base mature living chamber at 20 mm. ———— *tersum*

92 Miller, A. K. and Furnish, W. M.: *Lower Mississippian nautiloid cephalopods of Missouri*, in *Stratigraphy and paleontology of the lower Mississippian of Missouri*, Part II, Univ. of Missouri Studies, vol. 13, No. 4, 1938, pp. 164-169.

93 de Koninck, L. G.: *Faune du Calcaire Carbonifère de la Belgique*, 2me partie, Ann. du Musée Royal d'Hist. Nat. de Belgique, série Paléontologique, tome V, 1880, p. 66, pl. 38, figs. 8, 9.

94 *Ibid.*: p. 96, pl. 1, figs. 1-3.

95 *Ibid.*: p. 95, pl. 1, figs. 10-11.

EE. 4 cameræ in length equal to adoral diameter; septum 1/4 diameter in depth.

G. Rate expansion 4 mm. in 10 mm.; length: width siphuncular segments 3:2 .... *elegans*

GG. Length: width siphuncular segment 2:1; rate of expansion 1 mm. in 10 mm. .... *palmeræ*

DD. Siphuncle becoming eccentric at early stage (about 7 mm. diameter)

H. Siphuncle remaining eccentric throughout .... *exile*

HH. Siphuncule becoming central adorally

I. Gerontic living chamber at 20 mm.; section subcircular; sutures straight .... *telamon*

II. Gerontic living chamber beyond 27 mm.; section depressed, sutures with lateral lobes .... *revertum*

CC. Large species; maximum diameter over 35 mm.

J. 4-5 cameræ in length equal to diameter in flattened specimen........ *bebryx*

JJ. 7-8 cameræ in length equal in diameter in flattened specimen........ *cayuga*

Dolorthoceras parlenense (Williams)

Orthoceras parlenense Williams, H. S., 1916, U. S. G. S., Prof. Paper, No. 89, p. 283, pl. 13, fig. 25.

Orthoceras cf. *Orthoceras parlenense* Williams, H. S., 1916, U. S. G. S., Prof. Paper, No. 89, pl. 25, fig. 21.

The original description was based upon a fragment of a phragmocone representing an immature portion. A second specimen was referred to the species with doubt, but is here regarded as conspecific on the basis of the similarity of proportions with those found in the later portion of the holotype.

The holotype is 25 mm. in length, increasing from 2 mm. to 6 mm. in diameter. The section is circular. Sutures straight and transverse. Cameræ increasing very slowly in depth, so that adapically one and one-half cameræ occupy a length equal to the adoral diameter of 3 mm., while adorally three occur in a length equal to the diameter of 6 mm. The siphuncle is slightly eccentric. Where it is 1 mm. in diameter it is 1.5 mm. from one side of the shell and 2 mm. from the other. Its structure is not shown on the holotype.

The other specimen is a natural section. It increases from 6 mm. to 9 mm. in 18 mm. Three cameræ occupy a length equal to an adoral diameter of 8 mm. The septum has a depth of 3.5 mm. where the diameter is 8 mm. The siphuncle is made up of segments which are slightly expanded. A segment 3 mm. long increases from 1.4 mm. to 2 mm. in diameter. The outline appears to be of the neanic *Dolorthoceras* type, though the condition of the area of adnation is obscure, and the possibility of the *Anastomoceras* type is not entirely eliminated.

There are obscure traces of cameral deposits, though they must be regarded as doubtful due to the badly weathered condition of the specimen. The siphuncle shows traces of parietal annulosiphonate deposits.

Discussion.—This species occurs in a part of the section in which the Pseudorthoceratidæ are very poorly known, that is, in the interval comprising the upper part of the Lower Devonian and the lower part of the Middle Devonian. The earliest well preserved *Dolorthoceras* is Hamilton; the latest *Anastomoceras* is Helderbergian. A gradation between the genera is suspected in this time interval, a hypothesis to which this species lends some support. A slight area of adnation is suspected, though the poor preservation makes it necessary to admit that the evidence is not conclusive.

Types.—U. S. N. M. No. 59873.

Occurrence.—From the Moose River sandstone of the Oriskanian of the Lower Devonian, Detroit, Somerset County, Maine.

Dolorthoceras tersum (Hall)

Plate 1, figure 11; Plate 8, figure 6; Plate 9, figures 8, 17

Orthoceras tersum Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 286, pl. 84, fig. 5.

This is a small orthoceracone of subcircular section. The conch expands in a length of 27 mm. from diameters of 7.6 mm. and 8.5 mm. to 11.4 mm. and 12.6 mm.

The sutures are straight and transverse. The septa are evenly curved and are slightly less than one-fifth their diameter in depth, being 2 mm. deep where the diameter is 11 mm., or about equal to the depth of a camera. There are five cameræ in a length equal to an adapertural transverse diameter of 8.5 mm. This proportion appears to lessen slightly so that where the diameter of the conch is 11 mm., there are four and three-fourths cameræ in that length. At the base of the living chamber where the diameter is 14 mm., there are five and one-third cameræ in a length equal to the adapertural diameter, indicating a beginning of the gerontic contraction of the cameræ.

The siphuncle is slightly ventrad of the center of the conch. In an early portion it is .8 mm. in diameter and is 2.8 mm. from the venter and 4 mm. from the dorsum. At a later position it is 1.4 mm. in diameter and is 4 mm. from the venter and 5 mm. from the dorsum.

In section the segments of the siphuncle are cylindrical over the greater part of their length, and contract abruptly at the apices. Where the diameter of the conch is 11 mm., and the depth of a camera is 2 mm., the siphuncle is 1 mm. in diameter at the septal necks and expands within the camera to 1.4 mm. The necks are short and recurved, with the brim slightly less than the neck, though the proportions vary slightly from segment to segment. The neck is about one-tenth the depth of the cameræ. The middle portion of the connecting ring is very faintly convex though the curvature is marked only at the extremities. There is no area of adnation. No deposits are known within either the camera or the siphuncle.

The internal mold of the species shows the impression of a septal furrow. The living chamber is 12 mm. in diameter at the base and is 25 mm. in length on the hypotype. At the extremity there is a trace of contraction. The location of the contraction on this living chamber made it possible to correlate with the species some more nearly complete but isolated living chambers. One of these shows diameters at the base of 13.3 mm. and 14 mm., and is 30 mm. in length. The constriction begins about 18 mm. above the base. The aperture is not preserved. A slightly smaller specimen which appears to belong to the same species has diameters at the base of the living chamber of 12 mm. and 13 mm. The constriction begins 20 mm. beyond the base of the specimen beyond a maximum diameter of 14.8 mm. At the middle of the constriction the diameter has decreased to 14 mm., but 28 mm. beyond the base of the chamber the former diameter is nearly resumed. None of these specimens preserved a good aperture.

A slightly larger living chamber which is referred to this species preserves a remarkably well preserved aperture. On the venter there is a large well defined hyponomic sinus. Two dorso-lateral smaller sinuses are present separated by a mid-dorsal crest (Pl. 9, fig. 8.).

Discussion.—The outline of the siphuncle of this species is typical of *Dolorthoceras.* No deposits are known in either the cameræ or the siphuncle for this species, but the portion figured is removed from the living chamber by only three cameræ.

The dorsal furrow present in this species is the homologue of that found on the dorsum of *Striacoceras typus* Saemann, and not the homologue of the conchial furrow as Hall supposed. Consequently it has been necessary to reverse Hall's orientation of this species, and the siphuncle lies ventrad of the center and not dorsad as Hall believed.

Types.—Holotype: Amer. Mus. Nat. Hist., 4950/1. Hypotypes: Pal. Res. Inst., No. 5822-5825.

Occurrence.—In the Skaneateles division of the Hamilton, Middle Devonian. The holotype and one hypotype are from the limestone in the upper portion of the Pompey member at Pratt's Falls, Onondaga County, New York. The free living chambers are from the *Bembexia sulcomarginata* horizon in the Delphi Falls member at Delphi Falls, New York.

Dolorthoceras exile (Hall)

Plate 7, figure 4; Plate 8, figure 7

Orthoceras exile Hall, 1862, 15th Ann. Rep. Regents of the Univ. of the State of New York on the condition of the State Cab. of Nat. Hist., etc., p. 78, pl. 8, fig. 5; Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 290, pl. 39, fig. 3. *Non* pls. 84, 85.

Conch orthoceraconic, slender, subcircular in section. The hypotype is 107 mm. in length and represents a gerontic individual which retains the basal portion of the living chamber. The neanic and ephebic portions of the conch possess diameters which vary by about .5 mm., and the rate of expansion is between 1.5 mm. and 2 mm. in a length of 200 mm. In the adapertural portion of the specimen this is decreased to 1 mm. in the last 20 mm., the measurements being 14.5 mm. and 15.5 mm.

The sutures are straight and are inclined about 10 degrees from the horizontal. The proportion of the depth of the camera to the diameter varies during the growth. In the neanic stage, where the diameter is 10 mm. or less, there are three cameræ in a length equal to the adapertural diameter. Where the diameter is 14 or 15 mm., there are three and one-third cameræ in that length. In the gerontic portion of the phragmocone there are four and one-half cameræ in a length equal to the adapertural diameter of 16 mm.

The septum is between one-third and one-fourth the diameter of the conch in depth. Where the diameter is 8 mm., the septum is 2.2 mm. in depth; where the diameter is 13 mm., the depth has increased to 4 mm.

The siphuncle is about twice as far from the dorsum as from the venter throughout the known portion. It is 1.8 mm. in diameter where the conch is 8 mm. in diameter. The septal necks are less than one-tenth the length of the segment, and are sharply recurved forming a brim which is slightly greater than the neck. The connecting rings are unknown, but from the similarity of this species to *Dolorthoceras tersum* (Hall) and *Dolorthoceras telamon* (Hall) with which is it associated, it is believed that the condition is that of *Dolorthoceras* rather than of *Adnatoceras*. In the adapical end of the specimen the cameræ show faint traces of deposits against the outer wall. Deposits are not known in the siphuncle.

The mature living chamber is known from the lectotype, which is slightly crushed and not suitable for measurements, and from a hypotype. The hypotype consists of a living chamber which is 14 mm. in diameter at the base, and which is 41 mm. in length. The gerontic constriction begins 29 mm. above the base of the chamber, and the former diameter is not attained at the aperture. The surface of the shell is smooth and without ornament, though fine lines of growth may have been originally present.

Discussion.—This species differs from *Dolorthoceras tersum* in the eccentric siphuncle and more slender form. The species closely resembles *Dolorthoceras telamon*, but that species attains a much larger size. Of the specimens which Hall figured as *exile*, only two belong to the species. Of the others, one is clearly a living chamber of *Adnatoceras spissum* (Hall),[96] and the other is a crushed fragment which cannot be identified with certainty, but which appears to belong to *D. telamon*.[97] No figure accompanies the original description, and it cannot be

96 Type of Paleontology of New York, vol. 5, pt. 2, pl. 85, fig. 15. New York State Museum, No. 12365/3.

97 *Ibid*: pl. 85, fig. 14. New York State Museum, No. 12365/2.

definitely stated which of the specimens is that upon which the original description was based. The first specimen figured is recognizable and has been taken as typical *D. exile.* Specimen No. 4943/1 of the American Museum of Natural History, the type of pl. 85, figs. 1-2, of the Paleontology, is an immature living chamber with a few cameræ attached. This may be *D. telamon,* but cannot be identified generically or specifically with certainty. The specimen is from Cumberland, Maryland. In the catalogue of the American Museum the specimen is listed as "Internal cast which was used in the original description." Hall's final description shows clearly that while he may have had that specimen at the time he described *Orthoceras exile,* it played a minor part if any in his conception or description of the species, for under the heading of formation and localities he says: "Hamilton group, on the south shore of Lake Erie; at Cayuga Lake, and at Cazenovia, Madison County, N. Y. It has also been identified in the rocks of this formation at Cumberland, Maryland."

Types.—According to the catalogue of the New York State Museum, another specimen was used at the time of the original description. This specimen, the one figured on plate 39, figure 3 of the Paleontology of New York, specimen No. 12365/1 of the New York State Museum, is hereby selected as the lectotype of the species.

It is uncertain whether 4943/2 of the American Museum of Natural History is to be regarded as a paratype or a hypotype. The hypotypes upon which this redescription is largely based are Pal. Res. Inst., Nos. 5826, 5827.

Occurrence.—Probably widespread in the Hamilton shales of New York. The lectotype is from Cazenovia, New York. The American Museum specimen is from ten miles south of Buffalo, New York. The hypotypes of the Paleontological Research Institution were collected by the author from the Pompey member of the Hamilton at Pratt's Falls, Onondaga County, New York.

Dolorthoceras telamon (Hall)

Plate 2, figure 10; Plate 4, figures 10-11; Plate 8, figures 9-10

Orthoceras telamon Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 291, pl. 85, figs. 3, 4, 12.

Conch orthoceraconic, slender, subcircular in section. The diameter increases at a rate of 2 mm. to 2.5 mm. in length of 20 mm. The transverse diameter is less than .5 mm. greater than the dorso-ventral diameter throughout the late neanic and ephebic stages.

The sutures are straight and transverse in the young but are more or less oblique in the late ephebic and gerontic stages. At the base of the gerontic living chamber the diameter is 19.5 mm. and the obliquity is 5 mm., though this appears to represent an extreme case.

The cameræ vary somewhat in proportion, as the depth increases more slowly orad than the diameter of the conch. There are three and one-half cameræ in a length equal to an adapertural diameter of 9 mm., and three cameræ at a later stage where the diameter is 14 mm.

The septa are evenly curved, and in the early stage the depth is slightly more than one-fourth the diameter. In the ephebic portion this may increase to one-third, where the diameter of the conch is 13 mm.

The siphuncle is nearly central in the youngest known stage but becomes rapidly eccentric. Where the diameter is 8 mm., the siphuncle is 3.5 mm. from one wall and 4.5 mm. from the other. Where the diameter is 12.5 mm., the siphuncle is 1.5 mm. in diameter and is 4 mm. from the venter and 7 mm. from the dorsum. At the base of the gerontic living chamber the siphuncle is 2 mm. in diameter and is 5 mm. from the venter and 12.5 mm. from the dorsum.

The outline of the siphuncle is known from a fragment representing a relatively early portion of the conch. Where the diameter of the conch is 8 mm. the siphuncle is .8 mm. in diameter at the septal foramen and expands to a maximum diameter of 1.4 mm. within the segment. The outline is typical of *Dolorthoceras.* The brim and neck are subequal and about twice the area of adnation. The free part of the connecting ring is faintly convex over the middle portion but strongly curved at the ends. No trace of any organic deposit has been found within the siphuncle. Well defined mural deposits are present within the cameræ, and these are clearly better developed on the ventral side than on the dorsal side.

The mature living chamber is 20 mm. in diameter at the base and is 59 mm. in length. The aperture is unknown. A shallow elongate constriction occupies the outer third of the chamber on this specimen. The surface of the conch is ornamented by obscure lines of growth which show no trace of a hyponomic sinus.

Discussion.—In its slender form this species resembles *Dolorthoceras exile* (Hall) from which it can be distinguished by the more gradual increase in depth of the cameræ, the movement of the siphuncle from a subcentral position in an early stage to a markedly eccentric one in the gerontic stage, and in the deeper septa. Mature living chambers are of much larger size. The septal furrow is normally well developed in this species.

The early stage of this species may be confused with *Dolorthoceras tersum* which has shallower cameræ and septa, and which expands more rapidly.

Types.—Lectotype: New York State Museum, No. 12410/2. Paratype: New York State Museum, No. 12410/1. Hypotypes: Pal. Res. Inst., No. 5828-5834.

Occurrence.—In the Hamilton shales of New York, apparently wide ranging. The types are from Menteth's Point, Canandaigua Lake, New York, probably from the Ludlowville shales. The hypotypes are from the limestone on the top of the Pompey member at Pratt's Falls, New York and from the shales of the Delphi member at Delphi Falls, New York.

Dolorthoceras revertum Flower, n. sp.

Plate 8, figures 2-3; Plate 9, figure 18; Text fig. 15

This species attains a moderate size, and is characterized by the position of the siphuncle, which is close to the venter in the early portion, but comes to lie only slightly ventrad of the center in the ephebic portion. The section is slightly depressed throughout, with the venter moderately flattened in the ephebic portion.

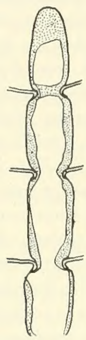


Fig. 15. Siphuncle in adapical end of holotype of *Dolorthoceras revertum* Flower Camera lucida drawing, x5. The section passes obliquely toward the wall of the siphuncle adorally.

The holotype expands from 10.5 mm. and 11 mm. to 16 mm. and 17 mm. in the basal 48 mm.; to 18 mm. and 22 mm. in the next 45 mm., and to 24 mm. and 27 mm. at the adoral end of the specimen in the next 48 mm. The sutures are exposed only in the adoral part of the specimen. They are sinuate, having lateral lobes separating dorsal and ventral saddles, and are slightly inclined orad on the venter. There are four and one-half cameræ in a length equal to the dorso-ventral diameter of 22 mm., and this relation holds throughout the ephebic portion. The septum has a depth of 8 mm. where the diameters are 19 mm. and 22 mm.

The center of the siphuncle is 9 mm. from the dorsum and 1.5 mm. from the venter at the apex, but where the dorso-ventral diameter is 19 mm., the siphuncle is 8 mm. from the venter and 11 mm. from the dorsum. Here its diameter at the septal foramen is 2 mm.

The outline of the siphuncle is known for the apical portion of the specimen. The segments are of the *Dolorthoceras* type. Where the transverse diameter of the conch is 11 mm., the segment is 3.2 mm. in length, and expands from .9 mm. to 1.5 mm. The septal neck is .3 mm., the brim is less than the neck and twice the area of adnation. Well developed deposits of the *Dolorthoceras* type line the siphuncle. Heavy mural deposits occupy the cameræ.

No trace of ornament can be seen on the holotype. The surface of the shell must have been smooth or nearly so. The living chamber is unknown. Up to a transverse diameter of 27 mm., there is no trace of the living chamber or of the shortened cameræ which indicate a mature condition.

Discussion.—The peculiar course of the siphuncle will serve to distinguish this from other species of *Dolorthoceras*. *D. revertum* can be distinguished from other Hamilton species by its size. The siphuncle of *"Orthoceras" eriense* is central, and that species is even larger. *Dolorthoceras bebryx* cannot be compared, because the undistorted section of that species is not known.

Type.—Holotype: Buffalo Museum of Science.

Occurrence.—From the *Pleurodictyum* bed, Wanakah member, Ludlowville shale, Hamilton stage, Middle Devonian. Collected at Wanakah, New York, by I. G. Reimann.

Dolorthoceras, sp. indet.

Plate 2, figures 8-9

Orthoceras subulatum Hall, 1879, Paleontology of New York, vol. 5, pt. 2, pl. 84, figs. 4, 6-10.

Among the various specimens which Hall placed in *Orthoceras subulatum* there are a number of more or less crushed apical portions of phragmocones from Pratt's Falls, Onondaga County, New York. These occur in the soft shales at the bottom of that section, and identical forms are numerous at Delphi Falls. A number of the specimens from Delphi Falls have yielded siphuncles which are sufficiently clear to show that the specimens are representatives of *Dolorthoceras*. The distortion makes specific identification impossible. It is probable that apical portions of *Dolorthoceras tersum*, *Dolorthoceras telamon* and *Dolorthoceras exile* are represented. Certainly there is variability in the depth of the cameræ which seems to indicate that several species may be represented. One specimen (Pl. 2, fig. 9) is of interest in that the condition of necks and brims is typical of the neanic *Dolorthoceras* outline, but the free part of the connecting ring is unusually straight in the middle. A second specimen (Pl. 2, fig. 8) is illustrated to show the *Michelinoceras* stage in the development of the siphuncular deposit.

The specimens from Pratt's Falls and Delphi Falls cannot be distinguished, and are regarded as conspecific. The localities are only a few miles apart. The Delphi Falls specimens are from the *Bembexia sulcomarginata* zone of the Delphi Falls member of the Hamilton. The Pratt's Falls material is from black shales which appear to represent the Delphi member rather than the Pompey member. There is no good boundary between these members. The typical Pompey consists of more arenaeous grayer shales which increase in the amount of silicious material upward, passing through sandy beds which are rich in pelecypods, and capped by a shell limestone characterized by a great abundance of *Nyassa arguta* Hall. It is from this limestone band that the well preserved cephalopods were collected upon which the revised descriptions of *D. exile, D. tersum, D. telamon* and *A. spissum* are based. There is probably no faunal break.

Types.—Figured specimens: Pal. Res. Inst., No. 5836, 5837.

Occurrence.—From the Delphi member of the Skaneateles division of the Hamilton, Middle Devonian, from Pratt's Falls and Delphi Falls, New York.

Dolorthoceras aff. exile (Hall)
Plate 1, figure 5

The figured specimen consists of a portion of a phragmocone of circular section which expands from 7 mm. to 9 mm. in diameter in a length of 18 mm. The interior of the cameræ is occupied by coarsely crystalline calcite which obscures the septa and the cameral deposits. The length of the siphuncular segments indicates that there were about four cameræ in a length equal to an adapertural diameter. At the adapical end of the specimen the siphuncle is slightly ventrad of the center. It is .6 mm. at the septal foramen and is 3 mm. from the ventral wall of the conch. The segment expands to a maximum diameter of 1.2 mm. and is 2 mm. in length. In outline the segments are intermediate between the neanic ephebic *Dolorthoceras* types. The area of adnation is less than the brim, the brim is still slightly less than the neck, and the free part of the connecting ring is more convex at its ends than in the middle.

The siphuncle, though distorted and broken, preserves its internal structure well. At the adapertural end of the specimen the *Michelinoceras* type of deposit is seen on the venter only. In more adapical segments successive stages in the fusion of the deposits can be seen. In the two adapical segments the deposits are fused along the venter, and appear to occupy half of the interior of the siphuncle. No deposits are noted against the dorsal wall.

Discussion.—The specific relation of this fragment remains a matter of doubt. The depth of the cameræ excludes *D. telamon* and *D. exile.* The rate of expansion is more slender than that of *D. tersum,* and by the condition of the deposits, the fragment belongs to a species which attained a considerably greater size than does *tersum.* It may be that this belongs to the species for which I proposed the name *Michelinoceras noveboracense.* The species is unfortunately known only from the living chamber which is of exceptional length, and from a few gerontic cameræ. Undistorted specimens retaining the phragmocone and siphuncle are not known as yet.

The confinement of the siphuncular deposit to the ventral side of the conch suggests *Pseudorthoceras.* The thick condition of the deposit may indicate a more primitive condition. It is possible that this species may be directly ancestral to *Pseudorthoceras* which appears in the Upper Devonian.

The differentiation of an outer carbonaceous layer and an inner calcareous layer of the siphonal deposit may be inorganic, but strongly suggest a tendency toward *Cayutoceras.*

Type.—Figured specimen: Pal. Res. Inst., No. 5835.

Occurrence.—From the limestone at the top of the Pompey member of the Skaneateles of the Hamilton, at Pratt's Falls, New York.

Dolorthoceras solitarium Flower, n. sp.

Plate 1, figure 9; Plate 4, figure 6

This is a slender orthoceracone of slightly depressed section. The dorso-ventral diameter increases from 11 mm. to 14 mm. in a length of 20 mm., and the transverse diameter, as estimated, increases from 14 mm. to 17 mm. in the same length.

The sutures are straight and transverse. The septa are moderately convex apicad, the depth being about one-fifth the dorso-ventral diameter throughout. There are five cameræ in a length equal to an adapertural diameter of 15 mm., and four and three-fourths in a length equal to a diameter of 13 mm.

The siphuncle is central. Where the dorso-ventral diameter of the conch is 15 mm. and the camera 2.5 mm. in depth, the siphuncle expands from a diameter of 1 mm. at the septal neck to 1.8 mm. within the camera. Necks and brims are subequal. The area of adnation is slightly less than half the brim. The free part of the connecting ring is convex throughout, attaining its greatest diameter orad of the middle of the segment.

Nothing is known of the living chamber, aperture or ornament of this species. The holotype shows no trace of organic deposits within the cameræ or siphuncle.

Discussion.—This species may be distinguished from all others in the Tully by the much greater relative width of the siphuncular segments. Its markedly depressed cross section will serve to distinguish it from any Hamilton species of *Dolorthoceras*.

Type.—Holotype, U. S. National Museum, No. 96778.

Occurrence.—In the West Brook member of the Tully limestone, Upper Devonian, from the northeast corner of the Pitcher Quadrangle, New York. Collected by J. S. Williams.

Dolorthoceras elegans Flower, n. sp.

Plate 9, figures 15-16; Text figure 16

The holotype is a small orthoceracone of circular section and of a uniform rate of expansion throughout. In the adoral 30 mm. the conch expands from 10 mm. to 14 mm. The sutures are apparently straight and transverse. There are four cameræ in a length equal to the adapertural diameter throughout the specimen. The septum is one-fourth the diameter of the conch in depth, being 2.5 mm. where the diameter is 10 mm.

The siphuncle is subcentral in position. In a nearly dorso-ventral section the diameter of the septal foramen is .8 mm., and it is located 4 mm. from the venter and about 4.2 mm. from the dorsum. The segments are of the *Dolorthoceras* type in outline. Where the segment is 3.5 mm. in length it expands from .8 mm. to

1.4 mm. The neck and brim are subequal, though their relation tends to vary rather erratically in the small portion of the specimen sectioned. The area of adnation is slightly less than the brim. The most adapical segments show the typical neanic *Dolorthoceras* outline, with the brim scarcely more than half the neck. Deposits are present in the siphuncle. In the portion sectioned they can be seen forming a continuous lining on the venter, though occasionally absent

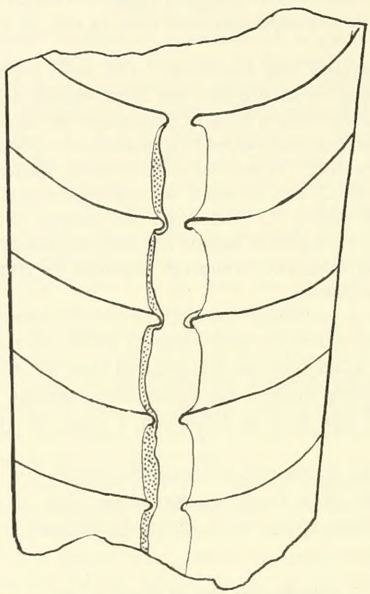


Fig. 16. *Dolorthoceras elegans* Flower. Camera lucida drawing of sectioned portion, ×3. Venter on left.

at the septal foramina. In part this is due to the removal of the deposit at the foramina by abrasion of invading sediments. On the dorsal side the deposits are present, but have not developed sufficiently to form a continuous pseudorthoceroid lining with the siphuncle. The connecting rings are preserved only where they are strengthened by the deposits of the siphuncle, a not uncommon condition.

Deposits within the cameræ are mural and are well developed, being concentrated on the venter. There is evidence of the progression of the ventro-lateral lobes to the dorsal side of the siphuncle as in *Pseudorthoceras*.

The shell is preserved only in part. The surface shows no trace of ornamentation of any kind. The living chamber of the holotype is incomplete. It is only

9 mm. in length and has a basal diameter of 14 mm. The adoral cameræ are not contracted, indicating that the species attained a larger size than is indicated by the holotype.

Discussion.—This belongs to the ecological group of orthoceracones which have deposits, both of the siphuncle and of the cameræ, markedly heavier ventrally than dorsally. This is, as usual, found in connection with a subcentral siphuncle. The completion of the siphonal deposit first on the venter is not an uncommon feature in *Dolorthoceras.* The development of dorso-ventral differentiation is greater than usual in this species, and suggests that it is not far removed from the *Pseudorthoceras* type, which appears for the first time as *P. senecum* from the same general locality and horizon as this *Dolorthoceras.* The sectioned portion of the specimen represents five cameræ, and is separated by seven cameræ from the base of the living chamber.

Although the size attained in a mature representative of this species is not known, the uniform depth of the cameræ throughout the holotype indicates an ephebic condition, and the proportions should remain adequate for the recognition of the species. It is the only species in the Naples which can be referred to *Dolorthoceras* with certainty at the present time.

Type.—Holotype: New York State Museum.

Occurrence.—Parrish limestone, Cashaqua shale, Senecan stage, Upper Devonian, from Naples, New York.

Dolorthoceras palmeræ (Flower and Caster)

Plate 1, figure 7

Pseudorthoceras palmeræ Flower and Caster, 1935, Bull. Amer. Paleont., vol. 22, No. 75, p. 31, pl. 7, figs. 1-3.

The original description of the species is adequate, and the reader is referred to it for specific characters. It is now evident that the species belongs in *Dolorthoceras* rather than in *Pseudorthoceras.*

The outline of the segments of the siphuncle is of the *Dolorthoceras* type. In comparable portions of Devonian *Pseudorthoceras* the *Pseudorthoceras* type of outline is already developed. Further, the siphonal deposits are of the *Dolorthoceras* type, showing practically no dorso-ventral differentiation in development.

The species is still known only from the holotype which is supposedly of Panama (lower Conewango, Upper Devonian) age.

Dolorthoceras (?) bebryx (Hall)

Orthoceras Bebryx Hall, 1876, Illustrations of Devonian Fossils; Cephalopoda. Expl. of pl. 39, figs. 1-2; Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 275, pl. 38, fig. 10; pl. 39, fig. 2; pl. 83, fig. 14; pl. 84 figs. 11-12.

Five specimens were figured under this name by Hall. All represent fairly large sized orthoceracones, and all except one are more or less flattened by pressure. Only one specimen among the types preserves the outline of the siphuncle, and it is highly improbable that sectioning would reveal any internal structure in the other specimens. The first specimen figured under the name of *O. bebryx* is flattened, and is not adequate for identification. The rate of expansion, the section, the position and structure of the siphuncle are all unknown. At the time of the original description two specimens were figured as *O. bebryx*. The first one was later refigured as *O. bebryx*, var. *cayuga*, therefore the other must be taken as the type of *O. bebryx*, and is here selected as such.

Occurrence.—Widespread in the Hamilton shales, Middle Devonian, of New York. The series of types includes only flattened specimens.

Dolorthoceras (?) cayuga (Hall)

Orthoceras Bebryx Hall, 1876, Illustrations of Devonian fossils: Cephalopoda. Explanation of pl. 39.

Orthoceras Bebryx, var. *Cayuga* Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 276, pl. 39, fig. 1; pl. 86, figs. 3-5; pl. 91, figs. 1-5; pl. 92, figs. 1-5.

All of the representatives of this species which are known to me are more or less flattened individuals, and it is not certain that there is not more than one species concerned. Good specimens preserve siphuncular segments of the *Dolorthoceras* type. Nothing is known concerning the condition of the deposits within the siphuncle. The surface of the shell bears prominent lines of growth, which show a broad shallow sinus on the ventral side of the conch.

After some years of collecting in the Ithaca shales I am convinced that it is highly improbable that an uncrushed specimen with the internal structure well enough preserved for section, will ever be found. Even in the limestone lenses specimens are fragmentary and badly flattened. The available evidence indicates that the species may be placed in the genus *Dolorthoceras*. The possibility of a relationship to *Cayutoceras* is not, however, eliminated. The ornament is such that the form could be placed in either genus. However, *Cayutoceras* is known at present only from the Chemung, in the strict sense, with a possible extension of its range into the Canadaway and Conneaut. *Dolorthoceras*, on the other hand, is already prolific in the Hamilton, and in general the species of the Ithaca fauna are derived from Hamilton forms.

The relationship of *D. cayuga* with "*Orthoceras*" *bebryx* cannot be determined because the latter species is too little known. At present the only similarities are in size, and a rough and very inexact correlation between flattened specimens.

Types.—Amer. Mus. Nat. Hist. No. 4939/1. N. Y. S. M. No. 12349/1-10.

Occurrence.—Widespread in the Ithaca shales, Nunda stage, Upper Devonian, from Ithaca, New York.

Genus **SPYROCERAS** Hyatt

Spyroceras Hyatt, 1884, Proc. Boston Soc. Nat. Hist., vol. 22, p. 276; 1900, Cephalopoda in Zittel-Eastman Textbook of Paleontology, 1st ed., vol. 1, p. 519. Reprinted in later editions; Grabau, and Shimer, 1910, North American Index Fossils, vol. 1, p. 600; Foerste, 1924, Denison Univ., Bull., Sci. Lab. Jour., vol. 20, p. 225; Foerste, and Savage, 1927, *Ibid.*, vol. 22, p. 38; Foerste, 1929, *Ibid.*, vol. 24, p. 162; 1932, *Ibid.*, vol. 27, p. 95; Flower, 1936, Bull. Amer. Paleont., vol. 22, No. 76, p. 25.

Original description.—*Spyroceras nobis*, includes the longitudinally ridged longicones, which at some stage of their growth are also annulated. The annular costæ are usually large, rendering the outline sinuous. The longitudinal ridges are present in the young and the annular costæ are developed later. Includes groups 5, 6 of M. Barrande. Type, *Spy.* (*Orth.*) *crotalum* sp. Hall. Mus. Geol. Survey, Albany, N. Y. Silurian and Devonian.

Until recently this genus contained all annulated orthoceracones with longitudinal ornament. Foerste[98] separated *Metaspyroceras*, based upon *Spyroceras ruedemanni* Foerste, a species common to the Cedarville of Ohio and the Racine of Illinois. In this genus the siphuncle is orthochoanitic, the sutures slope adorally on the venter, while the annuli slope adorally on the dorsum.

More recently Shimizu and Obata[99] have proposed a large number of genera which are summarized below:—

Eospyroceras.—Characterized by arching or undulating annulations and fine longitudinal striæ. Genotype: *Orthoceras arcuoliratum* Hall of the Trenton.

Hypospyroceras.—Characterized by broad slightly arching annulations and coarse longitudinal striæ. Genotype: *Orthoceras teretiforme* Hall (not *Orthoceras tretiforme*, which is a misprint,) of the Trenton.

Subspyroceras.—Characterized by more prominent annulations and coarser longitudinal striæ. Genotype: *Spyroceras middlevillense* Foerste of the Trenton.

Annaspyroceras.—Distinguished from *Spyroceras* by its more crowded, stronger annulation. Genotype: *Orthoceras anellum* Conrad from the Beloit of Wisconsin.

Gorbyoceras.—Characterized by annulations sloping apicad and weakening on the venter. Genotype: *Spyroceras gorbyi* (S. A. Miller) of the Richmond.

All of these new genera together with *Spyroceras* are placed in a new family Spyroceratidæ, characterized as annulated conchs with longitudinal markings and, at least so the authors hope, orthochoanitic siphuncles. The siphuncle is not known for any of the species used as genotypes. At present, there seems to be little justification for the recognition of these genera which are established solely upon the characters of the surface of the shell.

Spyroceras Hyatt is based upon *Spyroceras crotalum* (Hall) and that species must stand as the genotype in spite of the fact that it is fairly certain that the specimens Hyatt had in mind were *Spyroceras nuntium* (Hall). On the basis of a study of the genotype, together with two closely related species, *S. nuntium*

98 Foerste, A. F.: *Black River and other cephalopods from Minnesota, Wisconsin, Michigan and Ontario*, Part 1, Denison Univ. Bull., Sci. Lab., Jour., vol. 27, 1932, p. 111.
99 Shimizu, S. and Obata, T.: *New Genera of Gotlandian and Ordovician Nautiloids*, Jour. Shanghai Science Institute, sec. 2, vol. 2, 1935, pp. 3-5.

and *S. cœlamen* (Hall) it appears that *Spyroceras* should be restricted as follows:—

Annulated orthoceracones with slightly cyrtoconic apices. The sutures are straight and transverse, the annuli may be straight or slightly inclined apicad on the venter. The surface is variously marked, but longitudinal liræ play a conspicuous part in the ornament from the earliest stage. The siphuncle may be central or slightly ventrad of the center. Its segments are of the neanic *Dolortho-ceras* type, with brims and area of adnation equal to half the neck, in the neanic stage, but the brims and necks of the ephebic portion are subequal and greater than the area of adnation, thus attaining the condition typical of *Dolorthoceras*. Siphonal deposits are of the *Dolorthoceras* type. Cameral deposits are mural. Both cameral and siphonal deposits are more delayed in development than in other genera of the Pseudorthoceratidæ, and are therefore confined to more apical regions of the conch.

Discussion.—Owing to the delayed development of the deposits of the phragmocone and the rarity of fragments sufficiently apicad of the living chamber, the structures are rarely observed. Siphonal deposits have so far been observed only in one species, *S. oppletum* Flower, n. sp., of the Tully limestone of the Upper Devonian. Cameral deposits occupy a greater proportion of the phragmocone and are known for a greater number of species.

Of the annulated conchs which have been referred to *Spyroceras* in the past, only those which possess siphuncles of the neanic or ephebic *Dolorthoceras* types can be considered as typical representatives of the genus. Other generic names must be employed for orthochoanitic Ordovician and Silurian forms.

The condition of the siphuncular outline is known for only a few of the Devonian species of spyroceroid aspect. These include *S. crotalum* (Hall), *S. cœlamen* (Hall) and *S. nuntium* (Hall), all of the Hamilton shales of the Middle Devonian. In addition the siphuncular outline is known for most although not all of the Tully species. There remains a large number of described species for which the siphuncular outline is not as yet known. In view of the fact that no orthochoanitic conchs of spyroceroid aspect are known in the Devonian, the reference of these species to *Spyroceras* as well seems beyond reasonable doubt.

Inasmuch as the greater number of specimens of *Spyroceras* found in the Devonian of New York are more or less completely flattened, the rate of expansion, the spacing of the septa in relation to the diameter of the conch and other such features which can only be ascertained from undistorted specimens are of little use. However, the spacing of the annulations and the nature of the sculpture of the shell can be used as specific criteria, and it is upon those features that the recognition of species depends to a very large extent. Formerly the spacing of annuli has been used somewhat loosely, and confusion has resulted from the very different aspect presented by undistorted and flattened individuals. As all undistorted *Spyroceras* species are circular in section, it has been considered safe to assume a similar condition for completely flattened specimens and a restoration of the original proportions of the conch has therefore been possible.

Devonian Species of Spyroceras

Spyroceras (?) thoas (Hall) Schoharie-Onondaga
S. (?) multicinctum (Hall) Schoharie grit
S. (?) geneva (Clarke) Onondaga-Cherry Valley
S. (?) incarceratum (Clarke) Stafford limestone
S. (?) staffordense (Clarke) Stafford limestone
S. nuntium (Hall) Hamilton
S. crotalum (Hall) Hamilton
S. cælamen (Hall) Hamilton
S. nuntioides (Clarke) Hamilton
S. (?) rudens (Hall) Onondaga
S. (?) thestor (Hall) Hamilton
S. (?) idmon (Hall) Hamilton
S. (?) lima (Hall) Hamilton
S. oppletum Flower, n. sp. Tully
S. (?) pertextum (Hall) Ithaca

Space does not permit an adequate illustration of the known species of *Spyroceras* at this time. Only the genotype and one new species, both of which are important because of their known internal structure, are discussed below.

Spyroceras crotalum (Hall)

Plate 9, figures 11-12

Orthoceras crotalum Hall, 1861, Descriptions of New Species of Fossils etc., p. 50; Hall, 1862, 15th Rept. New York State Cab. Nat. Hist., 1862, p. 78, pl. 8, fig. 1; Hall, 1876, Illustrations of Devonian Fossils, pl. 42; Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 296, pl. 42, figs. 1-9, 11, 12; pl. 82, figs. 1-6; pl. 93, fig. 13.

An unflattened topotype agreeing with the original description and such of the types as have been examined, furnishes the basis for the following redescription of *S. crotalum*:—

Conch circular in section, the apex slightly and uniformly cyrtoconic. Conch expanding from 6 mm. to 13 mm. in a length of 60 mm. Sutures straight and transverse. Septa increasing in depth orad, depth one-fifth the diameter of the conch at a diameter of 7 mm.; slightly more than one-fourth the diameter at 12 mm. Siphuncle subcentral, the segments ranging from the neanic *Dolorthoceras* type at a diameter of 6 mm., to the ephebic *Dolorthoceras* type at a diameter of 12 mm. Siphuncle subcentral, the segments known only at a diameter of 6 mm., where they are typical of the neanic *Dolorthoceras* type. They are unusually short and broad at this stage, having a length of 1.1 mm., and expanding from .6 mm. to 9 mm. No siphonal deposits are present, but vestigial mural deposits can be seen in the cameræ at this stage. There are four cameræ in a length equal to an adoral diameter of 9 mm. and three and a half in a length equal to an adoral diameter of 10 mm.

The wall of the conch is corrugated into narrow rounded annuli with broad concave interspaces. Four annuli occur in a length equal to the adoral diameter of the conch up to a diameter of 13 mm. The surface of the shell bears numerous fine subequal longitudinal liræ, about eight in the width of 1 mm. Finer obscure transverse liræ occur, but cannot be seen in many specimens.

Judging solely from flattened specimens, the annuli become much more distant in the later part of the conch, so that three and a half or even as few as two occur in a length equal to the adoral diameter. The spacing of annuli is evidently rather variable in this species as in many others.

Occurrence.—The species appears to be best developed in the Skaneateles shale of the Hamilton, and is best represented in central New York in the region between Cayuga Lake and Hamilton. The holotype is from Pratt's Falls, Onondaga County, New York.

Types.—The first specimen figured, which is here selected as the lectotype, is in the New York State Museum, No. 12359/1. Hypotypes are Nos. 12359/2-10, in the same museum, and Paleontological Research Institution, No. 5866.

Spyroceras oppletum Flower, n. sp.
Plate 9, figures 9-10

The holotype consists of a portion of a phragmocone of circular section which expands in a length of 18 mm. from 6 mm. to 9 mm. The sutures are straight and transverse. The septa are about one-fifth the diameter in depth. Throughout the known portion, there are four and one-half cameræ in a length equal to an adapertural diameter. The siphuncle is eccentric, and supposedly ventral in position. At the apex of the specimen the siphuncle is 2 mm from the venter and 4 mm. from the dorsum, while at the adapertural end it is 4 mm. from the venter and 5 mm. from the dorsum.

In section the siphuncle is of the neanic *Dolorthoceras* type. Where the diameter is 7 mm. and the length of the camera is 1.8 mm., the siphuncle expands from .6 mm. at the septal foramen to 1 mm. within the cameræ. The brims are one-half the necks, and the area of adnation is subequal to the brim. The free part of the connecting ring is faintly and evenly convex within the camera. The siphuncle contains pseudorthoceroid deposits. The cameræ contain well developed mural deposits which are more strongly developed on the siphonal than the antisiphonal side.

The surface of the shell and the internal mold are marked by low obscure annulations which appear to be straight and transverse. These occur in a regular arrangement with the septa, each annulation lying just orad of the point at which the free part of the septum joins the wall of the conch. The ornament consists of relatively prominent longitudinal liræ of which there are two in the width of 1 mm., and finer transverse liræ of which there are five or six in a length equal to the width between two of the longitudinal liræ. The shell is very thin, and the spaces between the low annuli are faintly concave.

Discussion.—This species belongs in a very small group of species of *Spyroceras* characterized by subcancellate ornament. *Spyroceras geneva* (Clarke) of the Onondaga and Cherry Valley limestones has much finer liræ and more prominent annulations. *S. pertextum* (Hall) of the Ithaca shales of the Upper Devonian, has much finer and more closely spaced liræ, and more elevated and more distant annulations.

Type.—Holotype: Paleontological Research Institution, No. 5867.

Occurrence.—In the West Brook member of the Tully limestone, Upper Devonian, from the most easterly of the three quarries south of Borodino, New York.

Genus **GEISONOCEROIDES** Flower, n. gen.

Genotype.—*Geisonoceroides woodæ* Flower, n. sp.

This genus is erected for the reception of species which differ from *Dolorthoceras* chiefly in ornament and aperture. The conch is orthoceraconic, with simple septa and straight transverse sutures. The siphuncle is slightly ventrad of the center of the conch, and is of the dolorthoceroid type of outline. As only adapertural portions of the phragmocone are known, the deposits have not been observed. The ornament consists of transverse rounded ridges with equal concave interspaces. The fine ornament may vary, but in the genotype consists of fine distant transverse striæ. The ridges are slightly oblique, sloping adapically from dorsum to venter, but there is no lobation to form a definite sinus.

Discussion.—This is another of the ornamented derivatives of Middle Devonian *Dolorthoceras*, and one which bears the same relation to *Dolorthoceras* which *Geisonoceras* was thought to have to *Orthoceras* in the old sense. *G. woodæ* and *G. cylindricum*, are the only species which can be placed in *Geisonoceroides* with certainty. It is suspected that *Orthoceras aulax* Hall of the Hamilton and *Orthoceras anguis* Hall of the Ithaca may be related, but both are still known only from flattened specimens, and retain none of the siphuncular structure.

Geisonoceroides woodæ Flower, n. sp.

Plate 3, figure 4; Plate 7, figure 11; Plate 9, figure 4

Conch orthoceraconic, circular in section, and remarkably slender. The living chamber expands from 30 mm. to 31 mm. in a length of 80 mm. The sutures are straight and transverse. The septum has a depth of 8.6 mm. where the diameter is 30 mm. which is equal to the depth of one and one-half cameræ. There are normally four cameræ in a length equal to the diameter of the conch. There are four and one-third cameræ in a length equal to the diameter at the base of the living chamber, indicating the approach of a gerontic condition in the holotype.

The siphuncle is 3 mm. in diameter near the base of the living chamber, and is 11 mm. from the venter and 15.5 mm. from the dorsum. The segments are of the *Dolorthoceras* type. The greatest diameter of the segment lies well orad of the middle and contraction is gradual apicad and more abrupt orad. The brims and necks have not been observed; they are probably subequal or nearly so. The area of adnation is negligible, the connecting ring contracting to nearly the diameter of the septal foramen before joining the adapical septum. A segment 7 mm. in length expands from 2.5 mm. to 3.5 mm.

The condition of the deposits is unknown, either for the cameræ or siphuncle. Only the eight adoral cameræ are present on the holotype.

The incomplete living chamber has a basal diameter of 30 mm. and is 95 mm. in length. The ornament consists of transverse rounded ridges with equal concave interspaces, with seven or eight ridges in a length of 10 mm. No trace of longitudinal ornament can be made out, though the surface is well preserved. Fine narrow transverse striæ occur sparsely and rather irregularly placed, averaging three in the space between the crest of two of the ridges. The aperture is not preserved. The condition of the ornament shows that the aperture was inclined to the section, sloping adapically on the venter, but was without any distinct lobation.

Color markings.—The dorso-lateral area of the shell of the holotype shows traces of the color pattern unlike those previously noted on orthoceracones (Pl. 9, fig. 4). A lateral or dorso-lateral light area represented by white calcite meets a dorsal black area on one dorso-lateral area. The transition between the two is abrupt, forming a faintly irregular longitudinal line. The remainder of the shell shows no conclusive color markings. The other dorso-lateral area shows patches of light calcite which may represent the other light lateral area. No traces of color are found on the venter at all.

Discussion.—The presence of fine transverse ornament and the absence of longitudinal ornament distinguish this from *Orthoceras aulax* Hall of the Hamilton, which it otherwise resembles in ornament. Hall's species is based upon a flattened specimen, and it is impossible to compare the proportions of the conch or the structure of the siphuncle. Our species is represented by two specimens, both undistorted from western New York. It is remarkable for its very slender form. Complete specimens must have attained a length of nearly three feet, unless the adapical portion is much more rapidly expanding than the portions which have been available for study.

Types.—Holotype: Buffalo Museum of Science. Paratype: Buffalo Museum of Science.

Occurrence.—Both of the types, the only specimens I have seen, are from the *Pleurodictyum* beds of the Wanakah member of the Ludlowville shale of the Hamilton, collected at Wanakah, New York, by Dr. Irving G. Reimann.

Geisonoceroides cylindricum Flower, n. sp.

Plate 3, figure 5; Plate 6, figure 7

This species differs from *G. woodæ,* which it resembles closely, in its very shallow cameræ and its slightly depressed cross section.

The holotype consists of a part of a mature living chamber and one camera, the whole having a length of 65 mm. and expanding from 26 mm. and 28 mm. to 28 mm. and 32 mm. The markedly depressed condition of the adoral end is probably due to pressure. The condition at the basal end is probably normal. Here the venter is slightly flattened.

The sutures are straight and transverse. The septum has a depth of 11 mm., which is slightly more than one-third the diameter. The only camera preserved is 4 mm., but a paratype has two such cameræ showing that the condition is probably not gerontic, as the shallow gerontic cameræ are rarely of equal length. There should be between seven and eight cameræ in a length to the diameter of the conch. The siphuncle is 4 mm. in diameter at the septal foramen, and is 9 mm. from the venter lying slightly ventrad of the center of the conch. The living chamber of the holotype is only 62 mm. in length, but the paratype has a living chamber, apparently complete, which is 130 mm. in length. The transverse basal diameter of this section is 28 mm., identical with the measurement of the holotype. The specimen, as can be seen, is badly weathered.

The ornament consists of oblique rounded ridges with equal concave interspaces as in the genotype. There are between seven and eight ridges in a length of 10 mm. The aperture, as indicated by the ornament, is as in the genotype.

Discussion.—This species attains a slightly smaller size than *G. woodæ,* from which it can also be differentiated by the shallow cameræ, the deep septa, and the slightly flattened venter.

Types.—Buffalo Museum of Science. Holotype and paratype.

Occurrence.—The holotype is from the *Pleurodictyum* beds of the Wanakah member, at Wanakah, New York, the paratype is from the Tichenor limestone, Smoky Creek, Windom, N. Y. Both are from the Hamilton.

Geisonoceroides cf. cylindricum Flower

Plate 3, figure 6

Under this heading is figured a specimen believed to represent a nearly complete living chamber of this species. It has a basal diameter of 30 mm., and is 165 mm. in length. There is a broad shallow indistinctly outlined contracted area occupying nearly a quarter of the length and lying just orad of the middle of the specimen. The diameter at the adapertural end is 30 mm. A part of the aperture is preserved, which appears to be straight but oblique. The last septum is not preserved, so the living chamber may have been even longer than is indicated by this specimen.

Type.—Buffalo Museum of Science.

Occurrence.—South Shore cliff, Lake Erie. From the Tichenor limestone, Hamilton stage, Middle Devonian.

Geisonoceroides aulax (Hall)

Orthoceras aulax Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 293, pl. 84, fig. 18.

The holotype is a portion of a flattened conch 80 mm. in length, which is essentially cylindrical and with no appreciable expansion of the conch. The width of the flattened specimen is 28 mm. The surface bears regular low rounded ridges with equal concave interspaces, of which there are eight to ten in a length of 10 mm. Close examination of the type has failed to reveal any trace of the fine longitudinal ornament described by Hall.

Discussion.—The type is not sufficient to warrant the identification of this species. *G. woodæ* and *G. cylindricum* described above do not differ from each other or from this species in ornament or the obviously slight rate of expansion. *G. cylindricum* is distinguished from *G. woodæ* by the much shallowed cameræ and the longer living chamber. As the type of *G. aulax* does not retain the cameræ, and the fragment is short enough to represent a part of a living chamber of either species, identification is impossible.

Type.—New York State Museum, No. 12347/1.

Occurrence.—"Hamilton beds, Hamburg, Erie County, New York." Probably from the Wanakah member of the Ludlowville shale, Hamilton stage, Middle Devonian.

Geisonoceroides anguis (Hall)

Orthoceras anguis Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 312, pl. 89, fig. 9.

The holotype is an aseptate fragment 60 mm. in length, flattened, expanding from 10 mm. to 12 mm. in width. Its surface is marked with numerous closely spaced rounded ridges with equal interspaces. These are spaced about 15 in 10 mm. They are straight, but slightly oblique. No trace of the phragmocone is known.

Discussion.—Though the species is still known only from flattened individuals there can be little doubt that it is a *Geisonoceroides,* as is indicated clearly by the ornamentation. It is unique in the close spacing of the ridges.

Type.—Holotype: New York State Museum, No. 12344/1.

Occurrence.—From the Ithaca shales, Nunda stage, Upper Devonian. The holotype is from Cascadilla Creek, Ithaca, New York.

Genus **PETRYOCERAS** Flower, n. gen.

Genotype.—*Orthoceras thyestes* Hall.

Conch orthoceraconic, circular or slightly depressed in section. The sutures are straight and transverse, the septa are apparently evenly curved, and the siphuncle is subcentral in position or slightly ventral of the center of the conch. The siphuncle is similar to that of *Dolorthoceras* in outline in the ephebic portion of the conch. The neanic *Dolorthoceras* type of structure has been observed in an earlier portion. No deposits have been seen within the siphuncle. Mural deposits are present within the cameræ. The surface of the conch is marked by fine bands of short oblique zigzag stiræ and liræ. There is no trace of a hyponomic sinus in the ornamentation.

Discussion.—The genus is set apart from *Dolorthoceras* by the remarkable ornament which is unlike that known from any other cephalopod. Two species are placed in *Petryoceras*. Both of these are from the shales of the Sherburne of the Upper Devonian. *Petryoceras* is probably a specialization of *Dolorthoceras.* I have named this genus for Professor L. C. Petry of the Department of Botany of Cornell University who found the remarkably well preserved specimens of the genotype which made possible a description of the genus and accurate knowledge concerning the species.

Petryoceras thyestes (Hall)

Plate 8, figure 15; Plate 9, figure 13

Orthoceras thyestes Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 306, pl. 88, fig. 2.
Orthoceras, sp. indet. Hall. 1879, Paleontology of New York, vol. 5, pt. 2, pl. 89, figs. 7-8.

This is an orthoceracone which sometimes attains considerable size but which usually occurs in a badly crushed condition. The section is believed to have been slightly depressed; a fragment preserved in a concretion has diameters of 27 mm. and 28 mm., and a rate of expansion of about 2 mm. in a length of 20 mm.

The sutures are straight and transverse. The septa are shallow and evenly curved; where the dorso-ventral diameter of a slightly compressed specimen is 35 mm. the septum is 9 mm. in depth. There are five cameræ in a length equal to an adapertural dorso-ventral diameter of 26 mm. Where the dorso-ventral diameter is 36 mm., the siphuncle is 14 mm. from the venter. Here it expands within the camera from a diameter of 2 mm. at the septal neck to one of 3 mm. The segment is 4.5 mm. in length. The necks are short and sharply recurved, the connecting rings are faintly convex throughout the middle, contracting abruptly at the extremities. There is no area of adnation. No deposits are known in either the siphuncle or the cameræ.

The proportions of the living chamber are not known, all of the available living chambers being badly crushed. The aperture is not preserved.

The ornament, often impressed upon the internal mold, consists of close set transverse rows of broken zigzag liræ of which there are about nine in the length of 5 mm.

Discussion.—This species is very characteristic of the Sherburne horizon of Ithaca, New York, and the same facies, of approximately the same age, in the Seneca Lake section. The holotype is a badly flattened specimen which shows no trace of surface markings. Another specimen, that figured on pl. 8, fig. 15 of this paper, retains identical proportions but shows traces of the ornament. Through this it was possible to connect the holotype with better preserved specimens which made possible a study of the siphuncle.

Crushed fragments of the shell are apt to bear obscure traces of the ornament, and if the shell is not preserved the markings of the surface may be impressed upon the internal mold. In many instances the continuity of the transverse bands of broken diagonal markings can not be made out, and the effect is one of an oblique cancellation. It was apparently such a specimen that Hall mistook for an orthoceracone covered with Bryozoa. Though Bryozoa have been found on this species, as they have on many others of the Lower and Middle Devonian, none are of a type which would result in such an appearance.

The species apparently has a very short vertical range. Numerous fragments have been obtained from the Sherburne, but extensive collecting has failed to reveal this species either in the overlying Ithaca or the underlying Genesee.

Types.—Holotype: New York State Museum, No. 1246/1. Hypotypes: Pal. Res. Inst., No. 5843-5847.

Occurrence.—The holotype is from "the soft shales of the Portage group near Watkins, at the south end of Seneca Lake." Hall included in his Portage only the lower part of the section of the Seneca and Cayuga valleys which contained a predominance of black shale. The holotype is from such a facies in the Seneca section, while the hypotypes are from the Sherburne sandstone, Nunda stage, Upper Devonian, of Taughannock gorge on Cayuga Lake. Numerous fragmentary specimens have been found in the upper beds of the Sherburne at various localities near Ithaca, New York.

Petryoceras (?) atreus (Hall)

Orthoceras atreus Hall, 1879, Paleontology of New York, vol. 5, pt. 2, p. 305, pl. 88, fig. 1; pl. 89, figs. 10, 11.

The specimen first figured, and selected here as the lectotype, represents a large orthoceracone in a badly flattened condition. In its present condition the conch is 280 mm. in length and expands from 66 mm. to 80 mm. in 125 mm., which constitute the phragmocone. The living chamber is about 140 mm. in length. In the basal 110 mm. it expands to a diameter of 80 mm. and contracts noticeably beyond. The aperture is not preserved. There are five cameræ in a length equal to an adapertural diameter of 80 mm. in the present condition of the specimen. The sutures are straight and transverse. The siphuncle is not preserved on the lectotype.

The surface of the holotype bears a fine ornament identical with that of *Petryoceras thyestes,* (Hall), and is placed in *Petryoceras* on the basis of the ornament.

Discussion.—Though the proportions are not accurately known for this species it can readily be distinguished even in a crushed condition, for the cameræ are relatively deep. *Petryoceras thyestes* has between seven and one-half and eight cameræ in a length equal to an adapertural diameter in a crushed specimen. The ornament is believed to be sufficient for the generic diagnosis. It is known only in these two species which are associated in the Upper Devonian, and it would be remarkable if they differed in internal structure.

The septum figured by Hall and referred to *O. thyestes* with doubt probably belongs to that species. Among the Taughannock material I have observed other similar septa with eccentric siphuncles; the larger ones are depressed in section. The siphuncle of *O. thyestes* is subcentral in position.

Types.—Lectotype: New York State Museum, No. 12346/1. Paratypes: American Museum of Natural History, No. 4938/1. This number includes two specimens.

Occurrence.—"In the calcareous layers of the Portage group, at Penn Yan, Yates County, and in the shales at Rogers' Bridge on the Genesee River, below Portageville, N. Y." From this it would appear that Hall's types are from the lower part of the Upper Devonian, certainly not higher than the Cashaqua shales. Other specimens have been observed in the Sherburne at Taughannock Falls, Cayuga Lake, in association with *Petryoceras thyestes* (Hall).

Genus **PALMEROCERAS** Flower

Genotype.—*Orthoceras fustis* Hall.

Palmeroceras Flower, 1936, Bull. Amer. Paleont., vol. 22, No. 76, p. 58.

This genus contains orthoceracones of circular section and straight transverse sutures. The siphuncle is central, and is of the *Adnatoceras* type. The brim is nearly twice the neck and the area of adnation is nearly as great as the brim. The free part of the connecting ring is abruptly curved at the ends, and is slightly convex over the middle portion, and not perfectly straight as is normal in the *Adnatoceras* type of outline. The surface of the shell bears fine cancellate markings which recall the ornamentation of *Protokionoceras* Grabau and Shimer. The aperture is trilobed. One of the lobes is slightly deeper than the other two and probably represents the hyponomic sinus. The mature living chamber bears upon its interior a series of constrictions which increase in prominence toward the aperture. Deposits have not been noted in either the siphuncle or the cameræ.

Discussion.—This genus is set apart from the rest of the Pseudorthoceratidæ by its ornament, which suggests the Kionoceratidæ. The outline of the siphuncle suggests a relationship with *Adnatoceras,* but the convex free part of the connecting rings and the trilobed aperture suggest *Dolorthoceras,* and it is believed that the condition of the brim and area of adnation represent a development parallel to that of *Adnatoceras* but independent of it. The genus is regarded as a derivative of *Dolorthoceras.*

Only one species, the genotype, is included in this genus. This species is known only from the mature living chamber and the adapertural portion of the phragmocone. Deposits of the siphuncle and cameræ never occur in the adapertural part of the phragmocone and their absence here cannot therefore be considered as of any significance.

Palmeroceras fustis (Hall) has been recently refigured and redescribed. The species is known only from the Cherry Valley limestone of the Middle Devonian. For further information the student is referred to the redescription.[100]

ADNATOCERAS Flower, n. gen.

Genotype.—*Orthoceras spissum* Hall.

This genus is erected for the reception of orthoceracones which resemble *Dolorthoceras,* but differ from that genus in possessing an area of adnation which is at least equal to the brim.

The conch is orthoceraconic, normally slightly depressed in section. The neanic sutures are straight, and this condition may continue into the ephebic portion of some species, but in the genotype the sutures become sinuous, lateral saddles appearing which separate dorsal and ventral lobes. When the sinuosity is well developed the dorsal lobe becomes the deeper of the two. The siphuncle is normally slightly ventrad of the center of the conch though central in the early stages. In the earliest stage available the brim is slightly greater than the neck, and the area of adnation is subequal to the brim. The free part of the connecting ring expands sharply from the ends, but the middle portion is straight. In the late ephebic and gerontic portions of the siphuncle, this type of structure disappears. The diameter of the septal foramen increases more rapidly than the maximum diameter of the segment, bringing about a marked reduction of brim and area of adnation until the neanic *Dolorthoceras* type of structure appears. The brim and area of adnation remain subequal, but become slightly less than one-half the neck. Meanwhile the free part of the connecting ring becomes more faintly and uniformly curved throughout.

Deposits within the siphuncle are known from the genotype and one other species. They are annulosiphonate in origin, only slightly better developed on the venter than on the dorsum, and are of the *Dolorthoceras* type, eventually meeting to form a continuous lining within the siphuncle. It appears to be characteristic of the genus that the deposits are confined to the extreme apical part of the phragmocone.

Deposits in the cameræ are variable. All Devonian species which show these structures possess mural deposits, *Adnatoceras ciscoënse* (Miller, Dunbar and Condra)[101] has episeptal and hyposeptal deposits. It differs from the Devonian

100 Flower, R. H.: *Cherry Valley cephalopods,* Bull. Amer. Paleont., vol. 22, No. 76, 1936, p. 59, pl. 2, fig. 4; pl. 4, figs. 1-2; pl. 7, fig. 3.

101 *Ibid.*: p. 96, pl. 1, figs. 1-3.

species in no other important particular.

Discussion.—In possessing the *Adnatoceras* type of siphuncular outline this genus is intermediate between *Dolorthoceras* and *Euloxoceras*. The genus can be distinguished from *Dolorthoceras* by the equal brim and area of adnation in all stages, as well as by the relation of the brim and neck implied in the *Adnatoceras* type of outline as previously defined. *Euloxoceras* differs from *Adnatoceras* in the compressed section, the greater development of brim and area of adnation, and by the faintly concave outline of the middle of the siphuncular segment.

The late ephebic and gerontic reversion to a more primitive type of outline discussed on page 24 has so far not been noted in any other genus of the Pseudorthoceratidæ. The changes which take place are apparently a modification of the outline of the segment, and an increase in the septal foramen at the expense of the brim and area of adnation.

Adnatoceras appears in the Hamilton where it is represented only by the genotype, *A. spissum* (Hall). The genus is better developed in the Upper Devonian. The Tully limestone has yielded three species. *Adnatoceras* has not been definitely recognized in the Ithaca shales, where orthoceracones are flattened and the internal structures usually destroyed. Two species have been recognized from the Naples fauna, and numerous fragmentary specimens indicate that more were probably present. The genus has not been found as yet in higher strata of the Upper Devonian. The only species known as yet from the Mississippian is *Adnatoceras* cf. *neglectum* (de Koninck) from the Tournai limestone, of the Mississippian of Belgium. *Adnatoceras ciscoënse* is the only known Pennsylvanian species. A key to the American species of *Adnatoceras* is given below.

Key to American species of Adnatoceras

A. Section depressed; cameræ always shallow.
- B. Difference in ephebic maximum and minimum diameters 1 mm.; Sutures scarcely sinuous.
  - C. Cameral deposits mural .... *spissum*
  - CC. Cameral deposits episeptal and hyposeptal .... *ciscoënse*
- BB. Difference in ephebic maximum and minimum diameter 4 mm.; Sutures markedly sinuous .... *wellsi*

AA. Section circular.
- D. Length of brim and area of adnation greater than length of neck at least up to a conchial diameter of 20 mm.
  - E. Size large; gerontic contraction of cameræ beyond a conchial diameter of 35 mm .... *naplense*
  - EE. Size small; gerontic contraction of cameræ at a conchial diameter of 23 mm. .... *clarkei*

DD. The brim and area of adnation reduced to one-half the length of the neck at a conchial diameter of 20 mm.

F. Siphuncle subcentral; 5 cameræ in diameter equal to adoral diameter of conch........*cryptum*

FF. Siphuncle eccentric; 3 cameræ in length equal to adoral diameter of conch........*cooperi*

Adnatoceras spissum (Hall)

Plate 1, figure 8; Plate 4, figure 8; Plate 7, figure 10

Orthoceras spissum Hall, 1879, Paleontology of New York. vol. 5, pt. 2, p. 287, pl. 85, figs. 6-9.

Orthoceras exile Hall, *Ibid.*, pl. 85, fig. 15. *Non* p. 290, pl. 39, fig. 3; pl. 84, fig. 3; pl. 85, figs. 1-2.

This is a moderate sized orthoceracone of slightly depressed section. The conch enlarges at a rate of 6-7 mm. in a length of 20 mm. throughout the known portion. There is a difference between the diameters of 1 mm. from the earliest known stage, where they are 10 mm. and 11 mm. The sutures are straight and transverse in the early stages, but in the latter portion of the phragmocone slight lateral saddles separate dorsal and ventral lobes. The septum is shallow, its depth being about one-fifth the diameter, or 4 mm. where the transverse diameter is 19 mm. The cameræ are uniformly shallow. In the early portion of the conch there are five in a length equal to an adapertural transverse diameter of 20 mm. but the depth varies slightly erratically. The siphuncle is subcentral where the dorso-ventral diameter is 10 mm., but is ventrad of the center in the later portion. Where the dorso-ventral diameter is 19 mm., the septal foramen is 1.2 mm. in diameter as exposed at a septum, and is located 7 mm. from the ventral wall of the conch.

The outline of the siphuncle varies markedly. The earliest stages are not available, and the typical *Adnatoceras* type of outline appears where the conch has a dorso-ventral diameter of 10 mm. Here the siphuncular segment is 2 mm. in length, and expands from a diameter of .6 mm. at the septal foramen to one of 1.3 mm. within the camera. The necks are very short, about .2 mm. in length. The brim and area of adnation are subequal and slightly over .3 mm. The free part of the connecting ring is sharply curved to a vertical position just apicad of the septal neck, so that the greater part of the segment of the siphuncle is cylindrical, and not faintly convex as in *Dolorthoceras*. The connecting ring contracts abruptly as it approaches the adapical septum which it joins to form an area of adnation.

The later segments of the siphuncle show a very different sort of outline. Where the diameter of the conch is 17 mm. dorso-ventrally, the segment of the siphuncle is 3 mm. in length. The diameter is 1 mm. at the septal foramen and 1.9 mm. within the camera. The brim and area of adnation are equal but less than one-half the neck, the neck being .7 mm. and the brim and area of adnation measuring .3 mm. The free part of the connecting ring is faintly convex throughout.

The adapical segments of a hypotype show the deposits in an early stage of development, forming minute annulosiphinate rings. The most apicad of these show a slight adoral prolongation. The deposits are slightly better developed on the venter than on the dorsum. The siphuncular deposits are visible on the venter on the 25th camera from the living chamber, while the first trace of the deposit on the dorsum appears two cameræ apicad of this.

Deposits of the cameræ are concentrated on the ventral side of the conch and are mural. The exact position of the first trace of deposits is not known, but they are developed at the 17th camera.

The living chamber of the hypotype has a transverse diameter at the base of 22 mm., and is 29 mm. in length. The internal mold bears a constriction 9 mm. beyond the base which extends for 11 mm. The contraction is moderate; the diameter decreasing from 20 mm. to 18 mm., and returning to its original size just before the aperture. The aperture is straight and transverse with no trace of the hyponomic sinus. The surface of the shell is smooth, without even perceptible lines of growth.

Discussion.—The depressed section and shallow cameræ serve to distinguish this species from the Hamilton species, which can further be distinguished by the differences between *Dolorthoceras* and *Adnatoceras.* The living chamber can be recognized by its brevity and the absence of a hyponomic sinus. The proportions of the phragmocone and the condition of the sutures will serve to distinguish this species from congeneric forms of the Tully and higher horizons.

The species attains a maximum diameter of about 20 mm., and was probably about 150 mm. in length when complete. The internal molds of some specimens show a well developed dorsal carina. The living chamber of this species was referred by Hall to *Dolorthoceras exile,* but a specimen which retains both the phragmocone and the living chamber has made it possible to correct this error. The living chamber of *D. exile* is much more slender and bears a well defined hyponomic sinus.

Types.—Of the two syntypes figured by Hall only one can be located. This, upon which the first two figures of this species are based, is here selected as the lectotype. It is No. 1943/1 in the collection of the American Museum of Natural History. The topotypes are in the Paleontological Research Institution, Nos. 5840-5842.

Occurrence.—From the upper limestone band of the Pompey member of the Hamilton, at Pratt's Falls, Onondaga County, New York, and from Norton's Landing, on the east shore of Lake Cayuga, New York. The species is probably fairly widespread in the Hamilton, but uncrushed specimens which can be placed in this species with certainty are not commonly found.

Adnatoceras wellsi Flower, n. sp.
Plate 4, figures 1-4

Conch orthoceraconic, slender, slightly depressed in section. The diameters of the holotype increase from 20 mm. and 24 mm. to 24 mm. and 28 mm. in a length of 40 mm., giving a rate of expansion of 1 mm. in 10. The sutures are sinuate, with low lateral crests which separate a shallow ventral lobe and a slightly deeper dorsal lobe. The depth of the septum is about one-fourth the dorso-ventral diameter throughout the known portion, which includes only the late ephebic portion of the phragmocone. There are five cameræ in a length equal to an adapertural dorso-ventral diameter of 24 mm., and six in a length equal to the corresponding transverse diameter of 28 mm.

The siphuncle is ventrad of the center. At the adapertural end of the specimen it is 3 mm. in diameter, and is located 8 mm. from the venter and 13 mm. from the dorsum. The segments of the siphuncle are of the neanic *Dolorthoceras* type, which is characteristic of the later segments of *Adnatoceras*. Where the dorso-ventral diameter of the conch is 24 mm., the siphuncular segment expands from 2.5 mm., to 3.5 mm. and is 6 mm. in length. The neck is 1 mm., one-sixth the length of the segment. The brim is slightly more than half the neck and equal to the area of adnation. The free part of the connecting ring is faintly convex. Deposits are not known in either the siphuncle or cameræ of this species. The living chamber and aperture are unknown. The surface is poorly preserved, and shows no sign of ornament.

Discussion.—This species differs from *A. spissum* (Hall) in its larger size, more depressed section and more sinuate suture, as well as in the proportions of the conch. The sinuate sutures and depressed section will separate it from other Tully species placed in *Adnatoceras*. This form appears to be intermediate in size and in sinuosity of the sutures between *A. spissum* of the Hamilton and *A. naplense* of the Naples, though it differs markedly from the Naples species in its shallow cameræ. This species is named for Dr. J. W. Wells.

Type.—Holotype: Pal. Res. Inst., No. 5849.

Occurrence.—In the Tully limestone, from the most easterly of the three quarries south of Borodino, New York. Collected by Dr. J. W. Wells.

Adnatoceras cooperi Flower, n. sp.

Plate 7, figures 6-7

Conch orthoceraconic, circular in section. The holotype is a specimen 174 mm. in length which attains a maximum diameter of 50 mm. The rate of expansion varies between 2 mm. and 3 mm. in a length of 40 mm. The sutures are straight and transverse. The depth of the septum increases from one-fifth a diameter of 30 mm. to slightly over one-fourth a diameter of 37 mm. There are four cameræ in a length equal to the adapertural diameter throughout the known portion of the phragmocone.

The siphuncle is 21 mm. from the dorsum and 16 mm. from the venter. Where the camera is 9.4 mm. in length the siphuncle increases in diameter from 2.5 mm. at the septal foramen to 3.5 mm. within the camera. The necks are about .5 mm. in length and are slightly recurved, forming brims which are about half the necks. The connecting ring is faintly convex throughout its free portion and is adnate to the adapical septum for an area slightly greater than the brim.

The surface of the shell is not preserved. The outside of the internal mold bears longitudinal slickensides-like markings which are adventitious. The aperture is not known. The basal diameter of the living chamber is 42 mm. and the chamber is incomplete and 45 mm. in length. The aperture is not preserved. The absence of gerontic contraction and any decrease in depth of the cameræ indicate that the specimen is not mature.

Discussion.—The outline of the siphuncle agrees with that found in the latest segments of *A. spissum* (Hall) from which this species can be distinguished by the much larger size and the much deeper cameræ. The reduction of brim and area of adnation is such that this form might readily be confused with certain species of orthochoanitic affinities, but in such forms the necks are shorter and there is no area of adnation. The holotype is the specimen listed by Cooper and Williams as *Protokionoceras marcellense*[102] (Hall). *Striacoceras* possesses no area of adnation and is properly orthochoanitic.

Type.—Holotype: U. S. National Museum, No. 90758.

Occurrence.—In the Tully limestone at Carr's quarry near Tully, New York. Collected by J. S. Williams.

Adnatoceras cryptum Flower, n. sp.

Plate 8, figure 4

This is a moderate sized orthoceracone of circular section. The diameter increases from 20 mm. to 24 mm. in a length of 40 mm. The sutures are straight, and are nearly transverse, being very faintly inclined orad on the dorsum. The septa are between one-fourth and one-fifth the diameter of the conch in depth. There are five cameræ in a length equal to an adapertural diameter of 24 mm. The siphuncle is subcentral in position, and is rather poorly preserved in the holotype. Where the diameter of the conch is 20 mm., the segment is 3.5 mm. in depth and expands from a diameter of 1.5 at the septal foramen to one of 2.5 mm. one-third the distance to the preceding septum, where the diameter is greatest. The neck is one-sixth the depth of the camera. The brim is about one-half the neck, and the area of adnation is slightly greater. The free part of the connecting ring is convex throughout, but attains its widest point orad of mid-height.

The holotype consists of a portion of a phragmocone 51 mm. in length, representing a mature or nearly mature portion. The surface appears to be smooth.

Discussion.—In the central position of the siphuncle this is the simplest of the species referred to *Adnatoceras*. This and the circular section will serve to distinguish *A. cryptum* from other species of the genus.

Type.—Holotype: Pal. Res. Inst., No. 5850.

Occurrence.—In the Tully limestone at the most easterly of the three quarries south of Borodino, New York.

102 Cooper, G. A. and Williams, J. S.: *Tully formation of New York*, Geol. Soc. Amer. Bull., vol. 46, 1935, p. 859.

Adnatoceras naplense Flower, n. sp.

Plate 3, figure 2

This is a large orthoceracone apparently of slightly depressed section. The holotype is a portion of a phragmocone which is enclosed in a concretion so that none of the features of the surface are shown. The specimen has been ground down to the siphuncle, and the surface shown appears to be slightly oblique to the dorso-ventral plane so that more of the venter than of the dorsum is removed. The specimen is 124 mm. in length and expands at a rate of 5 mm. in a length of 40 mm.

The sutures appear to be slightly oblique in section, sloping adaperturally on the ventral or siphonal side. The cameræ occur three and one-half in a length equal to an adapertural diameter throughout. At the apical end of the specimen the siphuncle is 2 mm. in diameter and is separated from the two walls exposed in section by 8 mm. and 9 mm. respectively. The maximum distance of the siphuncle from the wall to the conch is 10 mm., and is inclined about 50 degrees from the plane of the section taken. At the other end of the specimen the siphuncle is 5 mm. in diameter and is 13 mm. and 17 mm. from the two walls, and its maximum distance is increased to 21 mm.

In the adapical part of the specimen the siphuncle is of the *Adnatoceras* type, with subequal brim and area of adnation which are greater than the neck. The connecting ring is cylindrical over the greater part of its length and contracts abruptly at its ends. In the adoral third of the specimen the brim and area of adnation are slightly less in proportion to the brim, and the free part of the connecting ring becomes faintly convex in outline. Where the camera is 10 mm. in depth the siphuncle expands from 3 mm. to 5 mm. in diameter. The neck is 1 mm. in length, and bears a brim which is 1.3 mm. The area of adnation is slightly greater than the brim.

Organic deposits within the siphuncle and cameræ are not known. The siphuncle shows in its adapical portion the phenomena of the incomplete internal mold supplemented by calcite. The dark matrix presumably represents the lower side of the conch as it lay in the sediments, and which invaded only the adapertural portion of the siphuncle, decreasing apicad in extent, and giving place there to the infiltrated calcite.

The living chamber, aperture and surface are unknown.

Discussion.—The specimen upon which this species is based was originally labeled *Orthoceras bebryx* but that species, probably a *Dolorthoceras*, is not known from the Upper Devonian. The species which has been called *Orthoceras bebryx*, var. *cayuga* Hall and which is probably specifically distinct from *O. bebryx* is discussed above. The large size, deep cameræ, and the relatively late retention of the *Adnatoceras* stage will separate this species from all others. It is approximated in size only by *A. cooperi*, which shows the gerontic type of siphuncular segment at a much earlier stage.

Type.—Holotype: New York State Museum.

Occurrence.—In the Naples of the Upper Devonian, at Naples, New York; probably from the Cashaqua shale.

Adnatoceras clarkei Flower, n. sp.

Plate 7, figure 2

Conch orthoceraconic, circular in section, expanding at a rate of 3 mm. in a length of 20 mm. The sutures are straight and transverse. The septa are less than one-third their diameter in depth, being 6 mm. deep where the diameter is 21 mm. The depth of the cameræ increases more rapidly than the diameter of the conch up to the ephebic stage as is shown in the following measurements:

diameter	17 mm.	18 mm.	20 mm.	22 mm.
cameræ	4¼	4	3½	4

The siphuncle is slightly ventrad of the center of the conch. At the apex of the specimen it is 7 mm. from the venter and 9 mm. from the dorsum. The outline is typical for *Adnatoceras*. The brim is slightly less than the neck; the area of adnation is slightly greater than the brim. A segment which is 6.5 mm. in length expands from 1.9 at the septal foramen to 4 mm. within the cameræ. In the first two cameræ the deposits of the siphuncle can be made out. They are small simple annuli, the oldest one showing slight adoral prolongation. The deposit is only slightly heavier on the venter than on the dorsum. The deposits of the cameræ are markedly stronger on the venter than on the dorsum. They are mural, but lie mainly against the free part of the septum.

The surface, aperture and living chamber are unknown. The specimen represents a portion of the phragmocone approaching the gerontic condition. This is shown by the contraction of the adoral cameræ which measure 7.5 mm., 6 mm. and 5.4 mm. respectively.

Discussion.—This species recalls in proportions *A. naplense,* but is much smaller, more rapidly expanding, and the relation between the diameter and the depth of the cameræ is not constant here. The proportions of the cameræ recall *A. cooperi* of the Tully limestone, but that species attains a much greater size, the rate of expansion is less, and the relation between the depth of the cameræ and the diameter is less variable.

Type.—Holotype: New York State Museum.

Occurrence.—Parrish limestone member of the Cashaqua shales, Senecan stage, Upper Devonian, from the Parrish gulley, near Naples, New York.

Adnatoceras cf. neglectum (de Koninck)

Plate 8, figure 1

Orthoceras neglectum de Koninck, 1880, Ann. Musée Royale d'Hist. Nat. de Belgique, t. 5, 2me. partie, p. 55, pl. 34, fig. 2.

The specimen illustrated here consists of a portion of a phragmocone 27 mm. in length, which expands dorso-ventrally from 8 mm. to 11 mm. The transverse diameter is 1.5 mm. greater throughout. The specimen contains sixteen cameræ which are spaced five to six in a length equal to an adoral dorso-ventral diameter. The sutures slope orad on the dorsum. The septum is shallow, measuring 1.5

mm. in depth at a diameter of 10 mm.

The siphuncle is subcentral in the early portion, being 1 mm. in diameter within the segment and 3 mm. from both the dorsum and venter. The distance from the venter remains nearly constant in the later part, while the distance from the dorsum increases, so that at the adoral end the siphuncle is 1.5 mm. in the camera and is 3 mm. from the venter and 5.5 mm. from the dorsum. In form the segments are typical of *Adnatoceras* in outline, but are a little broader at the septal foramen than is usual in the genus, and the contraction at either end of the siphuncle is more abrupt than has been noted in any other species. A segment 2 mm. in length expands from 1.1 mm. to 1.5 mm. The brim and area of adnation are subequal and very slightly greater than the neck. The recrystalized condition of the interior is such that it is impossible to say whether any organic deposits were originally present in the cameræ or siphuncle.

Discussion.—The specimen illustrated agrees in general with De Koninck's description and figure of *O. neglectum.* It has been impossible to make a critical study of this or other species from the Belgian Mississippian on the basis of the little material available for the present study. The specimen is of interest, however, in that it establishes the presence of the genus *Adnatoceras* in the Tournai limestone, Middle Mississippian of Belgium.

Figured specimen.—No. 8776 in the collection of the University of Cincinnati.

Occurrence.—From the Tournai limestone of the Mountain limestone(Mississippian,) Tournai, Belgium.

Adnatoceras ciscoënse (Miller, Dunbar and Condra)

Dolorthoceras ciscoense Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 96, pl. 1, figs. 1-3.

The original description and illustration of this species are quite adequate, and the reader is referred to them for details. The siphuncular segments are expanded at the ends, but straight in the middle. The brim and area of adnation are both slightly greater than the length of the neck. Siphonal deposits are of the *Dolorthoceras* type. The cameral deposits are episeptal and hyposeptal. This character alone will distinguish *A. ciscoënse* from other members of *Adnatoceras.*

Occurrence.—Cisco formation, Pennsylvanian, from a locality north of Brownwood, Texas.

EULOXOCERAS Miller, Dunbar and Condra

Genotype.—*Euloxoceras greeni* Miller, Dunbar and Condra.

Euloxoceras Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 97.

In this genus are placed orthoceracones which may be circular in the earlier stages, but which differ from most of the Pseudorthoceratidæ by a laterally compressed ephebic section which may be oval or subquadrangular. The sutures are sinuous and slope slightly adaperturally on the ventral or antisiphonal side. The normal suture pattern consists of prominent lateral lobes separating dorsal and ventral saddles. The sutures of the mid-dorsal and mid-ventral region may be straight and transverse or may possess rudimentary lobes as in *E. milleri*, n. sp.

The siphuncle is located half way between the center of conch and the dorsal wall. The segments are subcylindrical over the greater part of their length, but contract abruptly at the septal foramen. The brim is more than twice the neck. The area of adnation is less than the brim but greater than the neck. The free part of the connecting ring is transverse at either end, continuing the expansion of the siphuncle. The turn of the connecting ring to a longitudinal position is abrupt. The greater part of the length of the free part of the connecting ring is either cylindrical or faintly concave.

The deposits of the siphuncle are of the *Dolorthoceras* type and are relatively thick. Stages leading to the fusion of the adjacent segmental deposits have been observed, and show that the annulosiphonate ring is complete before fusion. The thickness of the deposit and the great constriction of the siphuncle at the septal foramen reduce the endosiphuncular cavity to a small perforation at the septal neck, which enlarges gradually orad as the thickness of the deposit decreases, and then decreases rapidly in diameter as the succeeding septal foramen is approached. The deposits of the siphuncle show only a slightly greater development on the venter than on the dorsum. Deposits within the cameræ are episeptal and hyposeptal, and are markedly heavier on the venter than on the dorsum.

Miller, Dunbar and Condra regarded the siphuncle as ventral in position in this genus. The presence of a well defined conchial furrow on the siphonal side of the conch together with the greater development of cameral and endosiphuncular deposits on the antisiphonal side of the conch lead to the conclusion that the siphuncle is dorsal in position.

The surface of the shell of the genotype is unknown. *E. milleri* which is described below, shows low longitudinal ridges separated by flat or slightly concave interspaces. The longitudinal ornament is slightly impressed upon the internal mold, enough so to obscure any trace of a septal furrow which may be present. The aperture is unknown.

Discussion.—This genus contains but two recognized species. The genotype, *Euloxoceras greeni* Miller, Dunbar and Condra[103], appears to be fairly widespread in the Pennsylvanian of North America. *Euloxoceras milleri* of the Jacksborough limestone may be distinguished by the more nearly transverse and more sinuous sutures, the more quadrangular section, smaller size, and shallower cameræ.

Euloxoceras represents the climax of one type of siphuncular enlargement, an enlargement by an increase in the brim and area of adnation while the middle portion of the segment tends to become first cylindrical and then slightly concave. An increase of brim and area of adnation together with the straightening of the

103 *Ibid.* p. 99, pl. 1, figs. 12-15.

middle of the connecting ring produce *Adnatoceras* from *Dolorthoceras*. An accentuation of the same characters will produce the siphuncle of *Euloxoceras* from that of *Adnatoceras*. It must, however, be derived from a relatively simple *Adnatoceras* with a subcircular section and a subcentral siphuncle, as the genera differ markedly in section and position of the siphuncle in the early stages.

Euloxoceras milleri Flower, n. sp.

Plate 2, figures 1-3 12-14

This is a small compressed orthoceracone which is slightly flattened on the dorsal and ventral faces and strongly flattened laterally, giving it a subquadrangular section. The holotype is a portion of a phragmocone 35 mm. in length, the adaptertural portion of which is slightly compressed by pressure. The adapical portion, which is slightly if at all distorted, expands from 4 mm. and 5 mm. to 6.5 mm. and 7 mm. in a length of 20 mm. The sutures are transverse but undulate. There is a shallow ventral lobe between ventro-lateral saddles. The lateral faces are occupied by conspicuous lobes. The dorsum is occupied by a broad saddle which is flattened in the middle.

The septa are shallow, being 1 mm. deep where the diameters are 4 mm. and 5 mm. The number of cameræ in a length equal to an adapertural dorso-ventral diameter increases from three at 6 mm. to three and one-half at 7 mm. The gerontic condition of the cameræ has not been observed. The siphuncle is dorsad of the center and faintly compressed at its passage through the septum. Where the dorso-ventral diameter of the conch is 5 mm., the siphuncle is 1 mm. in diameter as shown on the septum, and is 1.6 mm. from the dorsum.

In dorso-ventral section the siphuncle expands abruptly on either end of the septal foramen, and is slightly concave in outline within the cameræ. The expansion of the segment apicad of the septum is made up of the brim and a portion of the connecting ring. Orad from the free part of the septum it is made up of an adnate part of the connecting ring and a free transverse portion. The siphuncle expands from a diameter of .5 mm. to one of 1.5 mm. where the segment is 2 mm. in length. The dorso-ventral diameter of the conch at this point is 6 mm. The necks are very short, less than one-tenth the length of the segment. The brim is slightly more than twice the neck and the area of adnation is twice the neck. The effective expansion of the siphuncle at the region of the brim and area of adnation which consists of portions of the ends of the free part of the connecting ring is three times the brim.

The deposits of the siphuncle are of the *Dolorthoceras* type, but present a slightly different aspect than do the deposits of *Dolorthoceras* due to the more marked constriction of the siphuncle at the septal foramen. The deposits are clearly annulosiphonate in origin, and dorso-ventral differentiation of the development of the deposit is slight. Some segments of the holotype show the adjacent segmental deposits fused on the venter but still discrete on the dorsum. Each segment of the deposit grows thin as its adoral end is approached. This gives the endosiphuncular cavity a curious appearance. It is widest in the adoral third of each siphuncular segment and contracts abruptly orad and more gradually apicad to a smll perforation at the septal foramen.

The cameræ contain episeptal and hyposeptal deposits. Though enough material of the species is not available to permit a careful study of the lobation of the deposit by means of cross sections, it is apparent that the deposit is very heavy on the ventral side, almost completely filling the camera ventrad of the siphuncle, while only a thin lining of the septa is present on the dorsal side. The holotype further shows traces of complicated lobes projecting inward, similar to the inner pair of lobes of *Pseudorthoceras*. The episeptal and hyposeptal deposits show a well defined pseudoseptum in one specimen.

The internal mold bears a well defined septal furrow. The surface of the shell is ornamented by fine raised liræ with flat interspaces. These are spaced about .8 mm. apart in the holotype. A faint faceting of the internal mold appears to be an internal expression of the ornament of the exterior. It is sufficient to obscure any trace of a true ventral conchial furrow which may be present. The living chamber and aperture of this species are unknown.

Discussion.—This species differs from *E. greeni* Miller, Dunbar and Condra in the more approximate septa the presence of obscure mid-ventural lobes, the more quadrangular section and the transverse condition of sutures. *E. greeni* has only two cameræ in a length equal to an adapertural dorso-ventral diameter, whereas *E. milleri* has three or more in such a length.

Types.—Holotype: Pal. Res. Inst., No. 5852-5854.

Occurrence.—From the Jackborough limestone, Pennsylvania, Jack County, Texas.

Genus **CRYPTORTHOCERAS** Flower, n. gen.

Genotype.—*Cryptorthoceras productum* Flower, n. sp.

Up to the development of the gerontic aperture, the conch is a depressed orthoceracone. The sutures are straight and either transvers or very slightly inclined orad on the dorsum. The septa show no unusual features. The siphuncle is located slightly ventrad of the center of the conch. The segments are slender, faintly expanding within the cameræ The brim and area of adnation are equal and less than the neck, in a gerontic siphuncular segment. Ephebic segments unknown.

The mature aperture is turned abruptly ventrad, the dorsal wall being arched over the normal position of the aperture. The dorsal margin of the aperture is broadly arched, the lateral portions strongly rounded, the central portion like the dorsal side laterally, but with a prominent V-shaped hyponomic sinus in the middle.

Discussion.—This genus is erected from the reception of a single species which, by reason of its unique aperture, can be placed in no previously described genus.

The affinities of the genus are obviously with simple orthoceracones. The outline of the siphuncle as known is not all that might be desired, as it probably represents a gerontic condition. The gerontic outline of *Adnatoceras* is similar, as is also the neanic *Dolorthoceras* outline. The aperture, though admittedly aberrant, suggests a relationship with orthoceracones with trilobed apertures, such as *Dolorthoceras telamon* (Hall) or *Palmeroceras fustis* (Hall). Were the apertures of such forms turned toward the venter and the form of the lobation slightly modified the aperture of *Cryptorthoceras* would result.

The early portion of the phragmocone is unknown, therefore the deposits of the cameræ and siphuncle have not been observed.

The aperture and the form of the siphuncular segments are sufficient to show that this genus is a member of the Dolorthoceratinæ of the Pseudorthoceratidæ. It was probably derived from *Dolorthoceras* near to the point from which *Palmeroceras* and *Adnatoceras* sprang from the same genus.

Cryptorthoceras productum Flower, n. sp.

Plate 4, figures 12-15

The holotype represents a mature living chamber and part of a phragmocone of a large orthoceracone of depressed section, remarkable for the contracted aperture which is turned abruptly ventrad.

The phragmocone, 60 mm. in length, expands from 45 mm. and 60 mm. to 50 mm. and 72 mm. at the base of the living chamber. The living chamber is 120 mm. in length, attaining diameters of 65 mm. and 80 mm., 75 mm. above the base, at the level of the hyponomic sinus.

The sutures are straight and transverse. Although the specimen is apparently mature, the last cameræ are not contracted. In a length equal to the transverse diameter of 72 mm. at the base of the living chamber there are about four and one-half cameræ; in a length equal to the corresponding dorso-ventral diameter of 50 mm. there are about three and three-fourths cameræ. The siphuncle is located ventrad of the center. Where the diameters of the conch are 60 mm. and 45 mm., the siphuncle is 4 mm. in diameter and is 17 mm. from the venter and 22 mm. from the dorsum.

The siphuncle is preserved only in the earliest segment of the type. It is cylindrical within the camera and contracted abruptly at the ends as in *Adnatoceras*. The condition of the septal neck is obscure, but evidently the brim and area of adnation are considerably less than the neck, as in the gerontic stage of *Adnatoceras*.

The basal 100 mm. of the living chamber expand uniformly, but at that point the dorsal wall curves over the adoral surface, the sides contracting, so that the aperture is on the ventral side of the specimen. The aperture is a transverse oval with a V-shaped hyponomic sinus interrupting the ventral side for the middle third of its width. The sinus occurs 80 mm. above the base of the living chamber. The aperture measures 55 mm. and 70 mm. It is surrounded by a slightly produced lip which bears prominent lines of growth. No ornament is preserved elsewhere on the shell.

Discussion—The holotype is a specimen preserved in a concretion, and it at first seemed that the unique characters of the aperture might represent a fortuitous placing of septaria, but a careful working out of the aperture revealed its symmetry and the continuity of the shell over the whole of the specimen. Portions of this species and genus not preserving the aperture closely resemble ordinary orthoceracones, and in fact cannot be distinguished from them. A portion of a specimen representing the basal part of the living chamber and the adoral part of the phragmocone was figured by Hall[104] as *Orthoceras eriense*. It can be recognized as conspecific by the apparently originally depressed section, the slightly eccentric position of the siphuncle, and the depth of the cameræ. The specimen represents a part of a mature individual.

Orthoceras eriense Hall is a large circular orthoceracone with a central siphuncle and cancellate ornament. The siphuncular outline is unknown. The species might belong to *Palmeroceras* or to *Protokionoceras*.

Type.—Holotype: Buffalo Museum of Science, No. E9013.

Occurrence.—From the Wanakah member of the Ludlowville, Hamilton group, collected at Bay View Creek, by Dr. I. G. Reimann.

Genus **SCEPTRITES** Flower, n. gen.

Genotype.—*Orthoceras sceptrum* Hall

The conch is slightly compressed throughout and slightly cyrtoconic. The sutures are straight and transverse in the young, tending to develop slight lateral lobes in the later portion of the phragmocone. The siphuncle is subcentral in position, lying slightly closer to the convex side in *sceptrum* and closer to the concave side in *carteri*. The segments are apparently of the neanic *Dolorthoceras* type. No deposits are known in the siphuncle. *S. carteri* possesses well defined cameral deposits which are mural and concentrated against the concave side of the conch. The aperture is unknown. No trace of the surface of the shell is known and the internal mold shows no indication of any ornament.

Discussion.—It is uncertain whether the genus is endogastric or exogastric in the absence of internal carinæ and apertural characters. The position of cameral deposits suggests an endogastric condition. Two species placed in the genus are both from the Onondaga of New York. *Orthoceras ohioense* Hall shows a curvature which, if natural, suggests *Sceptrites*, but the absence of compression is inconsistent with the genus, and it is far from certain that the curvature is original. Two new species from the Columbus limestone of Ohio are described below.

Key to species of Sceptrites

A. Living chamber clavate.

[104] Hall, J.: Paleontology of New York, vol. 5, pt. 2, pl. 87, 1879, figs. 1-2.

B. Sutures transverse; $5\frac{1}{2}$ cameræ in length equal to diameter; living chamber gibbous .... *S. claviformis.*

BB. Sutures sloping apicad on convex side; $6\frac{1}{2}$ cameræ in length equal to diameter; living chamber scarcely gibbous .... *S. obliquus*

AA. Living chamber not clavate.

C. Size large; 7 cameræ in length equal to diameter of 44 mm., 6 in length equal to 73 mm. .... *S. sceptrum*

CC. Size small; $4\frac{1}{2}$ cameræ in 22 mm., 5 in 40 mm. .... *S. carteri.*

Sceptrites sceptrum (Hall)

Plate 6, figure 3, Plate 9, figure 1

Orthoceras sceptrum Hall, 1888, Paleontology of New York, vol. 5, pt. 2, suppl., p. 26, pl. 117, fig. 2.

The two specimens upon which this revised description is based agree in their large size, slightly compressed section, and subcentral siphuncle. Slight differences in the rate of expansion and proportions of the cameræ are attributable to the slight distortion which has affected both specimens to some extent.

The conch is compressed, very slightly curved throughout. The holotype has a length of 440 mm., in which the rate of expansion shows considerable variation. The dorso-ventral diameter only is known. The conch expands 15 mm. in the first 100 mm., from 35 mm. to 50 mm., 20 mm. in the succeeding 100 mm., 18 mm. in the next 100 mm., and 15 in the last 100 mm., attaining a maximum dorso-ventral diaeter of 95 mm. The hypotype, a slightly smaller specimen shows the following diameters at intervals of 100 mm., 40 mm. and 34 mm., 51 mm. and 48 mm., 68 mm. and 55 mm. and 85 mm. and 70 mm. It the adapical 50 mm. the conch expands more rapidly, increasing from 35 mm. and 30 mm. (estimated) to 40 mm. and 34 mm.

The sutures are transverse to the curving axis of the conch and are straight adapically, tending to develop slight lateral lobes in the adoral portion. The septum, as known from the hypotype, is slightly less than one-fifth the dorso-ventral diameter in depth, being 9 mm. at 41 mm. and 15 mm. at 59 mm.

The siphuncle is located slightly closer to the convex than to the concave side of the conch. Where the dorso-ventral diameter of the conch is 39 mm. the segment is 4 mm. in diameter at the septal foramen and is 15 mm. from the convex and 20 mm. from the concave side of the conch. The segment expands from 4 mm. to 6 mm. in the camera and is 6 mm. in length. The segment is of the neanic *Dolorthoceras* type, with the brim less than neck and subequal to the slight area of adnation. No deposits within siphuncle or cameræ are yet known in this species.

The living chamber of the holotype has a basal dorso-ventral diameter of 90 mm. and has a maximum length of 156 mm. The aperture is not preserved. The hypotype, representing a younger individual, has diameters at the base of the living chamber of 78 and 68 mm., and retains only the basal 40 mm. No trace of the surface of the shell is retained on any specimen known.

The cameræ occur six in a length equal to an adoral dorso-ventral diameter of 73 mm., but increase slightly in frequency apicad so that there are seven at 44 mm. in the hypotype. In the holotype the proportion is rather more variable, showing six and one-half at 41 mm., the same number at 50 mm., five and one-half at 67 mm. and five at 85 mm. Whether the adoral increase in depth is due to pressure or not is uncertain.

Discussion.—The very large size and the shallower cameræ distinguish this species from *S. carteri.*

Types.—Holotype: New York State Museum, No. 12403/1. Hypotype: Buffalo Museum of Science, No. E8997.

Occurrence.—From the Onondaga limestone of New York. The holotype is from Cherry Valley, Otsego County; the hypotype is from the Federal Crushed Stone Quarry near Lancaster, Erie County.

Sceptrites carteri Flower, n. sp.

Plate 6, figure 4

The holotype has a total length of 285 mm., and lacks the extreme apex and the greater part of the mature living chamber; 39 mm. from the apex, which is somewhat crushed, the diameters are 19 mm. and 22 mm. In 140 mm. the conch expands to 40 mm. and 28 mm., and in the next 120 to 55 mm. and 35 mm. Curvature is slight and uniform. The sutures are straight and transverse. The septum has a depth of one-fourth the dorso-ventral diameter of 21 mm. The cameræ occur four and one-half in a length equal to a dorso-ventral diameter of 22 mm., but five occur in a length equal to the dorso-ventral diameter throughout the later portion except in the region of the last camera which shows gerontic contraction, the last two measuring 9 mm. and 6 mm. at a dorso-ventral diameter of 50 mm.

The siphuncle is known only at a dorso-ventral diameter of 22 mm. The siphuncle is 10 mm. from the convex and 11 mm. from the concave side of the conch. Here the segment is 4½ mm. in length, and expands from 2 mm. to 3 mm. The segment is poorly preserved, but appears to be of the *Dolorthoceras* type. Mural deposits are present in the apical 13 cameræ of the specimen, leaving 18 cameræ without deposit. The fragment of the living chamber is 40 mm. in length, and evidently represents not much more than the basal half.

Discussion.—The smaller size and deeper cameræ at once distinguish this from the large *Sceptrites sceptrum* (Hall) the only associated form which resembles it remotely.

Type.—Holotype: Collection of Mr. Alec Carter, Buffalo, N. Y., to be deposited in the Buffalo Museum of Science.

Occurrence.—Onondaga limestone, Federal Stone Quarry, south of Lancaster, Erie County, New York. The species was collected by Mr. A. Carter for whom it is named.

Sceptrites claviformis Flower, n. sp.

Plate 6, figure 2

This *Sceptrites* is differentiated by the relatively rapid expansion of the apical portion, to which curvature is confined, and the fusiform condition of the living chamber. The holotype has a length of 340 mm. The dorso-ventral diameter is 8 mm. greater than the transverse diameter in the apical part of the specimen, but increases to 10 mm. in the adoral half. The conch expands at a rate of about 7 mm. to 9 mm. in 40 mm. in the phragmocone; this decreases to nothing over the living chamber and contraction occurs in the adoral half. Measurements of the dorso-ventral diameter taken at intervals of 40 mm. are as follows: 36 mm. 40 mm., 52 mm., 60 mm., 67 mm., 73 mm., 75 mm., 72 mm. and 70 mm. The living chamber has a length of 140 mm. and increases in the basal 55 from 72 mm. and 58 mm. to 75 mm. and 65 mm. and contracts in the next 85 mm. to 70 mm. and 60 mm.

The sutures describe broad lateral lobes but are transverse to the axis of the conch. Five and a half cameræ occupy a length equal to the diameter in the apical part up to a diameter of about 50 mm., where the number increases to six. The last three cameræ measure 12 mm., 10 mm. and 8 mm., showing a gerontic condition. The siphuncle is not known nor is the depth of the septum.

Discussion.—The fusiform condition of the conch and the straight condition of the living chamber characterize this species. The rate of expansion is greater than that of *S. sceptrum* with which it agrees most closely in size, further, that species is more uniformly curved and the depth of the cameræ is more constant.

Type.—Holotype: U. S. National Museum.

Occurrence.—From the Columbus limestone, near Columbus, Ohio.

Sceptrites obliquus Flower, n. sp.

Plate 6, figure 1

This species, from the same locality as the preceding, may be distinguished by the less gibbous form of the living chamber, and the oblique condition of the sutures. The dorso-ventral diameter changes as follows at intervals of 40 mm.: 41 mm., 50 mm., 65 mm., 60 mm., 75 mm., and 74 mm. The obscurity of the adoral sutures leaves some doubt as to the exact position of the base of the living chamber. Its maximum possible length is 190 mm. It expands from 62 mm. and 50 mm. to 74 mm. and 67 mm. in the basal 120 mm., and contracts to 74 mm. and an estimated horizontal diameter of 62 mm. at the aperture.

The sutures are straight and oblique, sloping apicad on the venter in the apical portion, becoming more nearly transverse toward the living chamber. The depth of the cameræ is the same as in the preceding species, ranging from six cameræ at a diameter of 50 mm., to six and a half cameræ at 70 mm. At the apex of the specimen the siphuncle is 4 mm. in diameter at the septal foramen and is 18 mm. from the concave side of the conch. No trace of cameral deposits is shown.

Discussion.—This species differs from the preceding in the less gibbous form of the living chamber, the larger size, and the oblique sutures, which together seem sufficient to warrant regarding this form as distinct.

Type.—Holotype: U. S. National Museum, No. 37228.

Occurrence.—From the Columbus limestone, Middle Devonian, from Columbus, Ohio.

Genus **FUSICOCERAS** Flower, n. gen.

Genotype.—*Fusicoceras eriense* Flower, n. sp.

The conch is breviconic, slightly curved exogastrically, and subtriangular in section with the dorsum transverse. The greater part of the living chamber is unknown, but slight cessation of expansion is marked at its base, which is indicative, together with the rapid expansion of the apical portion, of a breviconic condition.

The sutures bear broad low lobes on the dorsum which are well rounded centrally, and deeper lobes on the venter, which are less rounded in the median portion. The siphuncle is located close to the ventral wall and is of the *Dolorthoceras* type, both in outline and the form of the deposits. No cameral deposits are known.

Discussion.—Even in the absence of the aperture, this genus can be readily separated from all other breviconic genera by the outline and internal structure of the siphuncle. The genotype, the only known species of the genus, resembles *Endoplanoceras* Flower[105] somewhat in form, but has a subtriangular section, a marginal siphuncle and lacks longitudinal markings. The section is more angular than that of *Brevicoceras* Flower which is suggested by the sutures, and the dorsal concavity and the ventral lobes furnish other differences, as does the structure of the siphuncle. The genus is separated from other Pseudorthoceratidæ by the marginal siphuncle and the breviconic condition. No other genus of brevicones has as yet been recognized as having certain affinities with this family.

Fusicoceras eriense Flower, n. sp.

Plate 6, figures 5-6; Plate 7, figure 1

The holotype is a portion of a conch 80 mm. in length consisting of a part of a phragmocone and the base of a living chamber. The section is strongly depressed, subtriangular, with the venter strongly arched, obscurely keeled, and the dorsum transverse and scarcely convex. In vertical outline the dorsum is slightly concave throughout, becoming straighter adorally, the venter is uniformly convex. The sides diverge uniformly to the base of the living chamber, where the outline becomes faintly convex. The conch expands from 57 mm. and 33 mm. to 69 mm. and 35 mm. in a ventral length of 67 mm.

105 Flower, R. H.: *Devonian brevicones of New York and adjacent areas*, Palæontographica Americana, vol. 2, No. 9, 1938, p. 53.

The sutures bear broad shallow dorsal lobes, transverse centrally. The ventral lobes are slightly deeper, and strongly curved in the median portion. Six cameræ occur in the apical 55 mm., increasing from 7 mm. to 11 mm. in depth. The one remaining camera is gerontically contracted to a depth of 7 mm.

The siphuncle lies close to the venter, being 5 mm. in diameter at the apex and separated from the venter by 4 mm. A transverse section ground through the siphuncle, not, however, attaining its greatest diameter, shows segments of the *Dolorthoceras* type. As exposed, a segment 8 mm. long expands from 2 mm. at the septal foramen to 4 mm. in the camera. Neck and brim are subequal and one-eighth the length of the segment. The apical two septal necks show evidence of a deposit of the *Dolorthoceras* type.

In the apical segment the lining is very nearly continuous but in the next segment the condition is still immature, although the *Michelinoceras* stage is past. Succeeding adoral segments are not preserved.

Discussion.—In proportions this species does not agree with any described form, and is easily characterized by the development of the ventral lobes of the sutures from other brevicones. Other distinguishing characters are discussed under the genus, of which this is the only known representative.

The absence of cameral deposits is not surprising in a brevicone, which was apparently a floating form. Evidently the development of deposits in the siphuncle is more rapid than in most Pseudorthoceratidæ. The specimen exhibits a stage indicative of early maturity, but definitely pre-gerontic.

Type.—Buffalo Museum of Science.

Occurrence.—From the Wanakah member of the Ludlowville, Idlewood Cliff, near Eighteen Mile Creek, Lake Erie.

SUBFAMILY PSEUDORTHOCERATINÆ FLOWER, N. SUBFAM.

Siphonal deposits fuse ventrally to form a continuous lining before appearing on the dorsum. The *Pseudorthoceras* type of deposit characterizes the subfamily.

Pseudorthoceras is the simplest member of the subfamily, and the longest ranging one. The genus persists from the lower part of the Upper Devonian through the Pennsylvanian and into the Permian.[106] The thinning of the siphonal deposit from Devonian to Pennsylvanian time is slight. *Mooreoceras* makes its appearance slightly higher in the Devonian. Devonian species possess a rather thick siphonal deposit on the ventral side. Closure of the deposit on the dorsum has not been observed, and may not occur. Pennsylvanian species possess a much thinner deposit, which is scarcely thicker at the expanded region of the siphuncular segment than at the septal foramen.

Paraloxoceras Flower, n. gen., is a Mississippian derivative of *Mooreoceras*. The siphuncular segments become more expanded and the deposits more massive.

106 Teichert, C.: *fide litt.*, 1938.

In them can be seen traces of a radial canal system. *Bergoceras* Flower, n. gen., is evidently a cyrtoconic derivative of *Paraloxoceras*, and if De Koninck's figures are to be relied on the deposits develop equally on the dorsal and ventral sides of the siphuncle. On the basis of this character the genus cannot be said to be typical of the Pseudorthoceratinæ. It is highly probable that the best solution would be the separation of *Paraloxoceras* and *Bergoceras* in a new subfamily characterized by thick siphonal deposits in which radial canals are developed. Material of *Paraloxoceras* has been limited to one specimen, and no material of *Bergoceras* was available. It has seemed best to delay the proposal of a new subfamily until more material can be examined.

Genus **PSEUDORTHOCERAS** Girty, 1911[107]

Genotype.—*Orthoceras knoxense* McChesney.

This genus contains slender orthoceracones of circular or subcircular section in which the apex shows a very slight exogastric cyrtoconic curvature. The sutures are straight and transverse, the septa are moderate in depth and evenly curved, and the siphuncle is central or subcentral in position. In outline the siphuncle undergoes a marked ontogenetic development. A "false cyrtochoanitic condition" is followed by a *Michelinoceras* stage. This gives way shortly to the *Anastomoceras* stage. The neanic and ephebic *Dolorthoceras* stages follow in turn and give place to the *Pseudorthoceras* stage. Here the brim and neck are subequal and the area of adnation is half the brim or less. The free part of the connecting ring is convex, forming segments which vary between pyriform and subglobular in outline. The siphuncle contains deposits which are annulosiphonate and pseudorthoceroid. Deposits fuse along the venter forming a continuous lining before becoming circumferentially continuous at the region of the septal foramen.

The cameræ contain well defined mural deposits which show remarkable circumferential lobation which has been described in an earlier portion of this paper, (see text figure 17). The internal mold retains the septal and conchial furrows.

Discussion.—The genus is characterized by the generalized features of the phragmocone, the outline of the siphuncle and the form of the siphuncular deposits. The numerous specimens of *Pseudorthoceras* from the Pennsylvanian are referred to *P. knoxense* which appears to be a rather variable species. New species from the Naples fauna of the Upper Devonian are described below.

[107] Shimizu and Obata, (*Three new genera of Ordovician nautiloids belonging to the Wutinoceratidæ nov. from eastern Asia*, Jour. Shanghai Sci. Inst., sec. 2, vol. 2, 1936, p. 34, footnote 2) state of *Pseudorthoceras*: "Since the most important characters of the genus is the peculiar form of Girty's example being imperfectly preserved, satisfactory determination is absolutely impossible." This view is opposed not only to that put forward in the present paper, but takes no account of the descriptions and illustrations of previous workers, in particular Miller, Dunbar and Condra, 1933.

Shimizu and Obata apparently have as little first hand information on the genera which they regard invalid as they do concerning the species which they have made the types of new genera.

Pseudorthoceras knoxense (McChesney)

Plate 1, figure 6; Plate 2, figure 11; Plate 8, figures 5, 11-12; Text figure 17

The synonymy and a good description of this species have been recently given by Miller, Dunbar and Condra[108] and need not be repeated here. The absence of the living chamber in this species which is represented by abundant phragmocones

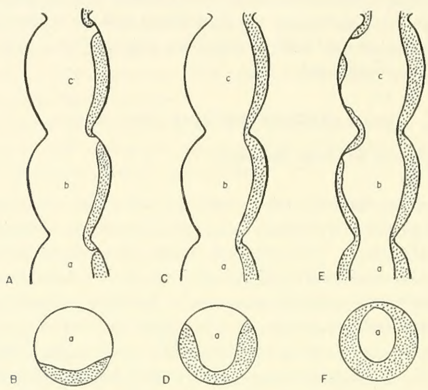


Fig. 17. Development of siphonal deposits in *Pseudorthoceras knoxense.*

A. *Michelinoceras* stage with discrete annulosiphonate deposits on the venter only.

B. Cross section through segment a, of the above stage.

C. Fusion of discrete *Michelinoceras* deposits forms the pseudorthoceroid deposit which is developed only on the ventral (right) side.

D. Cross section of segment a of the above. Deposits have developed by growth at the lateral margins, but have not fused on the dorsum.

E. Fusion of deposits on the dorsum and completion of growth. Segment c, the youngest, shows the fusion of deposits at the ends of the segment and the middle, while yet incomplete in the intervening regions. Segment b shows the simpler normal condition; a shows complete fusion.

F. Cross section of segment a of the above.

throughout the Pennsylvanian has been commented on but not explained. The species seems to characterize facies in the Pennsylvanian which are rich in clastics, and normally occurs in a more or less crushed condition. A typical specimen will consist of a portion of a phragmocone which is undistorted adapically but which becomes progressively more and more flattened adaperturally. If such a specimen is sectioned it will be found that there exists a very definite relationship between the extent of the deposits of the cameræ and the degree of distortion. The adapical portion in which deposits are pronounced is practically undisturbed by pressure, while the adoral portion in which the deposits are immature has been flattened to an extent which varies inversely with the amount of cameral deposit

[108] *Ibid.*: p. 81.

present. It is now known that in orthoceracones the cameral deposits are formed in the adapical part of the phragmocone and not at the base of the living chamber, and that the point of which deposits begin is separated from the base of the living chamber by a considerable number of empty cameræ. It would follow that in a typical specimen of *P. knoxense* not only the living chamber but also a considerable number of the adapertural cameræ are lost.

For this reason the earliest stages of the development of the deposits of cameræ and siphuncle have not been observed in this species. The earliest available stage of the siphuncular deposit shows the deposits which originate at the septal necks markedly developed adaperturally so that they extend about half way to the next adoral septal neck. Following this can be seen stages leading to the fusion of the deposits of adjacent segments along the venter. No deposits appear against the dorsal wall of the siphuncle at this stage. Cross sections taken at a stage at which the fusion of the deposits along the venter is complete show that the structure is confined to the ventral third of the siphuncle and is thickest at the mid-ventral region (fig. 14B). Beyond this stage material is added to the sides of the deposits until they meet along the dorsum. The advancing lateral margins of the deposit are lobed and are rather variable. Normally the two ends at the region at or near the septal neck are completed first and then the middle portion, indicating that the lateral margins of the deposit are trilobed (fig. 14 E). Two specimens have been seen which in cross section show a mid-dorsal mass of deposit which is isolated from the main mass. Enough material showing this phenomenon has not been available to demonstrate whether this dorsal body is really isolated or whether it represents an independent adoral extension from the deposit which is completed circumferentially at the septal neck.

The lateral growth of the deposits is shown diagramatically in fig. 14. The characteristic features are the fusion of adjacent segments of the deposit along the venter followed by an encroachment of the deposit laterally and finally dorsally. Though the completed deposits are similar to those of *Adnatoceras, Euloxoceras* and *Dolorthoceras,* the developmental stages are very different and the annulosiphonate origin of the structure is not at once apparent in *Pseudorthoceras,* as the annuli at the septal foramen are not complete until a pseudorthoceroid deposit is complete ventrally, thereby obscuring the resemblance.

It has been noted that in several adapical portions of *P. knoxense* the deposit is not closed on the dorsal side, though normal closure occurs in more adapertural segments of the same individual. In such specimens the failure to develop the dorsal wall of the siphuncular deposit is found in segments in which the cameral deposit has nearly filled the cameræ. This is of interest as it supports the belief that the pseudorthoceroid deposit when completed serves to sever the connection between the siphon and cameræ, thereby controlling the extent of the development of the cameral deposits. In *P. knoxense* the heavy cameral deposits must have been important hydrostatically, while the thin siphonal deposits could have had little direct significance, as they are not massive enough to affect the balance of the organism to any extent.

The radial distribution of the deposits of the cameræ has been discussed in detail in the morphological section of this paper, and need not be repeated here (see fig. 17, also pl. 1, fig. 6).

Of particular interest is the preservation of the original micro-structure of the cameral deposits in some specimens from the Hazelton Bridge limestone[109] of the Upper Pennsylvanian of western Indiana. Although the specimens are now completely composed of calcite, the original aragonitic pattern is retained in considerable detail.

Types.—The specimens here figured are deposited in the Paleontological Research Institution, Nos. 5859-5864.

Occurrence.—The species is widespread in the Pennsylvanian of America, apparently occurring throughout.

Pseudorthoceras senecum Flower, n. sp.

Plate 1, figures 1-3

Conch orthoceraconic, presumably originally circular or subcircular in section. The holotype is badly flattened, with one side ground away. The greater diameter of the specimen increases from 8 mm. to 11.5 mm. in a length of 26 mm. The sutures are straight and transverse. The septa, in their present condition, are less than one-seventh the diameter in depth. There are four cameræ in a length equal to an adapertural diameter of 10 mm.

The ground surface of the specimen represents a nearly dorso-ventral section as is shown by the slightly eccentric siphuncle and the uneven distribution of deposits. The siphuncle is 4.5 mm. from the venter and 5.5 mm. from the dorsum. Where the depth of the camera is 2.5 mm., the siphuncle expands from .6 mm. to 1.5 mm. The necks are about one-sixth the depth of the camera and are evenly recurved so that the brims and necks are equal. The connecting rings are convex throughout, though more strongly so at their apices than in the middle portion. There is no area of adnation. The interior of the siphuncle bears on the right or ventral side of the specimen continuous lamellar deposits. On the left side the deposits are rudimentary.

The cameræ bear well developed mural deposits which are better developed on the ventral than on the dorsal side of the specimen.

Discussion.—In the organization of the deposits and the outline of the siphuncle this species is a typical *Pseudorthoceras*. It differs from the genotype in the less pyriform outline of the segments, a character which suggests the possibility of an origin of the genus in some of the Middle Devonian species of *Dolorthoceras*.

The asymmetrical position of the siphuncle and the distribution of the deposits in the siphuncle and cameræ indicate that the section shown is dorso-ventral or nearly so. The surface is ground parallel to the plane of the bedding, and shows that the uneven distribution of the deposits is not due to inorganic agencies. Fre-

[109] Mallot, C. A.: MS.

quently orthoceracones are found in which the lower portion of the siphuncle is occupied by sediments while the upper portion which was left vacant at the time of burial was later filled in by infiltrated material. Schindewolf[110] has figured a condition found in the apical end of *Pseudorthoceras knoxense* which suggests such a phenomenon, but the presence of a similar asymmetrical structure in the Devonian specimen shows clearly that this is characteristic of the stock, as such an explanation cannot apply to a horizontally made section.

The extent of flattening of the specimen is not known, as it came into my hands with one side ground down to the siphuncle. The septa appear to be largely undisturbed in the plane of the section which is in the plane of the bedding. The depth of the cameræ and the outline of the siphuncle are not modified. It is questionable whether flattening has increased the dorso-ventral diameter. The septa show unusually few irregularities for a distorted specimen and suggest that vertical pressure may not have resulted in the usual horizontal expansion.

The species can be distinguished from *P. anomalum* the only other Devonian species of *Pseudorthoceras* so far known, by the shallower cameræ and the broader siphuncular segments.

Type.—Holotype: Pal. Res. Inst., No. 5858.

Occurrence.—In the Cashaqua shales of the Upper Devonian, Naples, New York.

Pseudorthoceras anomalum Flower, n. sp.

Plate 4, figure 9; Text figure 18

The holotype represents a portion of a phragmocone including the neanic and early ephebic stages, so that the adapical and adapertural ends of the specimen differ markedly in proportions as well as in the form of the siphuncle. The section is circular throughout. The specimen is 70 mm. long, expanding from 5 mm. to 15 mm., with the conch expanding from 10 mm. to 15 mm. in the last 25 mm.

The sutures are straight and transverse. The septum is 3 mm. deep where the diameter is 12 mm., or one-fourth the diameter. It is shallower adapically. The cameræ are deep adapically but become rapidly shallower adorally. The number of cameræ in a length equal to an adoral diameter varies from three at 6 mm., to five at 10 mm. and seven at 14 mm. The siphuncle is subcentral in position throughout. In the earliest segments the outline is that of the *Dolorthoceras* type except for the somewhat greater development of th area of adnation which is scarcely less than the brim. The connecting ring is convex over its free portion, with the greatest diameter in the adoral fifth of its length. Such a segment is 1.8 mm. in length, and expands from .8 mm. to 1.4 mm. Later segments retain the

[110] Schindewolf O. H.: *Bermerkungen zur Ontogenie der Actinoceren und Endoceren (Cephal., Nautil.)*, Neues Jahrbuch für Hineralogie etc. Beil.-Bd. 74, Abt. B, 1935, p. 96. fig. 6.

1:1:1 ratio of neck, brim and area of adnation, but the converging sides of the free part of the connecting ring apicad of the greatest diameter becomes straight. This type of outline is essentially the *Adnatoceras* type, except that the straight sides converge apicad, producing a segment which is more pyriform than cylindrical. This type of outline is developed where the conch is 8 mm. in diameter. The segment is 2 mm. in length, and expands from .8 mm. to 1.4 mm. as before. Orad of this the segments become more convex in outline, producing the typical early pyriform segment of *Pseudorthoceras*. This is developed at a diameter of 9 mm. The segment is 2 mm. in length, and expands from 1 mm. to 2 mm. The segments orad of this region are poorly preserved and fragmentary. The area of adnation remains equal to the brim, but apparently the convexity of the connecting ring increases still further.

The deposits of the siphuncle are well developed in the adapical part of the specimen. The specimen is sectioned nearly transversely, but at a point where the section passes through the dorsal wall of the siphuncle it is shown that the deposit is of the *Pseudorthoceras* type, the adjacent segments of the deposits fusing ventrally and then growing toward the dorsum. Adoral segments demonstrate the annulosiphonate origin of the structure, and show its ontogeny from the earliest stage. Mural deposits occupy the cameræ. The deposit can be seen adjacent to the ouside of the connecting ring in the adapical cameræ, which is taken to represent the development of the inner pair of lobes and the ventro-lateral masses. Transverse sections of *Pseudorthoceras knoxense* show similar phenomena.

The living chamber and surface of the shell are unknown. The ventral side of the specimen has been removed by grinding. It was studied previous to grinding. The shell was originally removed by weathering, also the mural part of the septa. The deposits had partly been weathered, and were less resistent than the matrix of the cameræ, with the result that the ventral sinus of the deposits could be seen. The lobation of the ventro-lateral masses was indistinct.

Discussion.—On the basis of the outline of the latest known segments of the siphuncle and the form of the siphuncular deposits this species is referred to *Pseudorthoceras*. It is unique in the retention of the strong area of adnation throughout. This feature might be carried through from a neanic *Dolorthoceras* stage. In view of the fact that the area of adnation is strong where the segments are of the typical *Dolorthoceras* outline, it appears that it represents the failure to suppress the neanic character of the area of adnation in the ephebic *Dolorthoceras* type of segment, and that the feature is merely continued.

The imperfect similarity of later segments to *Adnatoceras* appears to be accidental. Rather it seems that the straight form of the apical converging portions of the connecting ring is the logical origin of the *Pseudorthoceras* pyriform outline. The stage has not been observed in *P. knoxense*, but acceleration might cause it to be omitted in this later form. Sufficiently early stages of *P. senecum* to

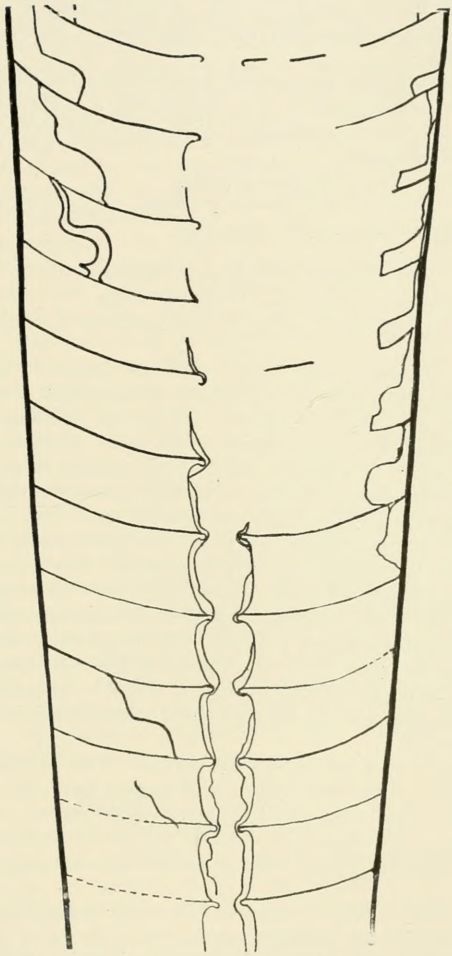


Fig. 18. Camera lucida drawing of adoral portion of *Pseudorthoceras anomalum*, about ×3, showing incomplete preservation of siphuncle in adoral portion. Adapically the transition from the *Adnatoceras* to the *Pseudorthoceras* stage is seen.

determine whether there is a similar condition in that species, are lacking. However, the holotype of *senecum* does show suggestions of the flattening of the siphuncular outline.

This species can readily be distinguished from *P. senecum* by the much shallower cameræ in the ephebic portion. The shallow cameræ of the adapertural end seem to indicate that this was originally a small species, though the gerontic condition has not been observed.

Type.—Holotype: New York State Museum.

Occurrence.—From the Parrish limestone member of the Cashaqua shales, Upper Devonian, Parrish gully, Naples, New York.

Genus **MOOREOCERAS** Miller, Dunbar and Condra

Genotype.—*Mooreoceras normale* Miller, Dunbar and Condra.

Mooreoceras Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv. ser. 2, Bull. No. 9, p. 85.

In this genus are placed orthoceracones which are similar to *Pseudorthoceras*, but differ from that genus in having a depressed section, oblique or sinuate sutures and an eccentric siphuncle. The section is circular in the young and in some species may remain so in the ephebic stage, though typical specimens are definitely depressed. The sutures in the early portion are straight and transverse but later normally slope adaperturally on the dorsum and are more or less sinuous, showing faint lateral saddles separating dorsal and ventral lobes. The septum is very shallow even in the younger stages, and serves as a good criterion to distinguish early fragments of *Mooreoceras* from *Pseudorthoceras*. The siphuncle is central in position in the younger stages but is ventrad of the center in the ephebic portion of the conch. The outline of the ephebic segments varies among the species. In some forms it is subglobular, but it is more typically pyriform, with the greatest diameter orad of the center and contracting more gradually apicad than orad. Occasionally the segments are slender enough to resemble those of *Dolorthoceras*, but they can be distinguished by the pyriform condition, which is not known in typical *Dolorthoceras*.

Siphonal deposits are of the *Pseudorthoceras* type. Thus far stages up to and including the fusion of adjacent deposits on the venter have been noted, but no specimen has been found which shows the closure of the deposits on the dorsum. It is possible that in *Mooreoceras* the deposits may not be developed dorsally at all, but at the present time enough material has not been examined to justify such a conclusion.

The deposits of the cameræ are concentrated on the ventral side of the conch. One internal mold has been observed which retains the dorsal hiatus and the ventral sinus, but the differentiation between the dorso-lateral bands and the ventro-lateral masses is not marked.

The surface of the shell is smooth. *Mooreoceras* appears to have a thicker shell than *Pseudorthoceras*. The internal mold bears well defined impressions of the conchial furrow and the septal furrow.

Discussion.—*Mooreoceras* is probably derived from *Pseudorthoceras* as is shown by the similarity of the siphonal deposits and the siphuncular outlines. The depressed section, and the eccentric siphuncle and the sinuous sutures represent a more specialized condition than that of *Pseudorthoceras*. The similarity between *Mooreoceras* and *Dolorthoceras* in section, sutures and occasionally in the form of the siphuncular segments is due to isomorphism.

The oldest known representatives of *Mooreoceras* are two species, *M. bradfordoides* Flower, n. sp. and *M. ruedemanni* Flower, n. sp. described below, from the Wellsburg monothem, which constitutes the upper half of the Chemung stage of the Upper Devonian of New York.

Mooreoceras is present in the Mississippian of America, though apparently not well developed there. A fragmentary specimen from the Salem limestone of the Middle Mississippian is described and illustrated below. Miller and Furnish[111] have described and illustrated several new and old species which are referred to *Mooreoceras*. Fusiform siphuncular segments are reported for *M. chouteauense* (Swallow) and *M. cliftonense* Miller and Furnish.

Several species figured by De Koninck[112] and Foord[113] from the Mississippian of Belgium and Ireland respectively recall *Mooreoceras* in section, sutures and the eccentric siphuncle. In particular *O. hindei* Foord appears to be a *Mooreoceras*, for the siphuncular outline as shown is correct for the genus. It is doubtful, however, whether the continuous lining within the siphuncle figured by Foord represents an organic or an inorganic deposit. Without knowledge of the siphuncular outline it is not possible to determine the generic position of the other species figured. *Paraloxoceras* can be distinguished by its much more expanded siphuncular segments, even in the absence of siphonal deposits.

I have made no attempt here to redescribe the Pennsylvanian species of *Mooreoceras*, and such as are figured are used here for purely morphological purposes. All of the Pennsylvanian species known to belong to *Mooreoceras* have been recently and quite adequately described. These and many new ones are at present being studied by Mr. Richard Schweers of the University of Indiana. I am indebted to Mr. Schweers for an opportunity to study his undescribed material and to figure such specimens as were required.

Mooreoceras bradfordoides Flower, n. sp.

Plate 7, figure 7; Text figure 19

The holotype consists of a portion of a phragmocone containing seven cameræ, 22 mm. in length. It has been ground so as to expose a surface inclined about twenty degrees from the dorso-ventral plane. Conch depressed in section, ex-

111 Miller, A. K. and Furnish, W. M.: *Lower Mississippian nautiloid cephalopods of Missouri* in *Stratigraphy and paleontology of the Lower Mississippian of Missouri*, Univ. of Missouri studies, vol. 13, No. 4, 1938, pp. 164-169.

112 de Koninck, L. G.: *Faune du calcaire carbonifère de la Belgique*, Ann. de Musée Royal d'Hist. Nat. de Belgique, Série Paleontologique Tome V, 2 me partie, 1880.

113 Foord, A. H.: *Monograph on the Carboniferous Cephalopoda of Ireland*, Part I, Family Orthoceratidæ (in part), Paleontographical Soc., vol. 51, 1897, p. 12, pl. 5, figs. 4a-c.

panding from 9 mm. and 14 mm. to 12 mm. and 18 mm. as nearly as can be estimated. Sutures oblique, sloping strongly orad on the dorsal or antisiphonal side. Septa shallow, having a depth of 1.5 mm. on the venter and 3 mm. on the dorsum. There are three and one-half cameræ in a length equal to the adapertural dorso-ventral diameter of 12 mm., and six cameræ in a length equal to the corresponding transverse diameter of 18 mm.

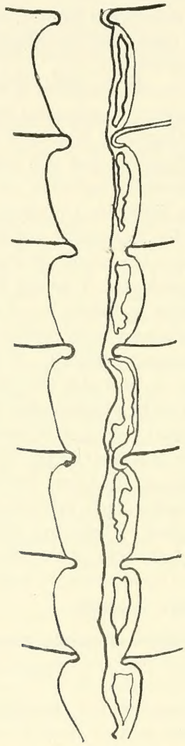


Fig. 19. *Mooreoceras bradfordoides* Flower, n. sp. Camera lucida drawing of siphuncle of holotype, ×2.5. Venter on right. The center of the organic deposit in each segment has been removed by solution.

Siphuncle fusiform in outline, located ventrad of the center of the conch. Its distance from the venter increases from 4 mm. to 5.5 mm. in 22 mm. Septal neck strongly recurved, the neck slightly greater than the brim. Where the segment is 4 mm. in length the diameter at the septal foramen is .8 mm. This increases to a maximum diameter of 3 mm. one-third the distance to the preceding segment, then contracting gradually apicad, producing a strongly fusiform outline. Area of adnation minute, about one-half the brim.

The deposits of the siphuncle are of the *Pseudorthoceras* type and are well developed on the ventral side, but can not be distinguished clearly on the dorsal side. Deposits of the cameræ are mural and well developed.

The surface, aperture and living chamber are unknown.

Discussion.—The holotype, the only representative of this species which has come to my attention, represents an adapical portion of the phragmocone, as is shown by the development of the deposits. It is an internal mold, originally badly weathered, so much so that the measurements of the conch are only approximate. The outer part of the mural deposits of the cameræ have been for the most part removed. Nevertheless, the species can be recognized by the very shallow cameræ, which will distinguish it from the species of *Bradfordoceras* which also occur in the Upper Devonian with the exception of *B. gomphoides* Flower and Caster.

The cameral spaces of the holotype are filled with white calcite; the cameral deposits are strongly limonitic. The deposits of the siphuncle appear to be replaced by some greenish iron compound, and have partly been dissolved. They can be distinguished from the matrix of the siphuncle only with difficulty.

Type.—Holotype: New York State Museum No. 1753.

Occurrence.—"From iron ore bed in the Chemung, Austinville, Bradford County, Pennsylvania." Dr. K. E. Caster has very kindly supplied a statement as to the horizon, which is quoted: "From the matrix of the material from the Upper Devonian of Bradford County, Pennsylvania, I would judge that it came from one of the local iron-limes or coquinites in the Wellsburg monothem. The iron ore bed near Austinville apparently lies near the horizon of the "Burlington limestone" of the Second Survey (Pa.) reports, for which Willard, 1936, suggested the name Luthers Mills coquinite."

Mooreoceras ruedemanni Flower, n. sp.

Plate 1, figure 4; Plate 7, figure 3; Plate 8, figure 8; Text figure 20

Conch orthoceraconic, depressed in section, with the venter more flattened than the dorsum and a ventral siphuncle. The conch expands from 5.5 mm. and 7 mm. to 9 and 11 mm. in the first 20 mm. of the holotype. In the next 20 mm., the conch expands to 13 mm. and 17 mm. The sutures are straight and transverse in the earliest part of the conch but develop a lobate pattern consisting of dorsal and ventral crests separated by lateral lobes. The dorsal crest is the higher of the two, giving the suture and septum a slightly oblique aspect. The septa are shallow. At diameters of 9 mm. and 11 mm. the depth is 2.5 mm.

Throughout the known portion of the conch there are five cameræ in a length equal to an adapertural dorso-ventral diameter, and six in a length equal to the corresponding transverse diameter.

The siphuncle is close to the ventral wall of the conch. Where the dorso-ventral diameter is 5.5 mm. the siphuncle is .6 mm. in diameter and 1.6 mm. from the

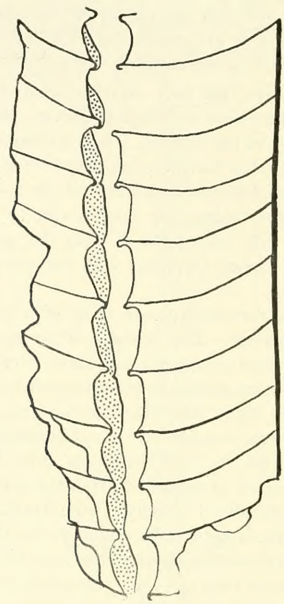


Fig. 20. *Mooreoceras ruedemanni.* Camera lucida drawing of sectioned part of holotype, ×2.5. The venter is on the left.

venter. Where the diameter has increased to 9 mm., the siphuncle is 1.5 mm. in diameter and 2 mm. from the venter. In section the segments are fusiform, expanding to their greatest diameter orad of the center of the segment. The brim appears to be considerably less than the neck, and there is no area of adnation. A segment which is 2.4 mm. in length expands from .6 mm. at the septal foramen to 1.4 mm. Deposits within the siphuncle are of the *Pseudorthoceras* type, and have been observed only on the ventral side. The anterior of the sectioned cameræ show the segmental deposits yet unfusd; in the more apical portion adjacent segments have joined and their boundaries cannot be made out. The deposit is thick in the interseptal space, and it occupies nearly half of the siphuncle, so that the endosiphuncular cavity is nearly straight on the ventral side. Deposits within the cameræ are mural. They extend along the free part of the septum nearly to the siphuncle on the venter and are not massive peripherally. The internal mold shows little lobation, but the ventral hiatus is well preserved. Deposits have not been observed on the dorsum. A well defined dorsal carina is present.

The living chamber, aperture and surface are not known.

Discussion.—The species is remarkable for its resemblance to *Bradfordoceras* in the lobation of the sutures, and suggests that some of the specimens referred to *Bradfordoceras* by Flower and Caster without knowledge of the siphuncular structure may eventually prove to belong to *Mooreoceras* instead. The specimen is of interest first for the heavy concentration of the deposits of cameræ and siphuncle on the venter, and second for the effect that this had on the conch after the death of the organism. The specimen was still embedded in its matrix when it came into my hands, and was contained in a small block one side of which showed considerable evidence of weathering. This appears to be the upper side. The conch rests with the venter on the opposite or lower side of the block, which is just what is to be expected in view of the condition of the cameral deposits. The deposits of the siphuncle are strongly replaced, and the margin of the deposit is irregular in the adapical end of the specimen. Were it not for the segmental condition of the deposit in the anterior portion, and were there no indication of the position of the conch in the sediments, such structures might be interpreted as the supplemental infiltration to an incomplete internal mold of the siphuncle. The specimen occurs in a highly ferruginous and micaceous sandstone, and is replaced with calcite, limonite and some unidentified iron silicates.

The species differs from *M. bradfordoides* in the more sinuate and less oblique sutures. So far as can be determined from the other species, the depth of the cameræ is about the same.

Type.—Holotype: New York State Museum.

Occurrence.—This bears the same locality number as the preceding, and like it, is probably from the Wellsburg monothem. The matrix sent to Dr. Caster is from this specimen. Both are undoubtedly from the same horizon as in indicated by the preservation, matrix, and the minerals in the siphuncles.

Mooreoceras, sp.

Plate 4, figure 5

This consists of a small fragment of an orthoceracone which does not furnish enough information to merit the use of a new specific name. Only three cameræ are preserved, and these are too fragmentary to furnish either the section of the conch or the rate of expansion. The total depth of the cameræ is 6.2 mm., and the adapertural diameter is 12 mm. The curvature of the septum in section is equal to the depth of a camera. Where the camera is 2 mm. in depth the siphuncle expands from 1 mm. at the septal foramen to 2 mm. within the camera. The necks are short and recurved, the brim appearing slightly less than the neck, and the connecting ring is convex throughout, not more curved at the ends than in the middle, and meeting the preceding septum with no area of adnation. Deposits are not known in either the cameræ or the siphuncle.

Discussion.—This species is referred to *Mooreoceras* for the outline of the siphuncle is similar to that of certain species referred to that genus, though in many species the siphuncle is more expanded. The outline of the connecting ring is too convex for *Dolorthoceras.* No known Mississippian species of Indiana agrees with this one in the outline of the siphuncle or in the very shallow cameræ. The specimen is of interest in that it establishes the existence of *Mooreoceras* in the Mississippian; previously described species are of Pennsylvanian age.

Type.—Figured specimen: Pal. Res. Inst., No. 5865.

Occurrence.—From a loose block of Salem limestone on the campus of the University of Indiana, collected by the author. The block is one of several which was removed when digging the foundation of the Biology building, which would place it in the lower or middle part of the Salem, probably not over 40 ft. above the top of the Harrodsburg limestone.

PENNSYLVANIAN SPECIES OF MOOREOCERAS

Mooreoceras normale Miller, Dunbar and Condra

Orthoceras colleti Morse, 1931, (not S. A. Miller) Kentucky Geol. Surv., ser. 6, vol. 36, pp. 300, 325, 326, pl. 54, figs. 1-2.

Mooreoceras normale Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 87, pl. 2, figs. 5-7.

Mooreoceras normale, var. **angusticameratum**, Miller, Dunbar and Condra

Mooreoceras normale, var. *angusticameratum* Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 89, pl. 2, figs. 8-10.

Mooreoceras tuba Miller, Dunbar and Condra

Mooreoceras tuba Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 90, pl. 2, figs. 2-4.

Mooreoceras bakeri Miller, Dunbar and Condra

Mooreoceras bakeri Miller, Dunbar and Condra, 1933, Nebraska Geol. Surv., ser. 2, Bull. No. 9, p. 92, pl. 2, figs. 11-13.

Mooreoceras conradi Newell

Mooreoceras conradi Newell, 1936, Jour. Paleont., vol. 10, p. 483, pl. 69, fig. 3a-e.

Mooreoceras, sp.

Plate 7, figure 12

A fragment of a *Mooreoceras* from the Winterset limestone is illustrated to show the form of the siphonal deposits which are developed at the stage illustrated on the ventral side only. Mural deposits appear in the cameræ. This specimen belongs to a species soon to be described by Mr. Richard Schweers, formerly of the University of Indiana, where this specimen is deposited.

Mooreoceras, sp.

Plate 2, figures 4-7

A sectioned specimen of a *Mooreoceras* from the Kansas City group, Pennsylvanian of Kansas City, Missouri, is illustrated to show the ontogeny of the siphuncular outlines, which can be seen grading from the *Michelinoceras* condition to the

Pseudorthoceras outline typical of mature *Mooreoceras*. This species belongs to a group in which the siphuncular outline remains fusiform throughout. University of Cincinnati, No. 22251.

Genus **PARALOXOCERAS** Flower, n. gen.

Genotype.—*Paraloxoceras konincki* Flower, n. sp.

Conch orthoceraconic, slightly depressed in section. Sutures oblique, sloping slightly orad on the dorsum and generally faintly sinuate. The siphuncle is ventrad of the center in the ephebic stage, though possibly central in the early stage. Its segments are subspherical, slightly broader than long in the genotype. The brim is slightly shorter than the neck and equal to the area of adnation. Siphonal deposits are typical of the Pseudorthoceratinæ in their mode of development, *i. e.* forming a continuous lining on the venter and then growing toward the dorsum, but differ in form. The deposits are massive, leaving as a cavity within the siphuncle only a cylindrical central tubular cavity when complete. The inner free margins of the complete deposit are essentially straight. On the ventral side of the deposits of the genotype radial canals can be seen, a single one in each siphuncular segment, which pass obliquely apicad from the central canal to the connecting ring.

Paraloxoceras konincki Flower, n. sp.

Plate 5, figures 8-9

cf. Orthoceras breynii de Koninck, 1880, Ann. Mus. Royal d'Hist. Nat. de Belgique, T. 5, 2me partie, p. 73, pl. 38, fig. 11a-c.
Non Orthoceratites breynii Martin, 1809, Petrifacta Derbiensia, pl. 39, figs. 17-18.

Conch orthoceraconic, slightly depressed in section. The holotype is 38 mm. in length and expands from 13 and 14.5 mm. to 19 mm. and 21 mm. in that length. The specimen was faintly compressed by flattening adorally, resulting in a slight decrease from normal of the transverse diameter and also in a slight modification of the course of the adoral septa. The sutures are faintly inclined orad on the dorsum. No sinuate suture pattern is apparent. The septum has a depth of about one-sixth the dorso-ventral diameter throughout the specimen. There are five to six and one-half cameræ in a length equal to an adoral dorso-ventral diameter throughout.

The siphuncle is located ventrad of the center, and becomes more eccentric adorally. At the apical end it is 1 mm. at the septal foramen and is 4 mm. from the venter and 7 mm. from the dorsum. At the adoral end it is 1.5 mm. in diameter and is 5 mm. from the venter and 12.5 mm. from the dorsum.

The siphuncular segments are nummuloidal, slightly broader than long. A segment 3.2 mm. in length expands from 1.5 mm. to 4.5 mm. The brim and area of adnation are subequal and slightly less than the neck, which is about one-eighth the length of the segment.

Siphonal deposits are annulosiphonate, pseudorthoceroid, and of the *Pseudorthoceras* type by their manner of growth. The first trace of a deposit on the dorsum appears in the third camera from the adoral end of the specimen, and on the venter in the same segment the adjacent deposits are barely discrete. The deposit is massive on the venter. In the earliest stage observed it extends for about two-thirds the length of the segment in the form of a broadly rounded lobe extending orad from the septal neck. The vacant space remaining is semicrescent-shaped in section. In the two apical segments the radial canal bifurcates just before reaching the connecting ring. It is not known how many radial canals there may have been nor how they may have been distributed radially. As the radial canals do not show in every segment, they were probably discrete. The deposits on the dorsum increase from the third to the sixth segments. Apicad of the sixth segment, the deposits vary slightly in size, but variation is erratic. This suggests very strongly that the deposit does not close on the dorsum. An identical condition has been found in the neanic stage of *Pseudorthoceras*.

Cameral deposits are mural, moderate in development and are seen only in the four apical cameræ of the holotype. The surface of the shell is smooth and without ornament.

Discussion.—The whole interior of the specimen has been recrystalized and the original structures are somewhat obscured. It is doubtful whether a slight variation in color of the crystaline material close to the connecting ring on the venter represents a perispatium or not. If so, this genus shows a remarkable parallelism in structure with the Actinoceroidea. The strong dorso-ventral differentiation and mode of growth of the siphonal deposit is opposed to an actinoceroid origin. The strong resemblance of the structure of this genus to that of *Mooreoceras* has already been discussed.

The only specimen available for the present study is the one figured and described above. Its specific name involves several problems. It is closely allied if not conspecific with a species to which De Koninck referred as *Orthoceras breynii* Martin. The cameræ in De Koninck's specimens are slightly shallower, but they represent slightly later portions of the conch than does the specimen studied.

O. breynii, the genotype of *Loxoceras* McCoy is known only from the original description and figure. Although various authors have attempted a redescription, it appears that until and unless the original type is examined, no specimen can be referred to the species with any certainty. Further, the lack of knowledge of what *O. breynii* is, makes it impossible to refer any species to the genus *Loxoceras* McCoy which was based upon it, and further the family Loxoceratidæ is one to which no genus other than *Loxoceras* can be referred.

It is evident that on purely nomenclatorial grounds a new name must be proposed for De Koninck's specimen. Further, if Martin's original drawing of *O. breynii* was accurate, De Koninck's specimen is not conspecific, for there is a clear difference in the depth of the cameræ, those of *O. breynii* Martin being considerably longer than those of *O. breynii* de Koninck.

De Koninck's species differs from *O breynii* as originally illustrated by Martin in having much shallower cameræ and less sinuate sutures, and the two are probably quite distinct.

Occurrence.—From the Visé limestone, of the Upper Mississippian, Visé, Bel-
Type.—Holotype: University of Cincinnati, No. 8738.
gium.

Genus BERGOCERAS Flower, n. gen.

Plate 9, figures 5-6

Genotype.—*Cyrtoceras antilope* de Koninck, 1880, Ann. Mus. Royal d'Hist. Nat. de Belgique, vol. 5, 2me partie, p. 36, pl. 37, fig. 1. Visé limestone, Mississippian, Visé, Belgium.

Conch cyrtoconic, exogastric, depressed in section. Sutures straight and transverse to the curving axis of the conch. Siphuncle ventrad of the center, composed of subspherical segments which are broader than long, and closely resemble the condition found in *Paraloxoceras*. Annulosiphonate deposits are as in *Paraloxoceras* except that dorso-ventral differentiation is not apparent.

Surface with rounded longitudinal liræ separated by fine striæ. Aperture unknown.

Discussion.—This is presumably a curved derivative of *Paraloxoceras*. The curvature, ornament, and the lack of dorso-ventral differentiation of the deposit distinguish the genus from other Pseudorthoceratidæ. From other cyrtoceracones it can be separated by the nature of the siphonal deposits.

Subfamily CAYUTOCERATINÆ Flower, n. subfam.

This subfamily is characterized by a siphonal deposit which is differentiated into two layers. An outer layer consists of discrete calcareous annuli of the *Michelinoceras* type. The inner layer apparently originally carbonaceous, consists of fused segmental deposits which form a continuous lining within the siphuncle.

Two genera, both simple orthoceracones, are placed here. The subfamily appears in the Cayuta shale, lower Chemung, Upper Devonian where it is represented by *Cayutoceras*. *Bradfordoceras* is characteristic of the Conewango, of the Upper Devonian, where it is represented by a variety of species. As yet the subfamily had not been recognized outside of the Penn-York embayment.

Genus CAYUTOCERAS Flower, n. gen.

Genotype.—*Cayutoceras casteri* Flower, n. sp.

Conch orthoceraconic, circular or slightly depressed in section. The sutures are straight and transverse and the septa are evenly curved. The diameter of the siphuncle in section is slightly less than one-seventh that of the conch. In the early portion it is central; in later portions it may lie slightly ventrad of the center. The segments are of the *Dolorthoceras* type (see p. 21), though slightly broader than in typical *Dolorthoceras*. The brim and neck are equal and the area of adnation is less than half the brim. The free part of the connecting ring is strongly curved at the ends and faintly convex in the middle. The segments are more or less barrel-shaped. The necks are short, less than one-tenth the length of the segment. The interior of the siphuncle bears a double deposit. Calcareous annuli develop into the *Michelinoceras* type of deposit. The adapertural end of the deposit may continue orad for over half the length of the segment, but the adjacent deposits are not known to fuse. The calcareous deposit is covered by a carbonaceous deposit which appears to be continuous, though its segmental origin can not be seen. This appears first as a thin black coating of the calcareous annulus. Where well developed it is continuous, lining the inside of the siphuncle, and is thickened markedly orad of the greatest development of the calcareous deposits, where it is massive and rather irregular. Both deposits are much heavier on the venter than on the dorsum, but the deposit appears on the dorsal side before the carbonaceous deposit is continuous on the ventral side from segment to segment.

The aperture of this genus is not known. The surface is poorly preserved in all specimens examined, but shows no trace of any ornament.

Discussion.—The deposits within the siphuncle are unlike those of any actinoceroid, but the double nature of the deposit suggests the type of structure which Teichert[114] has figured for *Westonoceras*. In view of the very different structure of the septal necks and the differences in the position of the break between the segmental deposits it is probable that the resemblance is isomorphic and is not indicative of any relationship. The genus suggests a relationship with *Bradfordoceras* if the deposits within the siphuncle of that genus have been interpreted correctly.

Cayutoceras is known only from the genotype, which occurs in the Cayuta shale of the Upper Devonian.

Cayutoceras casteri Flower, n. sp.

Plate 1, figure 10; Plate 3, figure 1

This is a moderate sized orthoceracone of subcircular section. The conch enlarges at a rate of 3-4 mm. in a length of 20 mm. No gerontic cessation of enlargement has been noted, though specimens with a diameter of 50 mm. have been found.

The sutures are straight and transverse. There are five cameræ in a length equal to an adapertural diameter of 23 mm. The septa are evenly curved and moderate in depth. Where the diameter of the conch is 21 mm., the septum is 4 mm. deep, slightly less than the depth of a camera. The siphuncle is subcentral in position in the earlier stages and is very slightly eccentric in the later portion, so that where the diameter of the conch is 40 mm. the siphuncle is 4 mm. in diameter at the septal foramen and is 17 mm. from the supposed venter.

114 Teichert, C.: *Untersuchungen an actinoceroiden cephalopoden aus Nordgrönland*, Meddelelser om Grönland udgivne af Kommisionen for videnskabelige undersogelser i Grönland, bd. 92, nr. 10, 1934, p. 36, fig. 18.

Where the conch is 21 mm. in diameter the camera is 5 mm. in depth. The siphuncle at this point is central. It expands from 2.5 mm. at the septal neck to 3 mm. within the cameræ. The neck is about one-sixth the depth of the camera and the brim is equal to the neck. The connecting ring is faintly convex in the middle and curves more rapidly at its ends. The area of adnation is about one-half the brim, but the connecting ring is only narrowly separated from the septum for a greater distance, giving an appearance of a much greater area of adnation than is actually present. The internal deposits of the siphuncle have been described under the generic discussion. The cameræ contain well defined episeptal and hyposeptal deposits which are concentrated on the ventral side.

The largest fragment of a living chamber observed for this species has a diameter at the base of 40 mm. and is 90 mm. in length. No trace of the aperture has been found. Several fragments of the shell which adhere to the internal mold show no trace of ornament.

Discussion.—This species appears to be widespread in coquinites of the Cayuta shale, but most of the specimens obtained represent relatively small fragments of phragmocones.

So far as known *Cayutoceras casteri* is the only representative of *Cayutoceras*, although it is possible that *Orthoceras palmatum* Hall[115] may belong here also. That species has a depressed section and much deeper cameræ than *C. casteri*. The horizon and locality of *O. palmatum* are unknown. Hall recorded it from "semicalcareous beds of the upper member of the Chemung group, in southern New York."

Types.—Holotype: Pal. Res. Inst., No. 5855. Paratypes: Pal. Res. Inst., No. 5856-7.

Occurrence.—In coquinites of the Cayuta shale from 2 miles south of Owego, New York, and from a road cut three miles west of Bainbridge, New York.

Genus BRADFORDOCERAS Flower and Caster

Genotype.—*Bradfordoceras transversum* Flower and Caster.

Bradfordoceras Flower and Caster, 1935, Bull. Amer. Paleont., vol. 22, No. 75, p. 32.

This genus contains orthoceracones of slightly depressed section. The sutures slope adaperturally on the dorsum and are more or less sinuous. When the sinuosity is well developed the suture pattern consists of lateral saddles which separate a shallow ventral lobe from a deeper dorsal lobe. The septum is shallow as in *Mooreoceras*.

The siphuncle is located ventrad of the center of the conch. The condition of the early segments has not been observed. The ephebic segments are of the *Pseudorthoceras* type of outline, and may be pyriform or globular. In the genotype the segments are as wide as long.

Deposits within the siphuncle are of the *Cayutoceras* type, consisting of discrete annulosiphonate rings which are only slightly better developed orad than

115 Hall, James: Paleontology of New York, vol. 5, pt. 2, 1879, p. 312, pl. 90, figs. 9-10.

apicad. These rings are overlaid by an apparently continuous deposit of calcite which is believed to correspond to the carbonaceous deposit of *Cayutoceras*.

The surface of the shell bears obscure lines of growth. The aperture bears a broad, shallow hyponomic sinus.

Discussion.—*Bradfordoceras* resembles *Mooreoceras* somewhat in section, sutures and position and outline of the siphuncle. The genera can readily be distinguished by the endosiphuncular deposits; those of *Mooreoceras* are of the *Pseudorthoceras* type while those of *Bradfordoceras* are of the *Cayutoceras* type. Each genus represents the end development of a different line; *Mooreoceras* being a specialization derived from *Pseudorthoceras*, while *Bradfordoceras* is more closely related to *Cayutoceras* than any other genus.

Bradfordoceras is definitely known only from the Conewango series of the Upper Devonian. Seven species were referred to the genus when it was first described. In the Salamanca conglomerate there are numerous fragmentary specimens which were described as variants of *B. hector* (Hall). It is highly probable that when these forms have been studied from additional material they may prove to be of specific rank.

The structure of the deposits of *Bradfordoceras* is known only from a few propitiously preserved fragments of the genotype. The structures present were recognized as organic, but the continuous deposits which were at first compared to the deposits of *Pseudorthoceras* are more probably the homologue of the carbonaceous deposits of *Cayutoceras*.

Bradfordoceras transversum Flower and Caster

Plate 5, figures 10-11

Bradfordoceras transversum Flower and Caster, 1935, Bull. Amer. Paleont., vol. 22, No. 75, p. 34, pl. 3, figs. 1-5; pl. 4, fig. 1; pl. 5, fig. 1; pl. 6, fig. 3; pl. 8, figs. 3-4.

The portion of the original description dealing with the external features and general proportions of the conch needs no revision; however, the internal structure needs further comment.

The internal structure is preserved in four specimens the cameræ of which are completely filled with crystalline calcite, The endosiphuncular cavity is occupied for the most part by matrix, and the septa, margins of the deposits and the connecting ring are variously represented by calcite and limonite.

A paratype, Pal. Res. Inst., No. 5023, shows the simplest condition. Here the siphuncle is filled with calcite. The annulosiphonate deposits are not developed, but the second deposit, that corresponding to the continuous carbonaceous deposit of *Cayutoceras* is represented by a limonitic band. In another specimen, likewise a paratype (Pal. Res. Inst., No. 5015,) the siphuncle is occupied for the most part by a matrix of yellowish sand. In the adapical part of this specimen the annulosiphonate rings are still calcareous, and they are covered by a thin layer which is carbonaceous adapically, limonitic adorally and in places seems to be destroyed by the invading matrix.

Unfortunately the holotype, which was selected largely because of the undistorted section and the outline of the siphuncle, represents an atypical condition. The carbonaceous deposit of *Cayutoceras* is here represented by a band of calcite lined on either side with limonite. This encloses spaces which correspond to the annulosiphonate deposits but which are occupied by a red sandstone, a part of the matrix. This must represent a specimen in which the annulosiphonate rings failed to calcify for some reason, though the protective continuous deposit was secreted. This must have been broken at some point to permit the entrance of the sand into the annulosiphonate spaces.

It seems impossible that the structures present here could be of inorganic origin, even when not considered in the light of the two paratypes mentioned above. The band of calcite enclosing annulosiphonate spaces filled with sand cannot be explained in terms of any sedimentary process of the filling of the siphuncle with matrix; rather it must represent a space which could not be filled with sand because it was occupied by some tissue or some deposit. After burial the original structure was dissolved out and replaced by calcite, doubtless from percolating waters.

Types.—Holotype: Pal. Res. Inst., No. 5014. Paratypes: Pal. Res. Inst., No. 5015-5023, and Acad. Nat. Sci. Philadelphia, Second Geol. Survey Pennsylvania Coll., No. 9602.

Occurrence.—Lewis Run sandstone member, Venango stage, Conewango series, Upper Devonian, from Lewis Run, Bradford County, Pennsylvània, and in the Salamanca sandstones of northern Pennsylvania.

Bradfordoceras moderatum Flower, n. sp.

Plate 3, figure 8

The holotype represents a portion of a mature specimen including most of the living chamber and several attached cameræ. The conch is slightly flattened, the pressure being directed about 25 degrees from the dorso-ventral diameter. Flattening is slight. The conch expands from 20 mm. and 27 mm. to 29 mm. and 35 mm. in the first 40 mm., which includes the lower part of the living chamber. Just beyond this there is a marked decrease in the rate of expansion. The phragmocone is 24 mm. in length and contains six cameræ. The sutures are only partially preserved. A broad evenly rounded dorsal saddle and lateral lobes can be seen. A ventral saddle shallower than the dorsal one must have been present, and is indicated by the slight anterior direction of the ventro-lateral part of the suture. The cameræ increase rapidly in depth, except the last which is contracted. The last four measure 3 mm., 4.4 mm., 5 mm., and 4 mm. respectively. There were seven cameræ in a dorso-ventral diameter of 26 mm. at the base of the living chamber, and eight or nine in a corresponding transverse diameter of 32 mm. The siphuncle in the present specimen is 2 mm. in diameter at the base, the only point where it can be seen, and is 3 mm. from the ventral wall. Oblique distortion results in the siphuncle being 12 mm. from one side and 13 mm. from the other.

The living chamber has diameters at the base of 26 mm. and 32 mm., and is 67 mm. in length. A small portion of the aperture is preserved. A little below mid-height, the rate of expansion decreases abruptly, giving the conch a faintly gibbous aspect. A marked constriction, probably only internal, appears in a region 55 mm. to 60 mm. from the base of the living chamber. Only the lateral part of the aperture is preserved. The constriction of the interior preserves the apertural pattern, a rather unusual feature, showing a well developed hyponomic sinus and a shallower and narrower lateral sinus.

Discussion.—The species is unique in the proportions and characteristic constriction of the internal mold of the living chamber. The sutures and the depth of the cameræ are intermediate between *B. transversum* Flower and Caster, and *B. sinuosum* Flower and Caster having a better developed ventral saddle than typical *transversum*, and lacking the mid-dorsal flattening of *sinuosum* to which it is closer in size and cameral proportions.

Type.—Buffalo Museum of Science.

Occurrence.—In the Lewis Run sandstone, at Lewis Run, Pennsylvania. Collected by I. G. Reimann.

Bradfordoceras giganteum Flower, n. sp.

Plate 3, figure 7

The holotype is a large specimen which has been crushed dorso-ventrally in such a way as to produce a transverse fold in the septa throughout. The dorso-ventral diameter is decreased, but the transverse diameter has apparently not been increased. The conch expands in the first 56 mm. from 32 mm. and 25 mm. to 37 mm. and 44 mm., and in the next 60 mm., to 60 mm. and 51 mm.

The depth of the septa has been destroyed and is of no value. The sutures are sinuous, producing rounded ventral and dorsal lobes, the ventral lobe low and well rounded, the dorsal lobe higher and less flattend in the median region. The depth of the cameræ is uniform throughout the phragmocone. There are nine to ten cameræ in a length equal to the transverse diameter, and eight to nine in a length equal to the dorso-ventral diameter. The siphuncle, as exposed at the septa is 3 mm. in diameter and 10 mm. from the venter at the base of the specimen where the diameters are 25 mm. and 32 mm. At the base of the living chamber the siphuncle is 4 mm. in diameter and is 16 mm. from the venter, measuring in each case the distance along the distorted septum. The form of the segments is unknown.

The living chamber has diameters at its base of 60 mm. and 51 mm. It is incomplete, but the basal 70 mm. of it are present. One side of the adapertural end is missing. The dorso-ventral diameter is 62 mm. The estimated transverse diameter is 80 mm.

The internal mold shows traces of irregular growth lines as in other species of *Bradfordoceras.*

Discussion.—This species is unique both for its large size and its rapid rate of expansion. The shallow cameræ recall *Bradfordoceras multicameratum* Flower and Caster[116] of the Salamanca, but the holotype of that species is much smaller and represents the gerontic portion of the phragmocone. Further the rate of expansion is not as large as it appears, for the specimen is badly flattened, while *B. giganteum* is only slightly flattened. The reference to *Bradfordoceras* rests upon the marked sinuosity of the sutures and the prominent growth lines. Both of these features are absent in *Mooreoceras* with which *Bradfordoceras* is easily confused.

Types.—Holotype: Buffalo Museum of Science.

Occurrence.—The specimen is labeled as follows.—"Conewango group (?) From Allegheny State Park. Donated by J. W. Ruobloch. Collector unknown." The form is preserved in a light colored very hard sandstone, normally yellowish but weathering lighter, which may represent the Wolf Creek conglomerate.

Bradfordoceras fusiforme Flower, n. sp.

Plate 7, figure 9

The holotype is a fragment 110 mm. long consisting of a mature living chamber and twelve cameræ. The conch is depressed in section expanding in the apical 40 mm. from 15 mm. and 17 mm. to 24 mm. and 28 mm. The conch expands at a nearly uniform rate to the middle of the living chamber which is slightly inflated, and the aperture is contracted.

The sutures describe broad lobes on the dorsum, rising orad on the ventrolateral areas as far as observed. The mid-ventral part of the suture has not been preserved. The septum has a depth of 5 mm. where the transverse diameter is 24 mm. and the estimated dorso-ventral diameter is 22 mm. The siphuncle has not been observed, but must lie well ventrad of the center. The cameræ occur five in a length equal to a transverse adoral diameter of 26 mm. The last two cameræ are slightly shorter.

The living chamber has basal diameters of 25 mm. and 28 mm. and is 60 mm. in length. In the basal 30 mm. the conch expands to 28 mm. and 32 mm., beyond which it contracts and is nearly cylindrical to the aperture where the diameters are 28 mm. and 28 mm. The apertural margin is not preserved.

Discussion.—The gibbous form of the living chamber suggests *B. gomphoides,* which is a much larger species with much shallower cameræ.

Type.—Holotype: Buffalo Museum of Science.

Occurrence.—From the Lewis Run sandstone, Lewis Run, Pennsylvania.

[116] Flower, R. H., and Caster, K. E.: *Ibid.*, p. 38, pl. 7, fig. 6.

APPENDIX TO SYSTEMATIC DESCRIPTIONS

For morphological purposes it has been necessary to illustrate and refer to two undescribed species which do not belong to the Pseudorthoceratidæ. These species and one new genus, *Virgoceras*, proposed for orthochoanitic ancestors of the Pseudorthoceratidæ, are described below.

Genus **VIRGOCERAS** Flower, n. gen.

Plate 3, figure 3

Genotype.—*Orthoceras palemon* Barrande.

Conch orthoceraconic, circular in section with straight and transverse sutures. The siphuncle is central or subcentral in position and is orthochoanitic in outline. Siphonal deposits are pseudorthoceroid, consisting of annulosiphonate deposits which fuse to form a continuous lining within the siphuncle. The surface of the shell is marked by fine transverse lines in the genotype, but the surface features are apparently not diagnostic of the genus.

Discussion.—This genus is erected for the reception of species which differ from typical members of the subfamily Dolorthoceratinæ of the Pseudorthoceratidæ in the orthochoanitic outline of the siphuncle. They differ from other orthochoanitic orthoceracones in possessing pseudorthoceroid instead of orthoceroid deposits.

Virgoceras cancellatum Flower, n. sp.

Plate 8, figure 14

Conch orthoceraconic, circular in section, expanding at a rate of 3 mm. in a length of 40 mm. throughout. Holotype 73 mm. in length, expanding from 20 mm. to 25 mm. Sutures straight and transverse. Cameræ occurring two and a half in a length equal to an adoral diameter throughout the known portion. Siphuncle perfectly cylindrical, 6 mm. in diameter where the diameter of the conch is 25 mm. Siphuncular segment broad and short, the length to the width as four is to three. Siphonal deposits pseudorthoceroid, the oldest portion, that at the septal foramen, considerably inflated so that in a section which does not quite attain the center, as in the one illustrated, the deposits of the two sides seem to fuse. Cameral deposits are mural and are well developed.

The surface of the shell of this species bears fine, low, longtiudinal liræ spaced four to seven in a width of 5 mm. Between these occur fainter liræ. The living chamber and aperture of the species are unknown.

Discussion.—This species differs from *Virgoceras palemon* (Barrande) in the large size of the siphuncle and the perfectly cylindrical siphuncular outline. It is comparable to species which have been referred to *Kionoceras* and *Protokionoceras*. While some species which are at present placed in those genera may prove to be closely related to *V. cancellatum*, the form of the siphonal deposits is sufficiently distinctive at present to distinguish the species. Further, this species is unique in the short, broad, siphuncular segments.

Type.—Holotype: Pal. Res. Inst., No. 5870.

Occurrence.—From the Laurel limestone, Clinton group, Middle Silurian, from Westport, Indiana.

Genus GEISONOCERAS Hyatt, 1883

Genotype.—*Orthoceras rivale* Barrande.

Hyatt's original description is as follows:—

"*Geisonoceras,* nobis, includes various groups of the banded longicones of M. Barrande. They fade into true *Orthoceras* and yet can certainly be distinguished by the transverse markings or bands which are formed on the surface of the shell. We include in this series groups 10, 11, 12, 13, 14, of M. Barrande. The young are either smooth or transversely striated. Type, *Gei.* (*Orth.*) *rivale,* sp. Barr., pl. 209, 216, 387. The banded longicones are directly connected by transitional forms with *Cycloceras,* and with the banded brevicones of the genus *Rizoceras.* The characteristic bands of the shells and the position of the siphon in some species makes a close approximation to *Bactrites.* Silurian, Devonian, Carboniferous?"[117]

There appear to be no significant additions to this generic description. For a time, all "banded" orthoceracones with orthochoanitic siphuncles, that is, all such forms with coarse transverse ornament, were placed in this genus. Later Foerste[118] erected the genus *Geisonocerina* for the reception of those forms ornamented by close raised transverse lines instead of comparatively broad bands, stating in the description that "the grouping of species under these generic terms is extremely artificial in either case."

Hyatt was probably in error in considering *Geisonoceras* as grading into *Cycloceras, Rizoceras* or *Bactrites.* The similarity between these genera is almost certainly isomorphic, as is that between mature portions of *Striacoceras* Flower[119] and *Geisonocerina* Foerste.

The following redescription of the genus, based upon Barrande's figures of the genotype may clear up some of the misconceptions concerning the generic criteria:—

Section circular or subcircular; conch orthoconic, expanding slowly; longiconic. The sutures are straight and transverse, or may be very slightly oblique. The siphuncle is central or slightly eccentric in position. The necks are short and vertical, and the connecting rings are very faintly convex within the cameræ. Small adorally attenuated annulosiphonate deposits are developed in the adapical portion, and the cameræ contain episeptal and hyposeptal deposits. The surface of deposits within the cameræ presents a smooth and continuous surface as

117 Hyatt, A.: *Genera of Fossil Cephalopods,* Proc. Boston Soc. Nat. Hist., vol. 22, 1883, p. 275.

118 Foerste, A. F.: *Big Horn and related Cephalopods,* Denison Univ. Bull. Jour. Sci. Lab., vol. 30, 1935, p. 22.

119 Flower, R. H.: *Cherry Valley cephalopods,* Bull. Amer. Paleont. vol. 22, No. 76, 1936, p. 28.

already discussed on page 55. (See also text fig. 11, p. 52; text fig. 12, p. 53.) The surface is marked by broad bands, the nature of which has been discussed above. Between these there are fine striæ or lines of growth. The aperture appears to bear a slight hyponomic sinus but is otherwise transverse.

Geisonoceras teicherti Flower, n. sp.

Plate 7, figure 8; Plate 9, figure 19

This is a large, slender orthoceracone of circular section. The conch expands at a uniform rate of 1 mm. in a length of 20 mm. The diameter at the apical portion is 20 mm. From this the conch expands to a diameter of 27 mm. at a point near the aperture.

The sutures are straight and are inclined less than 10 degrees from the horizontal. The septa are evenly curved, the depth being slightly less than one-third the diameter of the conch. The cameræ are deep; one and one-half cameræ occupy a length equal to the adapertural diameter throughout.

The siphuncle is subcentral in position, the difference in the distances from the two sides varies somewhat but is never more than 1 mm. At the apex the siphuncle is 3 mm. in diameter and is 9 mm. from one side and 9.5 mm. from the other. At the next to the last camera it is 4.6 mm. in diameter and is 14 mm. from one side and 14.6 mm. from the other. The septal necks are less than one-tenth the depth of the camera and are perfectly vertical. The siphuncle expands very slightly within the cameræ but is essentially tubular. Where the depth of the camera is 20.2 mm., the siphuncle expands from 4.6 mm. to 5 mm. The expansion is gradual at both ends, and there is no area of adnation. At the septal necks the siphuncle is occupied by small annulosiphonate deposits which are attenuated adorally to nearly one-fourth the depth of the camera at the adapical end of the specimen where these are best developed. At this point the endosiphuncular cavity is contracted to one-third its normal diameter by the lunettes or bulettes as the deposits are called.

Within the cameræ episeptal and hyposeptal deposits are present. At the adapical portion of the specimen these join to form short pseudosepta. It appears to be significant that the bulettes of the siphuncle are commensurate with the development of the episeptal deposits against the siphuncle.

The living chamber is 36 mm. in diameter at the base. The wall of the adapertural portion is broken and poorly preserved, but the chamber appears to extend for a length of about 105 mm. No trace of the aperture is preserved. The surface of the shell is unknown.

Discussion.—This species shows such close similarity to the genotype of *Geisonoceras* in the structure of the interior and in general proportions that I have placed it in that genus even in the absence of surface markings. The apical part of an orthoceracone, probably belonging to the same species, is contained in the living chamber of the holotype. This specimen shows transverse ornamentation which may develop into the typical pattern of *Geisonoceras* in a later part of the conch.

The species can be distinguished from other orthoceracones of the Middle Devonian of New York by its very slender form, deep cameræ, and by the pattern of the deposits.

The species shows the typical internal condition of *Geisonoceras,* in which there is a continuous secreting surface within the phragmocone. An exceptional feature is the presence of a carbonaceous band which corresponds in position to the cameral mantle, as postulated solely upon the basis of the deposits. Further, the species is of interest in being one of the very few forms in which the beginning of cameral deposits can be detected in the last camera before the living chamber.

Type.—Holotype: New York State Museum, No. 1255n/1.

Occurrence.—From the Onondaga limestone, Middle Devonian, of "western New York."

PART IV

PHYLOGENY

RELATIONSHIP OF THE PSEUDORTHOCERATIDAE

I. The outline of the mature segments of the siphuncle and the annulosiphonate nature of the siphonal deposits suggest that the Pseudorthoceratidæ might be allied to the Annulosiphonata of the Cyrtochoanites in which may be included the Actinoceroidea and a few forms of doubtful affinities.

The Pseudorthoceratidæ and the Actinoceroidea possess several features in common, but the differences are such that the two groups are believed to be merely isomorphic. The following features are common to the two families:—

(1). Cyrtochoanitic adult siphuncular segments. So far as the outline of the siphuncle is concerned it might be possible to derive the Pseudorthoceratidæ from the Sactoceratidæ of the Actinoceroidea.

(2). Deposits within the siphuncle are annulosiphonate.

The following differences are found:—

(1). The nepionic segments of the siphuncle approach the orthochoanitic form in all Pseudorthoceratidæ and attain it in the earlier and simpler genera. The earliest siphuncular stages of the Actinoceroidea are greatly expanded and definitely cyrtochoanitic. Simplification of the siphuncular outline in the Actinoceroidea occurs in the latest, not the earliest segments.

(2). Deposits within the siphuncles of actinoceroid forms are pendant and are normally extended about equally orad and apicad of the center of deposition at the septal foramen. The deposits of the Pseudorthoceratidæ are parietal, scarcely developed apicad, and elongated orad for the length of the segment.

(3) The central and radial canals of the siphonal vascular system together with the perispatium are characteristic of the Actinoceroidea but are absent throughout the Pseudorthoceratidæ. It is believed that this indicates a fundamental difference in the organization of the siphon.

(4). The septal furrow, well developed in all of the Pseudorthoceratidæ, is largely absent in the Actinoceroidea, being known only in a specialized group of Upper Ordovican *Ormoceras*.

(5). The apical end of the siphuncle is open in the Actinoceroidea but is closed by a siphonal cæum in the Pseudorthoceratidæ, in which that family agrees with other stenosiphonate cephalopods.

II. Another cyrtochoanitic annulosiphonate group is comprised in the family Westonoceratidæ Teichert. Here again the resemblances with the Pseudorthoceratidæ seem to be isomorphic. The segments are cyrtochoanitic, the deposits are annulosiphonate. But the perispatium is lacking and there is no trace of the radial canal system of the Actinoceroidea. The deposits resemble those of the Pseudorthoceratidæ in that they are parietal and consist of two layers, the outer layer calcareous and the inner one carbonaceous.

The condition recalls that of the Cayutoceratinæ. However, the septal necks of the Westonoceratidæ are recumbent and both ends of the connecting ring are broadly adnate to the free part of the septum, features which are opposed to anything known in the Pseudorthoceratidæ. Further, it may be noted that the Westonoceratidæ are confined to the Ordovician, while the Pseudorthoceratidæ do not put in an appearance until the Devonian. The Pseudorthoceratidæ which are closest to the Westonoceratidæ stratigraphically are those which have simple and slender siphuncular segments. *Euloxoceras* approximates the condition of the Westonoceratidæ in its siphuncular outline more closely than does any other genus of the Pseudorthoceratidæ, and this genus is known only from the Pennsylvanian. The structural and stratigraphic discrepancies between the two families seem to indicate that the resemblance between them has no genetic significance.

III. Among the cyrtochoanitic cephalopods which are not annulosiphonate there are several possible relatives which must be considered. One is *Troedssonoceras* Foerste[120] which possesses longitudinal ornament like that of *Kionoceras*, but which has markedly cyrtochoanitic siphuncular segments. The siphuncle contains lamellar deposits which superficially resemble the completed deposits found in the Pseudorthoceratidæ. Teichert[121] has figured the siphuncle of *Troedssonoceras striatum* (Troedsson). His figure shows lamellar deposits in

120 Foerste, A. F.: *American arctic and related cephalopods*, Denison Univ. Bull., Sci. Lab., Jour., vol. 23, 1928, p. 40.

121 Teichert, C.: *Untersuchungen an Actinoceroiden cephalopoden aus Nordgrönland*, Meddelelser om Grönland, bd. 92, nr. 10, 1934, p. 41, fig. 20.

which superimposed layers can be made out. While the layers are slightly irregular they are apparently not of segmental origin but seem to extend unbroken from segment to segment. The structure suggests rather that of *Stokesoceras balticum* Teichert and seems to support Teichert's[122] suggestions that the genus may be related to the Discosoridæ.

It might be noted in passing that *Troedssonoceras* is based upon *Orthoceras turbidum* Hall and Whitfield[123] of the Maysville.

At the time of the original description of the genus, Foerste referred to it two species from the Cape Calhoun beds of the Middle Ordovician of Greenland, *Sactoceras* (?) *lineatum* Troedsson and *S.* (?) *striatum* Troedsson.[124]

More recently Shimizu and Obata[125] have made *S. striatum* the type of a new genus *Striatoceras* which is placed in a new family Ohioceratidæ, based upon the new genus *Ohioceras* of the same paper, while *S. lineatum* is made the genotype of the new genus *Greenlandoceras* which is placed in the new family Greenlandoceratidæ of which it is the solitary member. From the descriptions it appears that the genera and families are separated because the segments of *Striatoceras* are "ormoceratoid" while those of *Greenlandoceras* are "actinoceratoid." Troedsson's figures show that the differences in the outline of the siphuncles are mainly concerned with the width of the siphuncle at the septal foramen. In *S. lineatum* the area of adnation is slightly greater and the segment on the whole is slightly broader in proportion to its length. The differences between the genera are such as might occur between different parts of the same species, though it is apparent here that the species are distinct. The differences are not, however, sufficient to warrant generic or family distinctions. Both genera are here regarded as synonyms of *Troedssonoceras* Foerste, of which Shimizu and Obata appear to be ignorant. Kobayashi[126] has proposed the family name Troedssonoceratidæ and suggested that the family might be related to the Stereoplasmoceratidæ, rather than to the Discosoridæ. A relation between all three families is not impossible.

IV. Kobayashi's family Stereoplasmoceratidæ presents another possible relationship. In a revision of the family by its author[127] it is defined as follows:—

"Longiconic orthoceracone[s], smooth or annulated; siphuncle ellipochoanoidal, more or less expanded between the septal necks; intracameral stereoplasmic deposit present; and if the stereoplasmic deposit is present in the siphuncle it is more or less tubular."

122 Teichert, C.: *Einige actinoceroide Cephalopoden aus dänischen Diluvialgeschieben und aus dem Gotlandium Skandinaviens*, Meddelelser fra Dansk Geologisk Förening, bd. 8, hft. 4, 1934, p. 387, pl. 8, fig. 3.

123 Hall, J., and Whitfield, R. P.: Geol. Surv. Ohio, vol. 2, pt. 2, Paleontology, 1875, p. 100, pl. 3, fig. 1.

124 Troedsson, G. T.: *On the middle and upper Ordovician faunas of northern Greenland, I., Cephalopodes*, Jubilæksspeditionen nord om Grönland 1920-23, nr. 3, 1926, pp. 79, 80, pl. **1**, fig. 7; pl. 47, figs. 1-7.

125 Shimizu, S., and Obata, T.: *New genera of Gotlandian and Ordovician nautiloids*, Jour. Shanghai Sci. Inst., 1935, sec. 2, vol. 2, pp. 6-7.

126 Kobayashi, Teiichi: *On the Stereoplasmoceratidæ*, Japanese Jour. Geol. Geogr., vol. 13, Nos. 3-4, 1936, pp. 230-242, pl. 26.

127 Kobayashi, T.: *Ibid.*, pp. 230-242.

The siphuncle outline of the family ranges from a nearly orthochoanitic type of outline which recalls the primitive pseudorthoceroid condition of *Anastomoceras* through forms with nummuloidal and definitely cyrtochoanitic segments. Deposits within the siphuncle are continuous and not segmental, as far as can be determined from published figures, and in this respect differ from the Pseudorthoceratidæ. There is a wide stratigraphic gap between the two families. The Stereoplasmoceratidæ appear to be largely if not entirely confined to the Lower and Middle Ordovician. The Pseudorthoceratidæ appear in the Devonian. Kobayashi[128] referred *Pseudorthoceras* to the Stereoplasmoceratidæ on the basis of the similarity of the siphuncular outlines and the continuous deposits within the siphuncle. However, it was not apparent at that time that the deposits of *Pseudorthoceras* and its allies were of annulosiphonate origin. Now that this has been demonstrated, it appears that the Stereoplasmoceratidæ and Pseudorthoceratidæ are perfect isomorphs, if only portions of the phragmocone containing mature siphonal deposits are considered.

V. The remaining possibility for the origin of the Pseudorthoceratidæ seems to be the Orthochoanites, and indeed the majority of the evidence favors such a hypothesis:—

(1). The early segments of *Dolorthoceras* and *Pseudorthoceras* and indeed the segments of all Pseudorthoceratidæ for which the ontogeny of the siphuncular outline is known, are consistent with the origin of the family in the Orthochoanites and the "Orthoceratidæ" in the old sense.

(2). The annulosiphonate deposits are parietal in the Pseudorthoceratidæ and also in *Michelinoceras* Foerste and *Geisonoceras* Hyatt of the "Orthoceratidæ."[129]

(3). The pseudorthoceroid deposit is the ultimate development of the orthoceroid deposit, and in all Pseudorthoceratidæ the deposit passes through an ontogenetic *Michelinoceras* stage identical with the condition found in many orthochoanitic genera.

(4). The conchial furrow and the septal furrow are typically developed in both the "Orthoceratidæ" and the Pseudorthoceratidæ.

(5). Species are known which form a transition between the two families, exhibiting the pseudorthoceroid type of siphonal deposit in conjunction with an orthochoanitic siphuncular outline. One is *Virgoceras palemon* (Barrande).[130]

128 Kobayashi, T.: *Ibid.*, pp. 233-234.

129 Teichert, C., and Miller A. K.: *What is Orthoceras*, Am. Jour. Sci., vol. 31, 1936, pp. 352-362. The authors have shown that the genotype of *Orthoceras* was probably a rudistid and *Orthoceras* and Orthoceratidæ cannot be used legitimately for cephalopods. Their proposal of the use of the old name *Orthoceros* and the proposal of a new family name Orthocerotidæ seems inadvisable, inasmuch as the name suggests a typographical error on the part of the original author. Further it appears that the slightness of the change will cause more confusion than it will eliminate.

130 Barrande, J.: Système silurien du centre de la Bohême, vol. 2, Céphalopodes, 4th ser., 1870, pl. 394, fig. 6.

The deposits are parietal as in the Pseudorthoceratidæ and show the *Dolorthoceras* type of structure. Their primitive condition is shown by the clarity with which the segmental nature is evident from the outline of the mature deposits. Related species are not uncommon in the Middle Silurian of America, though because internal structures have not been closely studied in the past they have gone unrecognized. These include not only smooth orthoceracones referred formerly to *Orthoceras,* but also forms referable on the basis of ornament to *Protokionoceras.*

The points upon which the families differ are as follows:—

(1). The ephebic segments of the siphuncle of the Pseudorthoceratidæ are cyrtochoanitic.

(2). The deposits of the siphuncle of the orthochoanites are limited in extent, as is discussed elsewhere, being commensurate with the development of the cameral deposits against the connecting ring. The pseudorthoceroid deposit is not thus confined.

SUMMARY

From the evidence reviewed here it appears that the closest affinities of the Pseudorthoceratidæ are with the orthochoanitic annulosiphonate cephalopods. Indeed, so close is the similarity that there is probably not a good genetic break between the groups and the position of the boundary might be questioned. For convenience in definition and recognition, the Pseudorthoceratidæ are limited to cyrtochoanitic forms. At the present time there is a good break between the orthochoanitic Silurian forms and the cyrtochoanitic Lower Devonian forms. But there is a stratigraphic break also, and it is quite possible that when Upper Silurian cephalopods are better known both gaps will be eliminated. Certainly there is ontogenetic and adult gradation in the siphuncular outlines of Devonian species, and there is no reason to assume that the gradational nature of the development of the siphuncular segments should be confined to the Devonian in the Pseudorthoceratidæ and their immediate ancestors.

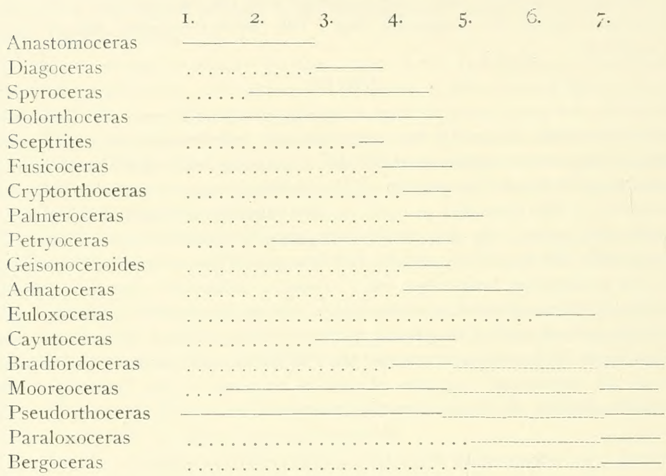
EVOLUTION OF THE PSEUDORTHOCERATIDAE

Text figures 21, 22

The changes which took place in the development of the Pseudorthoceratidæ had to do mainly with the modification of the siphuncular outline and the specializations of the siphonal deposits. The section of the conch and the position of the siphuncle are sometimes helpful, but seem to be matters of secondary importance which vary too much within a genus to serve as reliable criteria by themselves. Oblique and sinuous sutures are isomorphic characters, and accompany any modification from the generalized subcircular section. The aperture is of use only in rare instances, largely because it is unknown for many of the genera.

The outlines of the siphuncles of various representatives of the family can be arranged in a series of stages ranging from the simple orthochoanitic type to the various expanded cyrtochoanitic types. These have been described in detail under the discussion of the siphuncle and are shown in text fig. 3. They need only be summarized here. The siphuncular outlines seen in the *Michelinoceras, Anastomoceras,* neanic *Dolorthoceras* and ephebic *Dolorthoceras* types represent an evolutionary sequence. Beyond the *Dolorthoceras* type there is a division of the stem. One line passes through the *Adnatoceras* type to the *Euloxoceras* type, while two others show an almost identical change from the *Dolorthoceras* to the *Pseudorthoceras* type. The following table summarizes what is known and what is suspected of the various siphuncular outlines of the various genera.

Known and assumed changes of siphuncular outline in the Pseudorthoceratidæ



1. Michelinoceras type
2. Anastomoceras type
3. Neanic Dolorthoceras type
4. Ephebic Dolorthoceras type
5. Adnatoceras type
6. Euloxoceras type
7. Pseudorthoceras type

—Observed outline
. . Supposed outline (early stages not known)
_ Outline type absent

The structure and development of the siphonal deposits have likewise been discussed in an earlier part of this paper. The following types are recognized:—

1. The primitive annulus, which occurs in the early stages of all genera.
2. The *Michelinoceras* type, which occurs in the early stages in all genera.
3. The *Dolorthoceras* type. This occurs in all Dolorthoceratinæ where deposits are known. In *Anastomoceras* it is ephebic, and is modified gerontically into the *Anastomoceras* type. Owing to the lack of suitably preserved parts of the phragmocones, it has not been noted in *Sceptrites, Cryptorthoceras, Palmeroceras* or *Diagoceras*.
4. The *Anastomoceras* type. Confined to gerontic *Anastomoceras*.
5. The *Pseudorthoceras* type. This is characteristic of the genera placed in the Pseudorthoceratinæ, *Pseudorthoceras* and *Mooreoceras*.
6. The *Cayutoceras* type. In the Cayutoceratinæ, comprising *Cayutoceras* and *Bradfordoceras*.

The first two appear in all genera, but are modified in the Pseudorthoceratinæ. A complete ring is not formed there in the early stage of a deposit, because of the great retardation of development of the deposit on the dorsum. The incomplete ring on the venter, however, recapitulates these stages. These two types are not ephebic characters in any members of the family, but are the ontogenetic expression of the ancestral condition of the family, as is discussed elsewhere.

Anastomoceras is the earliest of the true Pseudorthoceratidæ, being the only representative of the family known from the Helderbergian of the Lower Devonian. By its siphuncular outline it is the most primitive genus of the family, but the gerontic siphonal deposits are complex. The deposits in the ephebic stage are those of the *Dolorthoceras* type. In the gerontic stage, however, a central sheath and irregular radial pillars are added, which result in the more complex *Anastomoceras* type (figs. 3, 21-22).

So far as the family Pseudorthoceratidæ is concerned the *Anastomoceras* type of deposit might be taken as the logical beginning of a progressive thinning of the siphonal deposit. In the transition to Middle Devonian *Dolorthoceras* the excessive gerontic deposits are lost. In contemporaneous and later forms there is noted a thinning of the deposit at the septal foramen, a necessary accompaniment to the increase in expansion of the siphuncular segments. In later forms the remainder of the deposit thins, so that all that remains is a very thin uniform siphuncular lining, the segmental nature of which is not at once apparent to the eye. This is a gradual and continuous process, and can be well seen by comparing Devonian and Pennsylvanian species of *Mooreoceras* or *Pseudorthoceras*. It is a significant process and is one indicative of some interesting changes of the functions of deposits.

The primitive annulosiphonate deposit had a dual function. First it apparently served as a depository for excess calcareous material, and was excretory in this sense. Second, the deposits were significantly heavy. Being concentrated apically, they undoubtedly served to weigh down the apex of the shell. This permitted active hyponomic swimming by weighting the tip of the shell. Further, by both ventral and apical concentration, it counteracted the buoyant effect of gas in the cameræ and permitted a horizontal mode of life. This was the function of the deposits of the phragmocone taken as a whole. The relative importance of cameral and siphonal deposits as excretory and especially hydrostatic factors varied with their mass, as is explained in another section of this paper. When the continuous lining of the siphuncle developed it became a controlling agent for the development of cameral deposits, for cameral deposition could not continue after the cameral tissues had been separated from the siphonal tissues by the pseudorthoceroid deposit. The gradual thinning of the siphonal deposit, which can be traced from the Middle Silurian through the Pennsylvanian, indicated that the siphonal deposits gradually came to be more and more exclusively devoted to their new function. The very thin siphuncular lining found in Pennsylvanian *Mooreoceras* could have had little significance due to its own weight, but its main function was that of a valve, separating the siphonal and cameral tissues when growth was complete in any siphuncular segment.

Yet it does not follow that the development of the *Anastomoceras* type of deposit is the beginning of this series. That it may not be is suggested by two lines of evidence. First, it must be remembered that the gerontic *Anastomoceras* type of deposit is developed only in the genotype, *A. mirabile*. There is not enough evidence to show whether it is really absent in other Helderbergian species or whether the apparent absence is due only to meagre material.[131]

A consideration of the ancestral Silurian types shows that it is not necessary to include the gerontic *Anastomoceras* type of deposit in the direct line indicated by the orthogenetic thinning of the siphonal deposits. The group of *O. palemon* Barrande given the generic name *Virgoceras* above, see page 162, is well represented in America, although it has not previously been noted owing to the lack of study of the internal structures of Silurian Orthochoanites. Such forms are now being studied, and are found to include both smooth and ornamented species in the

Fig. 21. Diagram of the structural changes which have taken place in the Pseudorthoceratidæ in relation to the approximate time relation of the appearance of each genus. Only the modifications of structure are shown. Thus, except when otherwise indicated by figures, the conch is a smooth orthoceracone throughout. Changes have to do with form as in *Sceptrites, Fusicoceras, Cryptorthoceras*, and *Bergoceras*, ornament as in *Spyroceras, Palmeroceras, Geisonoceroides* and *Petryoceras*, section and position of siphuncle, as in *Sceptrites, Cryptorthoceras, Fusicoceras, Mooreoceras, Diagoceras* and *Euloxoceras*, and siphuncular outline and siphonal deposits, which are indicated for all genera except the form and ornament deviations springing from *Dolorthoceras*.

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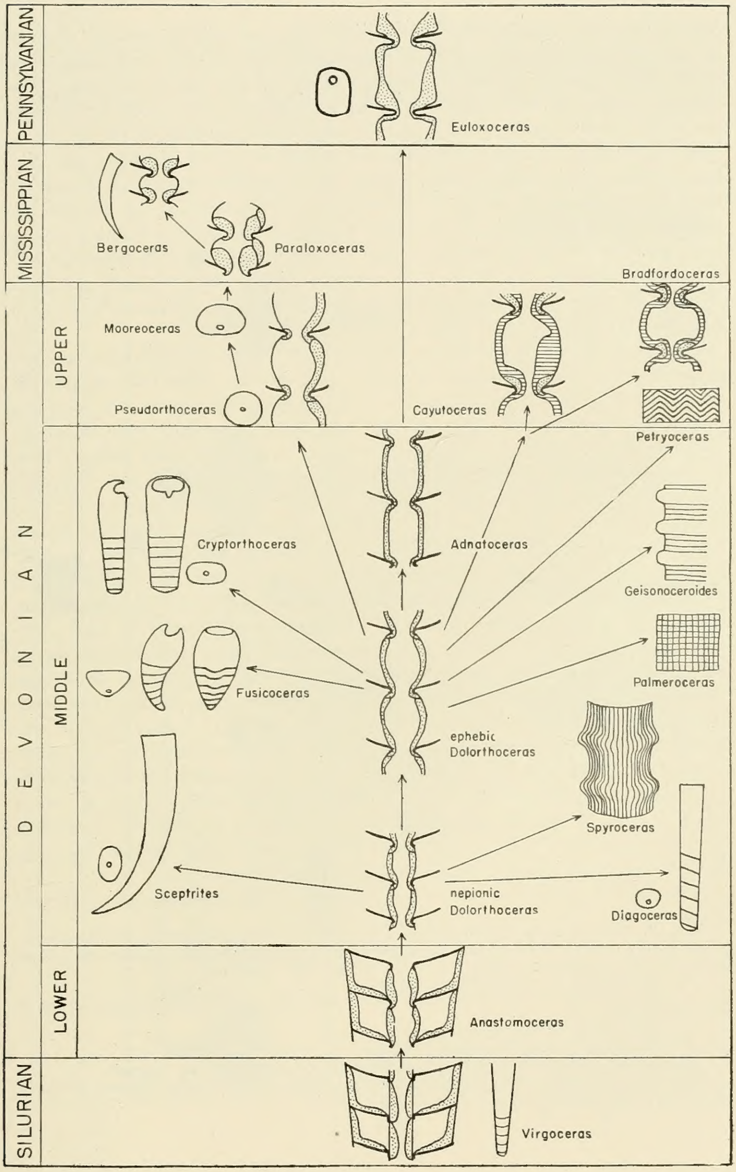
131 A nomenclatorial problem is also involved. If the gerontic deposits should prove to be confined to only a part of *Anastomoceras* as here delimited, a new genus might be proposed for species lacking the gerontic deposit. The practical difficulties involved as well as the uncertainty of the interpretation under discussion make such a step undesirable at the present time.


PENNSYLVANIAN
Euloxoceras
MISSISSIPPIAN
Bergoceras
Paraloxoceras
Bradfordoceras
D E V O N I A N
UPPER
Mooreoceras
Pseudorthoceras
Cayutoceras
Petryoceras
MIDDLE
Cryptorthoceras
Adnatoceras
Geisonoceroides
Palmeroceras
Fusicoceras
ephebic
Dolorthoceras
Spyroceras
Sceptrites
nepionic
Dolorthoceras
Diagoceras
LOWER
Anastomoceras
SILURIAN
Virgoceras

Laurel limestone of the Middle Silurian of Indiana, and judging from the affinities of associated cephalopods, it will be remarkable if this group is not found to be widely distributed in the Middle Silurian of east-central North America. The siphonal deposits form a continuous lining of segmental origin, and the deposits are thicker at the region of the septal foramina than elsewhere in the segments. This thickening is a primitive condition which hearkens back to the *Michelinoceras* type of deposit from which it was derived. In the ephebic deposits of *Anastomoceras* the foraminal thickening is eliminated; in *Dolorthoceras* the deposits become thinner at the septal foramina than elsewhere, and general thinning follows in later forms. The *Anastomoceras* type of deposit might be an independent offshoot from this line. It is the type of variation which is met with again and again in the early history of genetic groups: erratic development of a structure which later becomes stabilized and subject to only minor variation.

Dolorthoceras and its immediate relatives follow. The siphuncle becomes more expanded in the cameræ, largely by virtue of the increase of the brim and the development of a slight area of adnation, and the siphonal deposits are becoming thinner and more regular. In *Dolorthoceras* the *Anastomoceras* type of outline, which is without definite brim or area of adnation, is followed by the neanic *Dolorthoceras* type, in which the brim and area of adnation are slightly and subequally developed. The transition to the ephebic *Dolorthoceras* type is marked by an increase in the brim while the area of adnation remains stationary. The earliest well preserved and abundant material of *Dolorthoceras* which has been available for study is of Hamilton age. There *Dolorthoceras* is prolific, and further, with it are associated several of its ornamented or otherwise specialized derivatives, suggesting that the origin of the genus must be looked for in Ulsterian or more probably Oriskanian strata. Further, it is to be expected that in pre-Hamilton species the neanic *Dolorthoceras* type of outline may be found to appear as an ephebic character. *Dolorthoceras parlenese* (H. S. Williams) of the Moose River sandstone of the Oriskanian of Maine, shows in general a type of outline which is very similar to that shown in the neanic stages of later *Dolorthoceras*. The poor preservation of the only specimen known which shows the siphuncle leaves some doubt as to the exact condition of the area of adnation and the extent of the brim, but is adequate to show that this species must be considered as an advanced *Anastomoceras* or a primitive *Dolorthoceras*. *Dolorthoceras rudis* (Hall) of the Onondaga seems to represent a typical neanic *Dolorthoceras* condition.

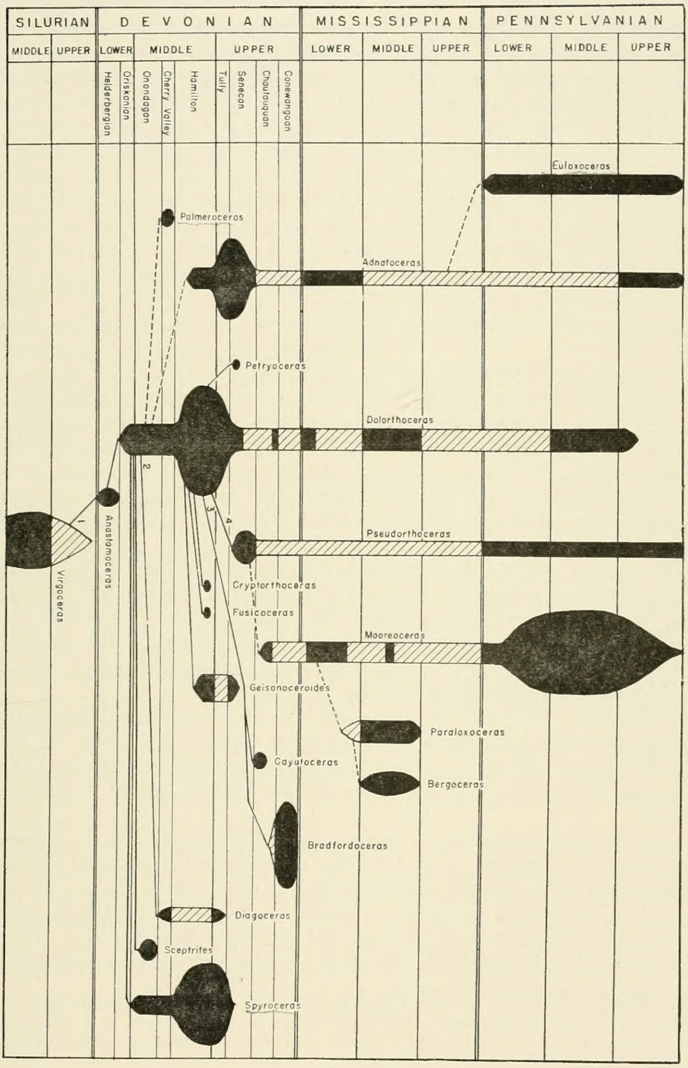
In the Middle Devonian, and more particularly in the Hamilton, *Dolorthoceras*

Fig. 22. Diagrammatic representation of the range of the genera of the Pseudorthoceratidæ. Known occurrence of a genus is indicated in black; the inferred occurrence by oblique lines. Relative abundance is indicated by the width of the black areas.

1. Development of cyrtochoanitic outline.
2. Early derivatives of *Dolorthoceras* which retain the neanic *Dolorthoceras* outline to the ephebic stage.
3. Development of the Cayutoceratinæ.
4. Development of the Pseudorthoceratinæ.

Pseudorthoceras extends into the basal Permian, not shown on this diagram.

The Devonian section has particular reference to New York; the other systems are necessarily more generalized.



SILURIAN
DEVONIAN
MISSISSIPPIAN
PENNSYLVANIAN
MIDDLE
UPPER
LOWER
MIDDLE
UPPER
LOWER
MIDDLE
UPPER
LOWER
MIDDLE
UPPER
Helderbergian
Oriskanian
Onondagan
Cherry Valley
Hamilton
Tully
Senecan
Chautauquan
Conewangoan
Euloxoceras
Palmeroceras
Adnatoceras
Petryoceras
Dolorthoceras
Pseudorthoceras
Anastomoceras
Virgoceras
Cryptorthoceras
Fusicoceras
Mooreoceras
Geisonoceroides
Paraloxoceras
Cayutoceras
Bergoceras
Bradfordoceras
Diagoceras
Sceptrites
Spyroceras
1
2
3
4

gave rise to many specializations, which find their expression in a variety of form and ornament. Probably each of these specializations is quite independent of the others. The variations of ornament will be considered first:—

Two genera proclaim their early development from *Dolorthoceras* by the retention of the neanic *Dolorthoceras* type of siphuncular outline. *Diagoceras* is specialized in section, sutures and in the development of a pattern of fine rhythmically spaced striæ. Its appearance in the Cherry Valley limestone in the basal Hamilton and its reappearance in the Tully limestone at the top of the Hamilton suggests that it is a form which favors a limestone facies. *Spyroceras*, characterized by annulations and longitudinal ornament, is prolific in the Hamilton, is well developed in the Tully and the latest known species are found in the Ithaca shales of the Upper Devonian in association with a fauna the other members of which are also presumably of Hamiltonian affinities and origin. Ulsterian species which agree in form and ornament are probably congeneric, though their internal structure is not known. Whether the one Helderbergian annulated orthoceracone, "*Orthoceras*" *tenuiannulatum* Hall[132], which was referred to *Spyroceras* by Foerste[133], really is a representative of the genus is very doubtful though not impossible. If so, an even earlier origin than is here suggested must be accepted.

Geisonoceroides possesses siphuncular segments showing the ephebic *Dolorthoceras* condition. The genus is characterized by low annuli and tranverse striæ, suggesting both *Cycloceras* and *Geisonoceras*. The genus is typically developed in the Hamilton of western (but not eastern,) New York, and persists into the Ithaca.

Palmeroceras suggests by its siphuncle that it originated close to the point at which *Adnatoceras* developed from *Dolorthoceras*. Its trilobate aperture suggests *Dolorthoceras* rather than *Adnatoceras*. The ornament is essentially that of the Silurian *Protokionoceras*, and strangely enough *Palmeroceras* is associated with the Devonian development out of that genus, namely *Striacoceras* Flower, in which the longitudinal ornament is lost in the ephebic stage.

Petryoceras is the last of the ornamented derivatives and the most singular of them all, its surface being marked with transverse bands of zigzag striæ and liræ. Although known only from the Sherburne sandstones and shales of the Upper Devonian, the siphuncular outline shows that the genus is derived from *Dolorthoceras*.

Three Middle Devonian genera serve to show that form is not more constant than ornament. *Sceptrites* of the Onondaga differs from *Dolorthoceras* in being a compressed cyrtoceracone. The orientation is not definitely known, but the cameral deposits suggest endogastric curvature. *Fusicoceras* of the Hamilton is a derivative of *Dolorthoceras* by the form and deposits of the siphuncle. It is a brevicone and is strikingly similar to *Brevicoceras* Flower[134] in section and sutures.

132 Hall, J.: Paleontology of New York, vol. 3, 1861, p. 345, pl. 72, fig. 1.

133 Foerste, A. F.: *American orthoconic Silurian cephalopods*, Denison Univ. Bull., Sci. Lab., Jour., vol. 23, 1928, p. 285.

134 Flower, R. H.: *Devonian brevicones of New York and adjacent areas*. Palæontographica Americana, vol. 2, No. 9, 1938, p. 24.

The siphuncular segments of *Brevicoceras* are subspherical and contain actinosiphonate deposits.

Cryptorthoceras is the most singular of the form types produced in the family and is without a duplicate elsewhere in the Nautiloidea. It is clearly derived from some such trilobate *Dolorthoceras* as *D. tersum* (Hall) by exaggeration of the mid-dorsal crest of the aperture, slight inflation of the living chamber, and a revolving of the aperture so that it opens on the ventral side.

The Middle Devonian development of the Pseudorthoceratidæ is essentially one of ornament and form. Most of the ornament patterns known for orthoceracones are developed. The ornament is no longer adequate for the reference of a species to a supposedly orthochoanitic genus. Further, one cyrtoceracone and one brevicone develop. None of these specialized types survived the last development of the Hamilton faunas, namely that of the Ithaca facies of the Upper Devonian. *Dolorthoceras* itself lived on into the Mississippian and Pennsylvanian apparently without change, but it never again attained the variety or abundance of species which are found in the Hamilton.

A continuation of the siphuncular expansion which has been already noted produces *Adnatoceras* from *Dolorthoceras*. The increase in the brim is slight, the increase in the area of adnation is great. The expansion of the siphuncular segment becomes concentrated at its end and the middle part looses the faintly convex outline found in *Dolorthoceras* and becomes essentially straight. *Adnatoceras* appears in the Hamilton, but does not become prolific until Upper Devonian time. It is the most abundant genus of the Tully and fragmental evidence suggests that it is also the dominant orthoceracone in the Ithaca fauna. The genus is not met with in higher strata until the Pennsylvanian, where *A. ciscoënse* Miller, Dunbar and Condra is found. Here the only new feature developed is the appearance of hyposeptal deposits. *Euloxoceras* carries the siphuncular expansion by marked increase at the ends of the segment to its final development. The genus agrees with *A. ciscoënse* in having episeptal and hyposeptal deposits, but is unique in its compressed form and dorsal siphuncle. Further, fragments of the shell suggest a kionoceroid ornament.

In the entire line which has been traced, which constitutes the Dolorthoceratinæ, there is no essential change in the structure of the siphonal deposits. In the Upper Devonian two new stocks develop which are characterized by modifications of the pseudorthoceroid deposit.

The Pseudorthoceratinæ are characterized by a dorso-ventral differentiation in the development of the siphonal deposits. In many orthoceracones with central siphuncles the annulosiphonate deposits are more strongly developed on the venter than on the dorsum; further in such forms the deposit in any given segment appears on the venter before it appears on the dorsum and an important feature of growth of the annulosiphonate ring is the addition of material to its lateral extremities until they meet and fuse dorsally. The development of the extreme differentiation found in *Pseudorthoceras* would doubtless not have been possible in a series of forms with siphuncles close to the venter. The ventral concentration of deposits is well marked in some Hamilton *Dolorthoceras* but the condition in which the ventral lining is completed before any deposit appears on the mid-dorsal region is not attained until Upper Devonian time, where it is accompanied by an increase in the convexity of the connecting ring, thereby producing *Pseudorthoceras*. It is apparently true that wherever a subcentral siphuncle occurs there is some ventral concentration of the siphonal deposit, but the condition is rarely advanced, and it cannot be traced as a permanent character through any considerable series. The causes bringing it about are partly, at least, mechanical. But in the Pseudorthoceratinæ the condition has become a genetic factor, for it is retained in *Mooreoceras*, a derivative of *Pseudorthoceras* in which the siphuncle is relatively close to the venter, and in which there is no mechanical reason for the retention of the unusual mode of growth. The peculiar modification of the ontogeny has all the earmarks of the genetic preservation of an acquired characteristic.

Before such a hypothesis can be accepted it is necessary to examine the evidence more closely. First of all it must be determined whether the dorso-ventral differentiation can be explained as a mechanical modification which is the necessary accompaniment of the form of the conch and the subcentral position of the siphuncle. It is a fact that among orthoceracones wherever the siphuncle lies close to the venter little dorso-ventral differentiation is found, but where it becomes central a marked ventral concentration is to be expected. This is found in the Orthochoanites as well as in the Actinoceroidea. Probably more than a hydrostatic factor is involved here. In the Pseudorthoceratidæ the cameral deposits are more affected by the position of the siphuncle than are the siphonal deposits, and while it is probably true that the changes producing the *Pseudorthoceras* type of siphonal deposit could not have occurred in an orthoceracone with a ventral siphuncle it does not follow that the central siphuncle is the essential factor. The other great difference between *Dolorthoceras* and *Pseudorthoceras*, namely the development of the pyriform siphuncular outline from the barrel-shaped one, suggests no solution to the problem.

Possibly the appearance and retention of the character are due to coinciding but independent elements. In a stock of forms with central siphuncles inherent variation might evolve a type in which dorso-ventral differentiation of the siphonal deposits was marked. The development of the cenogenetic character already noted in *Pseudorthoceras*, namely the failure of the deposit to complete the siphonal lining dorsally in neanic segments, might be a factor in the retention of this mode of growth. From this it would appear that the explanation of the origin is not entirely satisfactory, as it invokes a generalization which is known not to hold in the later members of the Dolorthoceratinæ to any great extent. However, if by chance this structure was developed, and we have evidence that it was, it is quite possible for another character, for the appearance of which we have no really convincing explanation, to form a pattern of which the first character is an essential part, resulting in its genetic preservation.

Pseudorthoceras appears in the Naples fauna of the Upper Devonian. In Chemung time it gives rise to *Mooreoceras*, which is now definitely known from the Wellsburg monothem of the Upper Chemung, as now restricted. Both genera persist into the Pennsylvanian, with a thinning of the siphonal deposit the only apparent change.

Paraloxoceras, which appears in the Mississippian, represents a new specialization derived from *Mooreoceras*. It differs from that genus in the more expanded siphuncular segments, a thickening of the siphonal deposits, and the development of a radial canal system. *Bergoceras* is a cyrtoconic derivative of *Paraloxoceras*, which shows, so far as is known at present, no trace of the ventral concentration of the siphonal deposits in their growth stages.

The Cayutoceratinæ are characterized by the differentiation of the siphonal deposits into a primary and a secondary layer. This is again foreshadowed in Hamilton *Dolorthoceras*. *Cayutoceras* is known only from the Chemung. The siphuncle is essentially of the *Dolorthoceras* type, though slightly broader than usual. The inner layer of deposits is irregular and the cameræ contain episeptal and hyposeptal deposits.

Bradfordoceras is definitely known only from the Conewango, though its presence in the Conneaut is suspected on the basis of the similarity of the suture pattern of crushed specimens in the Chadokoin shale to those of crushed specimens of *Bradfordoceras transversum* Flower and Caster. *Bradfordoceras* is more specialized than *Cayutoceras* in the depressed section, eccentric siphuncle, and the development of oblique and sinuous sutures. *Mooreoceras* is developed from *Pseudorthoceras* in the same way. *Bradfordoceras* is further specialized in the development of subspherical siphuncular segments. It is generalized in that the deposits are mural, as in most Pseudorthoceratidæ, and not episeptal and hyposeptal as in *Cayutoceras*. Doubtless forms combining the simpler features of the two genera await discovery.

It is significant that in this stock the dorso-ventral differentiation of siphonal deposits is essentially mechanical. It is to be found in *Cayutoceras* where the siphuncle is central, and is quite pronounced there. No dorso-ventral differentiation has been noted in *Bradfordoceras* where the siphuncle lies close to the venter.

The accompanying diagram illustrates the phylogeny and known distribution of the genera of the Pseudorthoceratidæ. The three groups typified by the three main types of siphonal deposits lend themselves well to subfamily groups. Known and assumed range are differentiated, and some attempt has been made to designate the relative abundance of the various groups in different times. Although our knowledge of the Pseudorthoceratidæ is as yet very incomplete there is a remarkable correlation between the appearance of the genera in the stratigraphic column and the phylogeny as based on the structures (text figs. 21-22).

POSSIBLE DERIVATIVES OF THE PSEUDORTHOCERATIDAE

It is the purpose of this section to call attention to several groups which it has not been possible to investigate thoroughly, but which it is suspected may be closely related to the Pseudorthoceratidæ.

Among orthoceracones the genus *Neocycloceras* Flower and Caster[135] of the Upper Devonian, a genus which is possibly also present in the Lower Mississippian, possesses annulations and transverse ornament. The siphuncle of the genotype is known only in the ephebic portion. The segments are subspherical. In the apical end of *N. harrisi* the segments are tubular and apparently orthochoanitic. The poor preservation of all specimens in Upper Devonian sandstones has made it impossible to determine whether any organic deposits are present in the siphuncle. On the basis of the stratigraphic occurrence it appears probable that the genus may belong to the Pseudorthoceratidæ, for no other stenosiphonate cyrtochoanitic orthoceracones are known in the Upper Devonian, or in any strata after the Ordovician for that matter.

Originally the Pseudorthoceratidæ were conceived as a family of orthoconic forms. However, in the Devonian *Sceptrites* is a cyrtoceracone which by the form of the siphuncular segments can hardly be placed anywhere else. *Fusicoceras* is evidently a breviconic derivative of *Dolorthoceras* and the aberrant *Cryptorthoceras*, an orthoceracone with the aperture contracted and bent ventrad, is probably a derivative of the same genus.

Cyrtospyroceras Flower[136] may easily belong to the family as well, and may represent a specialization out of *Spyroceras* from which it differs mainly in curvature, depressed section, and the ventral position of the siphuncle.

The Mississippian of Ireland and Belgium contains a large number of cephalopods which are of uncertain affinities. Some of these possess slender cyrtochoanitic siphuncles and may belong to the Pseudorthoceratidæ.

Dolorthoceras, *Adnatoceras*, *Pseudorthoceras* and *Mooreoceras* are to be expected, as these genera extend in range from the Devonian into the Pennsylvanian. Our material has been meagre and the illustrations of internal structure are few in number and not always sufficiently detailed. *Adnatoceras* is represented by *A. cf. neglectum* (de Koninck), described and illustrated in the systematic portion of the present paper. *Orthoceras sollasi* Foord[137] may be an *Adnatoceras* of a *Dolorthoceras*, by the outline of the siphuncle.

Paraloxoceras Flower, n. gen., and *Bergoceras* Flower, n. gen., show that the Mississippian development of the Pseudorthoceratidæ is characterized by new developments of both form and internal structure. There are numerous cyrtoconic

135 *Ibid.*: p. 14.

136 Flower, R. H.: *Devonian brevicones of New York and adjacent areas*, Palæontographica Americana, vol. 2, No. 9, 1938, p. 212.

137 Foord, A. H.: *Monograph of the Carboniferous Cephalopoda of Ireland*, Part I, Family Orthoceratidæ (in part), Paleontographical Society, vol. 51, 1897, pl. 8, fig. 1.

species described, the internal structure of which has not been sufficiently investigated. Foord[138] has figured a section of *Poterioceras fusiforme* (Sowerby) which shows a continuous lining within the siphuncle and mural deposits within the cameræ. Both features suggest the Pseudorthoceratidæ, and indicate that *Poterioceras* may eventually prove to represent another deviation from the generalized orthoceraconic form when it has been more closely studied.

At the present time it appears that the development of the Pseudorthoceratidæ was centered in Europe in Mississippian time and that only occasional strays reached America. A restudy of the Nautiloidea of the Mississippian of Europe should yield rich morphological and taxonomic results, and may serve to disclose modifications of the Pseudorthoceratidæ in form, structure and ornament of which the two genera *Paraloxoceras* and *Bergoceras* already show some indication.

GENETIC RECAPITULATION IN THE PSEUDORTHOCERATIDAE

The recent discussions of Spath and Schindewolf of recapitulation in cephalopods have been well summarized and discussed by Swinnerton.[139] In view of the importance of the problem, it seems desirable to review briefly the evidence already set forth which the study of the Pseudorthoceratidæ brings to bear upon the problem, and also to consider the possibility of other interpretations. The evolutionary development herein set forth requires a monophyletic line up to Upper Devonian time, from which offshoots sprang which were characterized by deviations from the simple orthoconic form or the smooth exterior of the shell or both. In Upper Devonian time two side lines become differentiated from the main stem by modifications of the siphonal deposits. In tracing the development of the siphuncular outline from the beginning of the family in *Anastomoceras* to any of the three termini, there is seen an orthogenetic progression in the expansion of the siphuncular segments. Further in tracing the development to *Pseudorthoceras* there is seen a progressive thinning of the siphonal deposit. Assuming the trend to have been orthogenetic before the appearance of *Anastomoceras*, it is possible to trace the group back to Middle Silurian orthochoanitic forms which have been placed in the new genus *Virgoceras*, which is the logical beginning of the sequence, as judged both by the expansion of the siphuncular segment and the thinning of the deposit.

The evidence on which the classification is based consists first, of the ontogenetic changes which occur in the species. Second, this is checked with the stratigraphic appearance of the genera. Third, the thinning of the siphonal deposits and its other modifications are seen in tracing genera upward in the stratigraphic column. Other possibilities have been eliminated on stratigraphic and morphological grounds.

138 *Ibid.*: pl. 15.

139 Swinnerton, H. H.: *Development and evolution*, Proc. British Association Adv. Sci., Presidential address, sec. E, 1938, pp. 57-84.

Throughout the series there is a progression from an orthochoanitic siphuncle in the nepionic stage to the cyrtochoanitic siphuncle in the neanic stage, while the outline typical of the genus is attained in the ephebic stage. This is essentially a recapitulation of *adult* conditions of the ancestral types. To be sure, only the outline of the siphuncle is considered. It is all that can be considered. The developmental stages of the siphonal deposits are differently preserved, so that any modifications such as are found in the Pseudorthoceratinæ and Cayutoceratinæ will affect the whole ontogney. Nevertheless the simple annulus, the *Michelinoceras* type and the generalized pseudorthoceroid type can be recognized, though preserved with some modification. Other characters are not of a type which are preservable or significant. There is no great modification of section which persists beyond the genus, and such modifications as do occur are to be found in specialized end lines of development without known descendants. Such are the compressed *Sceptrites* and *Euloxoceras*, and the subtriangular breviconic *Fusicoceras*.

Specific characters, by their very nature, are not capable of preservation in the ontogeny. These consist of the depth of the cameræ, the rate of expansion, the position of the siphuncle, details of its outline, and the condition of the sutures. Further, the gerontic decrease in depth of the cameræ and the internal gerontic co striction of the living chamber are of great specific value when considered in relation to the proportions of the conch. These are incapable of appearing in any except the gerontic stage and therefore cannot be expected to appear in the ontogeny. These statements are made not with the intention of delimiting what shall or shall not be regarded as of specific or generic value in orthoceracones, but as a generalization based upon observation. Indeed in some species these specific characters may vary considerably and their use has been proven unwise in the case of *Striacoceras typus* (Saemann) of the Cherry Valley limestone. Nevertheless the proportions of the conch, which are what most of these features amount to in the last analysis, are the specific criteria with which we must deal for all practical purposes, and we are forced to trust them in the absence of safer and more stable characters. In the past they have been found to be useful in the greater number of instances.

It may be questioned whether the early orthochoanitic condition of the siphuncle cannot be an apical simplification of outline, or a character which appears in the early stages and gradually spreads toward the apertural end of the phragmocone. The answer to that is found in a comparison of a Hamilton *Dolorthoceras* and a Pennsylvanian *Pseudorthoceras*, and the younger form shows a marked reduction in the regional extent of the *Michelinoceras* orthochoanitic outline. A more perfect and convincing comparison would be between Devonian and Pennsylvanian species of the same genus, such as *Pseudorthoceras*, but such a comparison is not possible on the basis of the present fragmentary material. However, it is evident that the ontogenetic stages are pushed farther apicad in *Pseudorthoceras knoxense* of the Pennsylvanian than in *P. anomalum* of the Upper Devonian. However, the present evidence is adequate to show that the acceptance of such an interpretation as the advance of cenogenetic larval characters would necessitate the ignoring of the stratigraphic succession of species and genera.

The stratigraphic succession of the genera furnishes evidence which correlates remarkably well with the phyletic succession as worked out on the basis of structures. The correlation is found not in the extent of the genera, but in their first appearance. The usefulness of the Devonian section of New York in this regard is exceptional. It presents a largely continuous series of deposits in which the sedimentary breaks are poor enough that there is still considerable controversy as to where the exact boundaries between Lower and Middle and Middle and Upper Devonian should be placed. It is due to this largely uninterrupted sequence that we probably owe the remarkable perfection of the record. The condition exhibited here by the Pseudorthoceratidæ serves as a possible explanation for the conditions exhibited elsewhere in the stratigraphic occurrence of related genera. Let us suppose for a moment that there were no Middle Devonian deposits preserved in the Penn-York embayment. We would be confronted in the Senecan by an association of *Dolorthoceras, Adnatoceras, Spyroceras, Petryoceras* and *Pseudorthoceras.* Here we would have an association of related genera all occurring together, and yet on morphological grounds it would be possible to place them in their correct genetic sequence, on the basis of the outline of the siphuncle. The only important discrepancy would be that the outline of the segments of *Spyroceras* is slightly more primitive than that of *Dolorthoceras.* The derivation of the smooth *Dolorthoceras* from the highly ornamented *Spyroceras* is so absurd that it would hardly be attempted. Rather, it would be recognized that the two sprang from a common ancestor, a smooth shelled form characterized by the neanic *Dolorthoceras* type of outline in the ephebic stage. The separation of such forms from *Dolorthoceras* has been considered impractical, but they are the primitive late Oriskanian and early Ulsterian types. But on such evidence as is offered by Upper Devonian forms there could be no stratigraphic solution to the problem, and the argument might continue ad infinitum as to whether the ontogeny recapitulates the phylogeny in this instance, or whether the genetic series moved in the opposite direction, that is, toward a simplification of siphuncular outline which is first apparent in the early stages.

The failure of earlier strata to be preserved, or the migration of a fauna to a new area would produce just such phenomena, and certainly must have occurred in numerous instances. In the Fort Cassin beds of the Beekmantown of the Canadian series in the Champlain Valley we have a genetic series, according to Hyatt, living together. This consists of *Schroederoceras, Trocholitoceras* and *Trocholites.* Further, the ontogeny indicates an origin of this stock in the Tarphyceratidæ which are typically developed in the same association. Without the progressive closing of the umbilical perforation which is carried farther in Chazy, Black River and Trenton times, there would be no clue as to which way the evolution ran, and the basis for another difference of opinion would be at hand.

A similar problem is found in the relationship of *Jolietoceras* of the Joliet limestone and *Bickmorites* of the Liston Creek limestone, both of the Middle Silurian. *Jolietoceras* might be an uncoiled derivative of *Bickmorites,* or *Bickmorites* might be a coiled derivative of *Jolietoceras.* The two limestones are both Upper Clinton in age, and the exact correlation is too uncertain to permit one to say which of the two, if either, is slightly older than the other.

It would appear that under such conditions as have been outlined above, the faunal association of genera in a genetic series and the occurrence of members of a genetic series in approximately contemporaneous beds in different regions, are useful in a way which has not hitherto been considered enough. Not only do they indicate that earlier forms await discovery, granting of course that they are preserved, but they are a clear indication of an imperfection of the record and may be interpreted as either a faunal invasion which implies a breaking down of barriers of some sort, or the loss of a part of the record either by original absence of deposits or their subsequent destruction. Precisely the same genetic problems confront the student of Recent faunas, where the fossil record is either not considered or, as in insects, is of no great help.

Let us now review briefly a consideration of the other possibilities of the origin of the Pseudorthoceratidæ. In an attempt to interpret the phylogeny as the reversal of the ontogeny, we are met with practical difficulties. There appears to be nothing from which the Pseudorthoceratidæ can be derived legitimately. Other cyrtochoanitic forms in the Devonian consist of the Actinoceroidea, and a considerable variety of brevicones, all of which, however, are actinosiphonate. The Actinoceroidea are represented in the Devonian only by the Sactoceratidæ. Even ignoring the stratigraphic sequence, an origin of the family in the Actinoceroidea is not convincing on morphological grounds already considered. The condition of the protoconch and the organization of the siphonal deposits in the Actinoceroidea oppose such an explanation and present obstacles which at present seem insurmountable.

Likewise, the Troedssonoceratidæ, Stereoplasmoceratidæ and Westonoceratidæ have been considered and eliminated on stratigraphic and morphological grounds. The Jovellaniidæ and other Actinosiphonata are too different in siphuncular outline and in siphonal deposits to merit serious consideration as ancestors of the Pseudorthoceratidæ. The only apparent connection of the family with brevicones is through *Fusicoceras,* which though breviconic, can hardly be placed elsewhere than in the Pseudorthoceratidæ on the basis of the siphuncular outline and siphonal deposits. It is evident then that on both stratigraphic and structural grounds there is no other possible origin of the Pseudorthoceratidæ than the Orthochoanites.

The modifications of form present features of interest and show that in a stock of essentially orthoconic forms other types may be derived, as *Sceptrites* and possibly *Cyrtospyroceras* among the cyrtoceracones, and *Fusicoceras* and possibly *Poterioceras* in the brevicones. The form deviations of the Devonian are interesting in that they show what must either be a convergence of internal structures too remarkable to be credited, or the beginning of curvature in derivatives of an orthoconic stock. The occurrence of such curvature has long been suspected. It would hardly be necessary to emphasize the overwhelming evidence for it here, were it not for recent statements that such things do not and cannot happen. Such statements have been made on the basis of a few series, mostly questionable, which have been supposed to represent uncoiling. Yet there is no reason why the two processes should be mutually exclusive.

Spath has remarked that a phylogenetic series based upon the hypothesis of the biogenetic law cannot be invoked to support that law. Yet the test of any theory is whether it can be applied. In the Pseudorthoceratidæ, where we have to deal with the recapitulation of adult siphuncular outlines in the ontogenetic stages, no other hypothesis is applicable. Yet the tachygenesis here exhibited does not exclude by any means proterogenesis in Nautiloidea.

GEOGRAPHIC AND GEOLOGICAL RANGE

Quite probably our knowledge of the geological and geographical distribution of a family recognized as recently as was the Pseudorthoceratidæ is still very incomplete. Nevertheless, the present evidence indicates, while it cannot be said to prove, certain generalizations which will serve at least as a starting point for an increase in our knowledge of the stratigraphic and faunal significance of the family.

The orthochoanitic ancestors of the Pseudorthoceratidæ for which the generic name *Virgoceras* is proposed above (p. 162), are of Middle Silurian age. *Orthoceras vebrayei* Barrande is the only species which can be recognized as a member of this group on the basis of published illustrations. The Silurian of east-central North America contains a number of related species, both smooth and ornamented, one of which, *V. cancellatum* Flower, n. sp., is described here. It is sufficient for the purposes of the present discussion to know that this generic group is quite widely distributed geographically in the Middle Silurian.

No representatives of the stock are as yet known from the Upper Silurian anywhere. The examination of the considerable though largely undescribed cephalopod faunas of the Upper Silurian of New York has convinced the author that the primitive pseudorthoceroids are not represented. The appearance of *Anastomoceras* in New York in the Helderbergian is only one aspect of a general faunal invasion which marks the beginning of Devonian time.

The record is very meagre for the upper part of the Lower Devonian. *Dolorthoceras* appears in the Moose River sandstone (Oriskanian) of Maine. It may be represented by orthoceracones in the Oriskany sandstone of New York. Thus far the few Oriskany orthoceracones known have failed to show the outline of the siphuncle, and generic determination is impossible.

The poor preservation of internal structures in the Schoharie grit of the Middle Devonian has made it impossible to recognize any of its numerous species of orthoceracones as members of the Pseudorthoceratidæ. Orthoceracones are very rare in the Onondaga limestone and internal structure is frequently not preserved. However, one Onondaga species, *Dolorthoceras* (?) *rudicula* (Hall) is apparently an early and relatively simple *Dolorthoceras*, and two genera derived from *Dolorthoceras* appear. Of these *Spyroceras* appears to be widely if sparsely distributed in Onondaga time and later becomes prolific and ever more widespread in the Hamilton. The other, *Sceptrites*, is developed in western New York but not in the eastern part, and persists outside of the state into the equivalent Columbus limestone of Ohio. The absence of *Sceptrites* in eastern New York offers an interesting problem which may possibly be explained by the change of the upper beds of the Onondaga eastward. The author visited the locality from which *Sceptrites* was taken near Buffalo with Dr. Irving G. Reimann who pointed out that the cephalopod bearing beds were in the extreme upper portion of the Onondaga.

The upper Onondaga in the vicinity of Buffalo is the equivalent not only of the upper Onondaga of eastern New York, but also of the lower part of the Marcellus, including at least the Union Springs and Cherry Valley members. The present author has recently discussed this problem, and no new evidence has been brought forward.[140] Two independent lines of evidence suggest the correlation of the upper Onondaga of western New York with the basal members of the Hamilton of eastern New York. Stratigraphically, not only are the basal members of the Hamilton "absent" in the west, but the basal member, the Union Springs shale, is known to thin gradually and to become more calcareous as it is traced from east to west. Faunal evidence is supplied by the reported occurrence of *Agoniatites* and characteristic (but undesignated) Cherry Valley brachiopods in the Onondaga at Stony Point, on the shore of Lake Erie near Buffalo, and the occurrence of *Agoniatites* at the top of the Onondaga on Flint Creek, near Phelps, Ontario County, New York.[141]

Further, the reported occurrence of *Agoniatites* and *Anarcestes*, listed by Stauffer[142] from the upper part of the Columbus limestone, suggests that it too may be the equivalent of the basal beds of the Marcellus, up to and including at least the Cherry Valley horizon. The *Anarcestes* specimen is lost. It is regarded as highly suggestive of *Werneroceras plebiforme* (Hall) which occurs in the Marcellus shale just below the base of the Cherry Valley limestone at Cherry Valley, New York. At the time of the original designation of the Columbus specimen, *Werneroceras* had not been separated from *Anarcestes*. Although the specimen was referred to *A. lateseptatus* (Beyrich) of the Middle Devonian of Germany, the lack of conspecific forms in Europe and America among the Devonian Ammonoidea leaves the determination very doubtful. The distribution of *Sceptrites* may be ex-

140 Flower, R. H.: *Cherry Valley cephalopods*, Bull. Amer. Paleont., No. 76, 1936, pp. 5-10.

141 Clarke, J. M.: *Limestones of central and western New York associated with bituminous shales of the Marcellus stage with notes on the nature and origin of the faunas*, New York State Museum., Bull. No. 92, 1906, pp. 120-121.

I have not been able to find the specimens under discussion in the New York State Museum. However, there is little reason to suspect an error, as there is nothing else known which can be readily mistaken for large *Agoniatites*.

142 Stauffer, C. R.: *The Middle Devonian of Ohio*, Ohio Geol. Surv., 4th ser., Bull. No. 10, 1909, p. 168.

plained as the confinement of a series of forms to a limestone facies, and is consistent with this stratigraphic interpretation.

The Hamilton development of the Dolorthoceratinæ is a prolific one, and is characterized by an abundant variation of form and ornament. *Dolorthoceras* is continued on from the Onondaga. *Spyroceras* likewise passes upward from Onondaga to Hamilton, and attains its maximum abundance both in species and in individuals here. To these are added *Geisonoceroides, Palmeroceras, Diagoceras, Fusicoceras* and *Cryptorthoceras,* and possibly also *Cyrtospyroceras* Flower. Yet the Hamilton fauna of New York is not homogeneous. Rather it is made of several distinct faunules which have been distinguished as much as possible in the faunal lists at the end of this section. The earliest abundant fauna is that of the Cherry Valley limestone. The fauna here is not closely related to that of the higher beds of the Hamilton. None of the cephalopod species extend into overlying beds.[143] Two genera of the Pseudorthoceratidæ appear in the Cherry Valley for the first time, *Palmeroceras* and *Diagoceras. Palmeroceras* is not as yet definitely known from any other species or horizon, though it is not impossible that *Orthoceras eriense* Hall and *Orthoceras linteum* Hall may be placed in the genus when the condition of the siphuncles are known. *Diagoceras* on the other hand, is absent throughout the Hamilton shales but reappears in the Tully limestone at the base of the Upper Devonian. This suggests that the genus favored a limestone facies.

The Stafford limestone carries a distinct fauna characterized by two species of *Spyroceras* not found elsewhere in the Hamilton. No other Pseudorthoceratidæ have been recognized in the Stafford, but several other cephalopod species are confined to it.

In higher beds three faunules of cephalopods may be recognized for purposes of convenience. The most distinctive is that found on the shore of Lake Erie, in beds of Ludlowville age extending from *Nautilus* beds or *Pleurodictyum* beds up to the Tichenor limestone. *Geisonoceroides* appears to be confined to this association in the Hamilton of New York. Here also occur *Fusicoceras, Cryptorthoceras* and the characteristic *Dolorthoceras revertum.*

Another quite distinctive association is that found in the Skaneateles shales of central New York, consisting of the small species of *Dolorthoceras, D. telamon, D. exile, D. tersum, Adnatoceras spissum* and several species of *Spyroceras. S. cœlamen* is conspicuous by its absence.

The third faunule is less well known owing to the absence of good limestone

143 Several species have been reported from beds even as high as the Tully limestone. Such determinations are largely embodied in faunal lists and the specimens upon which they were based have not been preserved. In several instances it has been possible to restudy the specimens, and in every case it has been found that an error in determination has been made, except in one instance, namely that of *Striacoceras typus* (Saemann) which was reported from the Stafford limestone. Here the error was due to the inclusion of a specimen from the Cherry Valley limestone in the Stafford limestone collection. The limestones differ so widely in lithology that it should be very difficult to confuse them. Apparently it isn't.

beds in the region for adequate preservation of the species. It appears to be a rather generalized fauna, probably derived from the Skaneateles association, which is developed in higher beds (Ludlowville and Moscow) in central New York, and which appears to interfinger to some extent with the Ludlowville fauna of the Lake Erie section. Particularly characteristic is a small undescribed orthochoanitic orthoceracone, formerly included with a great many other things in *Orthoceras subulatum*, a species which cannot be recognized owing to the condition of the type specimen. *Spyroceras cœlamen* (Hall) is particularly characteristic of this faunule, and *S. crotalum* (Hall) is completely absent.

Rather strangely, none of the orthoceracones from the Hamilton of southern Ontario which have come to my attention are pseudorthoceroids. The family has been recognized in Maryland. Here *Geisonoceroides* and *Spyroceras* occur, and a smooth shelled species very closely allied to and possibly conspecific with *Dolorthoceras telamon* is found. I have not as yet seen a specimen which retains the internal structure, and generic determination is doubtful.[144]

The Tully limestone cephalopods consist of a mixture of species of Hamilton origin, species characteristic of Middle Devonian limestone facies, and forms which are definitely related to the Middle Devonian of more westerly areas. The Pseudorthoceratidæ are represented by a *Diagoceras*, the only other known species of which occurs in the Cherry Valley limestone. *Diagoceras* is apparently one of several genera which favors a limestone facies. Species of *Spyroceras* are of undoubted Hamilton origin and affinities. None are conspecific with Hamilton forms however. *Dolorthoceras*, so prolific in the Middle Devonian, is here represented by a single species, while *Adnatoceras*, which is represented by a single species in the Hamilton but which becomes more abundant in the Naples fauna, is here represented by three species which show considerable variation in both internal and external features.

The Ithaca fauna of the Senecan stage contains the last of the genus *Spyroceras*. Here also there is a fauna of Hamilton affinities. Most of the smooth orthoceracones are too badly crushed to permit generic identification. There are numerous large orthoceracones which in the past have been identified as *Dolorthoceras cayuga* (Hall). It is impossible to say how many species are involved. *Petryoceras* is the last of the ornamented derivatives of *Dolorthoceras* and is particularly characteristic of the Sherburne sandstone between the Cayuga and Seneca valleys. Ornamented derivatives seem to be a special feature of the Middle Devonian, but this genus occurs in an association of Hamilton origin.

The coexisting Naples fauna carries few identifiable orthoceracones. *Dolorthoceras* is represented by a single known species. Two species of *Adnatoceras* have been recognized, and numerous fragments too small to serve as a basis for descriptions suggest the presence of other species. It is in the Naples fauna that *Pseudorthoceras* appears.

144 The recent finding of a small orthochoanitic species which is almost identical in proportions with *Dolorthoceras tersum* (Hall) indicates that determination on the basis of proportions may be unsafe here as well.

Mooreoceras appears in the Wellsburg monothem of the Chemung, where it is represented by two species. No other species of *Mooreoceras* have as yet been recognized in the Devonian. However, it should be pointed out that *Mooreoceras* is very similar externally to *Bradfordoceras* of the Conewango, and some species referred to *Bradfordoceras* may eventually prove to be representatives of *Mooreoceras* in higher beds of the Devonian. Both *Mooreoceras* and *Pseudorthoceras* pass upward into the Pennsylvanian with a thinning of the siphonal deposit as the only constant change.

In the Cayuta shale *Cayutoceras* appears, which is set apart from *Dolorthoceras* and the *Dolorthoceratinæ* by the double deposits of the siphon. *Bradfordoceras* is so far known only from the Conewango group of the Devonian, where it is represented by eleven species in one of which several variants have been recognized. It is probable that some of these variants may prove to be specifically distinct when they are known from better material. The genus is doubtfully present in the underlying Chadakoin shales, uppermost Conneaut. It has not been recognized in the Mississippian.

It would appear from what has been reviewed so far that the Middle Devonian development of the Pseudorthoceratidæ is characterized by deviations of form and ornament, while the Upper Devonian is largely characterized by variation of internal structure. Apparently the development of the Cayutoceratinæ is confined to the Penn-York embayment. The other subfamilies are very poorly represented above the Nunda stage in New York, and must have spread to other areas.

The American Mississippian is poor in Pseudorthoceratidæ. As noted above, Miller and Furnish have referred several species to *Mooreoceras*. An abundant cephalopod fauna from the St. Louis limestone of Greencastle, Indiana has failed to yield a single pseudorthoceroid. *Dolorthoceras* has been recognized from the Rockford limestone, and *Mooreoceras* from the Salem limestone in Indiana. The evidence suggests, by the rarity of specimens and the few species, that the major development of the Pseudorthoceratidæ was not centered in America, but rather that these forms represent occasional strays entering from other associations.

In spite of the little European material available for this study and the paucity of published illustrations of sections of European Mississippian orthoceracones, it has been possible to recognize several of the genera in the Mississippian of Belgium and Ireland, including *Dolorthoceras, Adnatoceras* and *Mooreoceras.* It appeared at first that the Pseudorthoceratidæ were largely a static family in Mississippian time, but it has since been possible to recognize two new generic types, *Paraloxoceras* and *Bergoceras*. *Paraloxoceras* of the Visé limestone is derived from *Mooreoceras* by the development of radial canals and an increase in the convexity of the siphuncular segments. *Bergoceras* is merely a cyrtoconic *Paraloxoceras.* Possibly, as was pointed out above, *Poterioceras,* which is present in both the European and American Mississippian, belongs to the Dolorthoceratinæ of the Pseudorthoceratidæ. The investigation of the Mississippian faunas of

Europe will probably bring to light other representatives of the family. The investigation of American Mississippian orthoceracones is hampered by scarcity of material and poor preservation of internal features.

In the Pennsylvanian the persistent genera, *Dolorthoceras, Adnatoceras, Pseudorthoceras and Mooreoceras* reappear. *Pseudorthoceras,* although represented by only a single recognized species, is probably the most abundant form, and appears to have attained a world wide distribution by Pennsylvanian time. *Mooreoceras,* thus far recognized only in the Pennsylvanian of America, attains considerable variety and abundance, especially in the Kansas City group of the Middle Pennsylvanian. The only exclusively Pennsylvanian genus so far known is *Euloxoceras,* represented by two species, both from America. Both *Pseudorthoceras* and *Dolorthoceras* become cosmopolitan in Pennsylvanian time, and are known from Asia as well as from America. Dr. Teichert[145] has recently informed me of the presence of *P. knoxense* in the Artinskian, basal Permian, of Australia. The family is not as yet known to extend higher.

In general, it is apparent that externally simple forms are long lived. *Dolorthoceras* has a range from the Middle Devonian through the greater part, at least, of the Pennsylvanian. *Adnatoceras* is not far behind, extending from the Hamilton stage of the Middle Devonian through to the Pennsylvanian. *Pseudorthoceras* and *Mooreoceras* extend from the Upper Devonian through the Pennsylvanian, and the former extends into the Permian. In contrast to this group of simple forms is the vast array of short lived genera. *Sceptrites* characterizes the Ulsterian. *Fusicoceras, Cryptorthoceras, Palmeroceras* and *Geisonoceroides* are confined to the Hamilton. *Spyroceras* and *Diagoceras* extend from the Middle into the Upper Devonian, although only into its lower portion where other faunal elements are of Middle Devonian origin. *Petryoceras,* which is unique in its ornament, is confined to a small zone and region in the Sherburne sandstones of the Nunda stage of the Upper Devonian. The Cayutoceratinæ appear to be confined to the Upper Devonian of New York and Pennsylvania.

Likewise *Paraloxoceras* and *Bergoceras* of the Mississippian are relatively short lived and not widely distributed.

At present the evidence seems to suggest that the Pseudorthoceratidæ entered the Penn-York embayment in Lower Devonian time, and that they were confined rather closely to that region until Upper Devonian time. With the penetration of the Pseudorthoceratidæ into the Naples association, the fauna becomes potentially world wide in distribution. The Dolorthoceratinæ and Pseudorthoceratinæ were largely crowded out of the New York region by the swift but short lived development of the Cayutoceratinæ.

However, it must be remembered that while the present available evidence suggests such a conclusion, the evidence is still very incomplete. The recognition of the Pseudorthoceratidæ depends upon internal features of a type which have only recently come into their own, and the internal structure of many

145 *Fide litt.*

orthoceracones is still unknown.[146] For that reason, the picture of the development of the family presented above is built upon the present published evidence, and will doubtless be subjected to considerable revision. Consequently the conclusions, or rather hypotheses, presented above may be subject to considerable revision upon further study. They will at least serve to crystallize the present knowledge and serve as a basis for revision.

STRATIGRAPHIC LIST OF SPECIES

LOWER DEVONIAN

HELDERBERGIAN

Anastomoceras mirabile Flower, n. sp., New Scotland limestone (?)
A. rudis (Hall). New Scotland limestone
A. (?) longicameratum (Hall). New Scotland limestone (?)

ORISKANIAN

Dolorthoceras parlenense (Williams). Moose River sandstone, Maine.

MIDDLE DEVONIAN

ULSTERIAN

Onondaga Limestone.—
Dolorthoceras rudicula (Hall)
Sceptrites sceptrum (Hall)
S. carteri Flower, n. sp.
Spyroceras (?) thoas (Hall)
S. geneva (Clarke)

Columbus Limestone.—
Sceptrites claviformis Flower, n. sp.
S. obliquus Flower, n. sp.

ERIAN

Hamilton Stage, Cherry Valley Limestone.—
Diagoceras aptum (Hall)
Palmeroceras fustis (Hall)
Spyroceras geneva (Clarke)

146 During publication of this paper I have received a letter from Dr. Schindewolf who, in response to my request, presents a brief summary of his observations on Pseudorthoceratidæ in Europe. He has recognized the family not only from the Mississippian and Upper Devonian, but from the Middle Devonian of the Eifel region and the Silurian. No new generic types, however are mentioned. Whether the Silurian forms are related to *Virgoceras,* which is here regarded as outside the family but ancestral to it, must await the appearance of Dr. Schindewolf's results.

Hamilton Stage, Stafford Limestone.—
Spyroceras incarceratum (Clarke)
S. staffordense (Clarke)

Hamilton Stage, Skaneateles Shale and Limestone.—
Dolorthoceras tersum (Hall)
D. telamon (Hall)
D. exile (Hall)
D., sp.
Spyroceras crotalum (Hall)
S. nuntium (Hall)
S. nuntioides (Clarke)
Adnatoceras spissum (Hall)

Hamilton Stage, Ludlowville of Lake Erie Section.—
Dolorthoceras revertum Flower, n. sp.
Spyroceras, sp.
S. nuntium (Hall)
Geisonoceroides woodæ Flower, n. sp.
G. cylindicum Flower, n. sp.
G. aulax (Hall)
Fusicoceras eriense Flower, n. sp.
Cryptorthoceras productum Flower, n. sp.

Hamilton Stage, Undifferentiated.—
Dolorthoceras bebryx (Hall)
Spyroceras cælamen (Hall)
S. idmon (Hall)
S. thestor (Hall)
S. lima (Hall)

UPPER DEVONIAN

SENECAN SERIES

Tully Limestone Stage.—
Dolorthoceras solitarium Flower, n. sp.
Diagoceras tullium Flower, n. sp.
Adnatoceras wellsi Flower, n. sp.
A cooperi Flower, n. sp.
A. cryptum Flower, n. sp.
Spyroceras (three undescribed species)
S. oppletum Flower, n. sp.

Nunda Stage, Ithaca Fauna.—
Dolorthoceras (?) cayuga (Hall)
Spyroceras cf. nuntium (Hall)
S. pertextum (Hall)

Geisonoceroides (?) anguis (Hall)
Petryoceras thyestes (Hall)
P. atreus (Hall)

Nunda Stage, Naples Fauna.—
Dolorthoceras elegans Flower, n. sp.
Adnatoceras naplense Flower, n. sp.
A. clarkei Flower, n. sp.
Pseudorthoceras senecum Flower, n. sp.
P. anomalum, Flower, n. sp.

CHAUTAUQUAN SERIES

Chemung Stage.—
Cayutoceras casteri Flower, n. sp.
Mooreoceras bradfordoides Flower, n. sp.
M. ruedemanni Flower, n. sp.

CONEWANGO SERIES

Venango Stage.—
Dolorthoceras palmeræ (Flower and Caster)
Bradfordoceras transversum Flower and Caster
B. sinuatum Flower and Caster
B. gomphoides Flower and Caster
B. hector (Hall)
B. consortale (Hall)
B. expositum (Hall)
B. multicameratum Flower and Caster
B. ignotum Flower and Caster
B. moderatum Flower, n. sp.
B. giganteum Flower, n. sp.
B. fusiforme Flower, n. sp.

MISSISSIPPIAN

AMERICAN

Dolorthoceras icarus (Hall). Rockford limestone
D., sp., Salem limestone
Mooreoceras, sp., Salem limestone
M. chouteauense (Swallow)
M. (?) pettisense Miller and Furnish
M. cliftonense Miller and Furnish

EUROPEAN

Dolorthoceras goldfussianum (de Koninck). Visé limestone, Belgium

Adnatoceras cf. neglectum (de Koninck). Tournai limestone, Belgium
Paraloxoceras konincki Flower, n. sp. Visé limestone, Belgium
Bergoceras antilope (de Koninck). Visé limestone, Belgium
Moorecceras (?) hindei Foord. Mountain limestone, Ireland

PENNSYLVANIAN

Dolorthoceras circulare Miller
Adnatoceras ciscoënse Miller, Dunbar and Condra
Pseudorthoceras knoxense (McChesney)
Mooreoceras normale Miller, Dunbar and Condra
M. tuba Miller, Dunbar and Condra
M. bakeri Miller, Dunbar and Condra
M. angusticameratum Miller, Dunbar and Condra
M. conradi Newell
Euloxoceras greeni Miller, Dunbar and Condra
E. milleri Flower, n. sp.

CONCLUSIONS

I. MORPHOLOGICAL

1. The deposits of the cameræ and siphuncle are laid down upon the surfaces of specialized secreting tissues, functional mantles, similar to the mantles which secrete the shell wall and the septa. On structural grounds the connecting ring appears to be mesodermal and to be laid down within the tissues.

2. The tissues of the cameræ and siphuncle may be traced through similar cycles of (1) areal growth without differentiation of tissues, (2) development of secreting surfaces, (3) increase in surface and folding and invagination of the tissue, sometimes with resorption, and regional differentiation of secretion of calcareous deposits terminating in a cessation of deposition.

3. Cessation of deposition of the cameral and siphonal deposits appears to be controlled by the axial gradient in generalized forms.

4. In the Pseudorthoceratidæ the continuous lining within the siphuncle serves to sever the connection between the cameral mantle and the rest of the organism, thereby controlling the extent of development of the cameral deposits. This is advantageous, as is shown by the development of such a lining in the Ordovician in the Westonoceratidæ, Troedssonoceratidæ, Discosoridæ and Stereoplasmoceratidæ, and in the Devonian in the Pseudorthoceratidæ.

5. Deposits may have had originally an excretory function, but have been modified to serve a hydrostatic function. The apical concentration permits the orthoceracone with air-filled cameræ to occupy a horizontal position; further the

weighted tip of the shell permits effective hyponomic swimming. The concentration of deposits on the venter serves to orient the conch with the venter beneath. Thus orthoceracones with deposits were capable of a nektonic or even a planktonic existence.

6. Orthoceracones without deposits may have occupied a vertical position, or may have lived horizontally with little or no gas in the cameræ.

7. The relation of color bands to the dorsum or venter is at present not conclusive. In most instances the complemental filling of the internal mold by calcite dictates the region of the conch on which color bands are preserved, and for that reason they are commonly found only on one side of the shell.

8. In generalized orthochoanitic orthoceracones of the Silurian there is a continuous surface of secretion of deposits in the phragmocone, partly in the siphuncle and partly in the cameræ. It is conceivable that all other types may have been derived by the upsetting of this relation, permitting excessive development of cameral or siphonal deposits with numerous variations and specializations.

9. The relationships of tissues within the phragmocone and their deposits are of great systemic value, inasmuch as they reflect fundamental physiological and morphological conditions.

10. The cameral deposits are bilaterally symmetrical. Details of lobation are specific. They have not as yet been used in the definition of genera, which purpose is served by the siphonal deposits, but in many instances they appear to be constant in generic or higher groups.

11. On the basis of siphonal deposits, siphuncular outline, and gross features of the shell a total of eighteen genera of Pseudorthoceratidæ are recognized.

12. Orientation even of fragmentary shells is possible on the basis of the continuous ventral conchial furrow which corresponds to the ventral aponeurotic bands of *Nautilus*, or the dorsal discontinuous septal furrow.

II. SYSTEMATIC

1. In the ontogeny of the siphuncle and annulosiphonate deposits the Pseudorthoceratidæ show indications of a derivation from the Orthoceratidæ (in the old sense) in Silurian time.

2. The cyrtochoanitic cephalopods are polyphyletic isomorphs and the term cyrtochoanitic is useful for descriptive purposes, but is without taxonomic value.

3. Even with the present incomplete data the genetic sequence of genera corresponds to a remarkable degree with the appearance of the genera in the stratigraphic column. The family can be traced from the Silurian ancestors through the development of most of the generic types in Devonian time, to the disappearance of the family in the early Permian.

4. The development of the family is orthogenetic in regard to (1) the development of a thin continuous siphuncular lining from a series of thick annulosiphonate deposits, and (2) the development of expanded cyrtochoanitic segments. The Middle Devonian types are remarkable for divergence in form or ornament; the Upper Devonian types for modifications of the siphonal deposits.

5. Siphonal deposits in the Pseudorthoceratidæ are isomorphic with those of the Troedssonoceratidæ and Stereoplasmoceratidæ of the Ordovician, but differ in being of segmental origin. The deposits of the Cayutoceratinæ are almost perfect isomorphs of those of the Westonoceratidæ of the Ordovician.

PLATES

PLATE I (VOL. PL. 23)

(Due to slight reduction of the original plates from a width of 6½" to 6" all figures are slightly smaller than indicated in the explanation.)

EXPLANATION OF PLATE I (23)

Figure *Page*

1-3. *Pseudorthoceras senecum* Flower, n. sp. 142

Three views of the holotype: (1) dorso-ventral section of the specimen, with plane of section parallel to bedding; ×3; (2) fourth siphuncular segment from apical end, ×14; The siphonal deposit (white calcite) is thick against the ventral wall, on right. The two adjacent deposits shown on the opposite side of the siphuncle, have not completely joined on the dorsal wall. The deposit is developed more than usually apicad of the septal neck. (3) Second segment from apical end of the same speecimen, ×14. In this segment the siphonal deposit is only very meagerly developed on the dorsal wall. Pal. Res. Inst., No. 5858. Cashaqua shale, Naples, New York.

4. *Mooreoceras ruedemanni* Flower, n. sp. 149

Portion of the siphuncle of holotype, ×14. The venter is on the left. The light material in the siphuncle represents the organic deposit, which is present here only on the ventral side. See also pl. 7, fig. 3, and pl. 8, fig. 8. New York State Museum. Wellsburg monothem, from Austinville; Bradford County, Pennsylvania.

5. *Dolorthoceras* aff. *exile* 104

Dorso-ventral section through siphuncle, with venter on the right, ×14. The siphonal deposits are unlike those of typical *Dolorthoceras*, in their extreme ventral concentration. They resemble the Pseudorthoceratinæ, while the apparent differentiation into a calcareous (light) and a carbonaceous layer (dark) suggests the Cayutoceratinæ. Pal. Res. Inst., No. 5835. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

6. *Pseudorthoceras knoxense* (McChesney) 140

Cross section through a camera, about ×20. The siphuncle in the center shows mature siphonal deposits. Beneath the siphuncle the ventral sinus of the cameral deposits is seen. The two processes of the ventrolateral masses are asymmetrical and partially embrace the siphuncle. The cameral deposits show traces of the original structure, although the specimen is a calcite pseudomorph. Pal. Res. Inst. No. 5859. Hazelton Bridge limestone, Pennsylvanian of Indiana.

7. *Dolorthoceras palmeræ* Flower and Caster) 107

Enlargement of siphuncle of holotype, ×14. Horizontal section. Antioch College, Yellow Springs, Ohio. Panama horizon. Upper Devonian, Erie County, Pennsylvania.

8. *Adnatoceras spissum* (Hall) 122

Hypotype: siphuncular segments showing outline and the *Michelinoceras* stage of the siphonal deposits, ×14. Pal. Res. Inst., No. 5840. Pompey member, Hamilton stage, from Pratt's Falls, Onondaga County, New York.

9. *Dolorthoceras solitarium* Flower, n. sp. 105

Holotype: enlargement of siphuncle, ×14. See also pl. 4, fig. 6. U. S. National Museum, No. 96778. West Brook member, Tully limestone, basal Upper Devonian, from the northeast corner of the Pitcher Quadrangle, New York.

10. *Cayutoceras casteri* Flower, n. sp. 156

Holotype: enlargement of 5th and 6th siphuncular segments of the dorso-ventral section; venter on left, showing differentiation of siphonal deposits into two layers, one dark and rich in organic matter, the other light and calcareous, about ×9. Pal. Res. Inst., No. 5855. Cayuta shale, Upper Devonian, two miles south of Owego, New York. See pl. 3, fig. 1.

11. *Dolorthoceras tersum* (Hall) 97

Hypotype: portion of phragmocone showing siphuncular outline, ×3. See also pl. 8, fig. 6; pl. 9, fig. 8. Pal. Res. Inst. No. 5831. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

Note:—*In these and all succeeding longitudinal sections the conventional orientation is retained, with the adoral end at the top.*

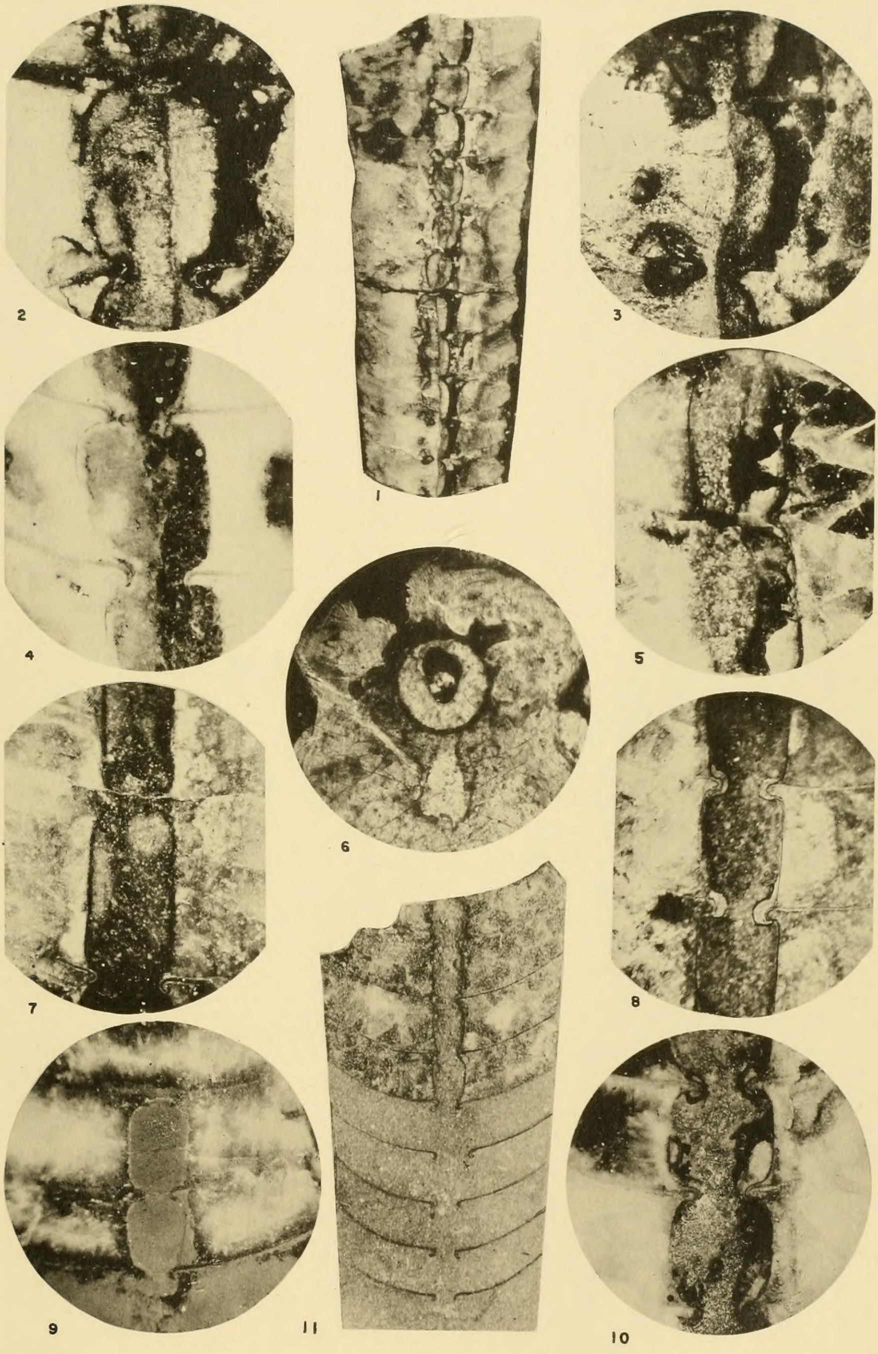

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PLATE II (VOL. PL. 24)

EXPLANATION OF PLATE II (24)

Figure *Page*

1-3. *Euloxoceras milleri* Flower, n. sp. 130

(1) Dorso-ventral section of holotype showing siphuncular outline, siphonal and cameral deposits, ×9. Venter on right. Pal. Res. Inst., No. 5851. (2) Dorso-ventral section of paratype at a slightly later stage. Pal. Res. Inst., No. 5852. (3) Enlargement showing detail of siphuncular outline of the preceding, ×15. See also figs. 12-14 below. Jackborough limestone, Caddo formation, Canyon group, Pennsylvanian, Jack County, Texas.

4-7. *Mooreoceras*, sp. 152

(4) Late siphuncular segments, 6th and 7th from adoral end of specimen, showing typical fusiform outline of *Mooreoceras*; no siphonal deposits; ×16. (5) 12th and 13th segments from adoral end. The siphuncular outline is of the *Dolorthoceras* type. Siphonal deposits present only on ventral side (right) ×16. (6) 20th and 21st segments from adoral end. The *Anastomoceras* type of siphuncular outline, containing well defined deposits on the venter (right) ×16. (7) The complete specimen sectioned dorso-ventrally, of which the above three figures are enlargements, ×1½. University of Cincinnati, No. 22251. Kansas City group, Pennsylvania, Kansas City, Missouri. Note:—The white lining of cameræ and siphuncle is of inorganic nature. The siphonal deposits show in black in the adapical end; the cameral deposits, developed only on the venter, do not show in this figure.

8-9. *Dolorthoceras*, sp. 103

Early stages of unidentifiable fragmentary specimens, showing early siphuncular stages ×14. (8) Siphuncular outline intermediate between the *Anastomoceras* and the *Michelinoceras* types. Siphonal deposits of *Michelinoceras* type. (9) Siphuncular outline of the neanic *Dolorthoceras* type; siphonal deposits of *Michelinoceras* type. Pal. Res. Inst., Nos. 5836, 5837. Delphi member, Hamilton stage, Delphi Falls, Onondaga County, New York.

10. *Dolorthoceras telamon* (Hall) 100

Enlargement to show form of ephebic siphuncular segments, ×10. No siphonal deposits are developed. Same specimen as pl. 4, fig. 10. Pal. Res. Inst., No. 5831. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

11. *Pseudorthoceras knoxense* (McChesney) 140

Dorso-ventral section with venter on right, showing outline of ephebic siphuncular segments and the concentration of deposits first on the venter ×10. Pal. Res. Inst., No. 5859. Hazleton Bridge limestone, Pennsylvanian, southwestern Indiana.

12-15. *Euloxoceras milleri* Flower, n. sp. 130

(12) Holotype, lateral aspect. (13) Holotype, dorsal aspect. (14) paratype, lateral aspect. Pal. Res. Inst., Nos. 5851, 5852. Jackborough limestone, Pennsylvanian, Jack County, Texas.

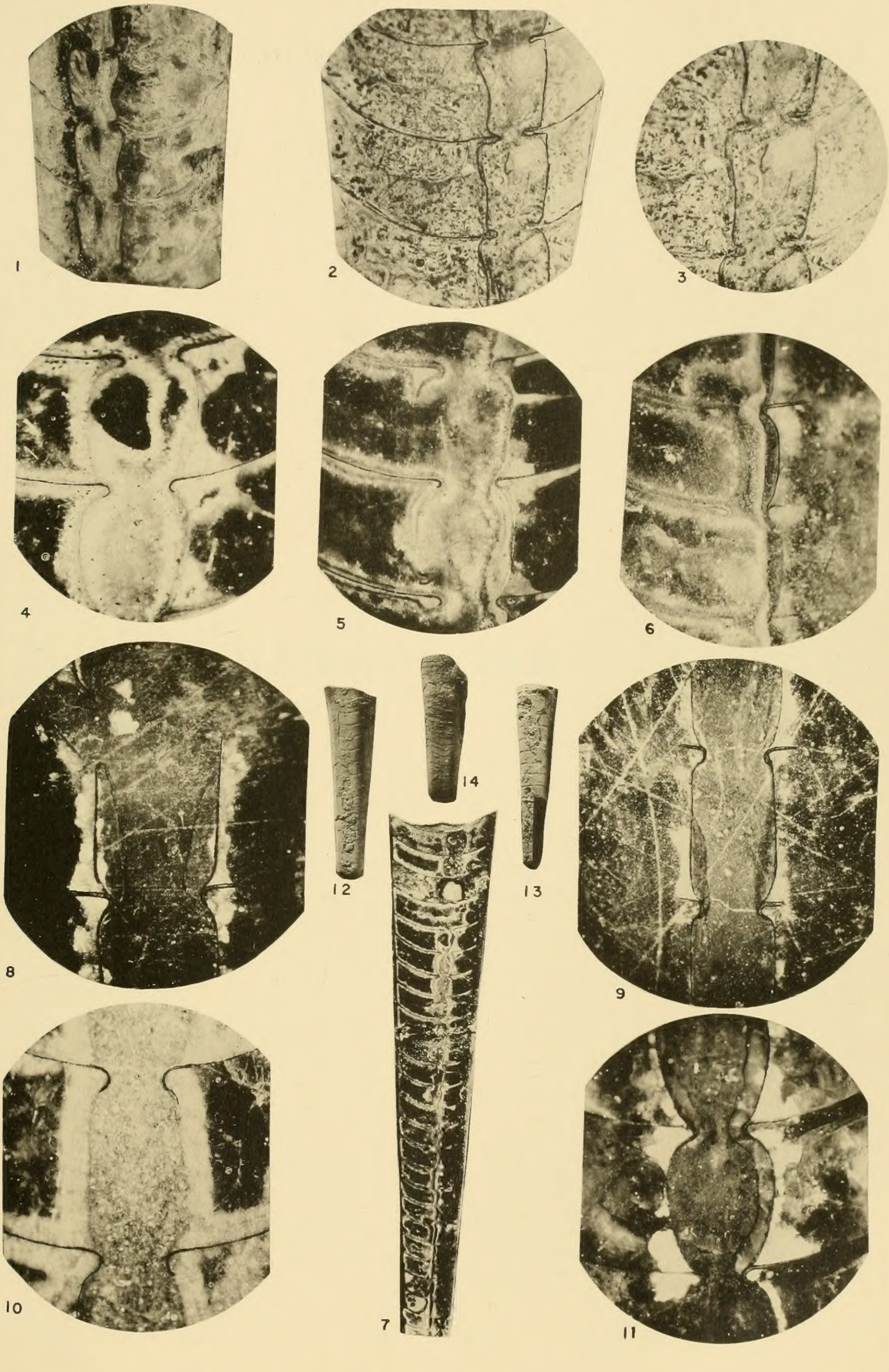
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PLATE III (VOL. PL. 25)

EXPLANATION OF PLATE III (25)

Figure *Page*

1. *Cayutoceras casteri,* Flower, n. sp. 156

   Holotype: vertical section with venter on right ×2½. Septa are destroyed on right, but the margins of episeptal and hyposeptal deposits can be traced. See also pl. 1, fig. 10. Pal. Res. Inst., No. 5855. Cayuta shale, Upper Devonian, two miles south of Owego, New York.

2. *Adnatoceras naplense* Flower, n. sp. 126

   Holotype: Note the phenomenon of the incomplete internal mold shown in the siphuncle indicating invasion of mud (black) from adoral end, ×2/3. New York State Museum. Cashaqua shale, Naples, New York. (Courtesy of New York State Museum.)

3. *Virgoceras palemon* (Barrande) 162

   Reproduction of Barrande's original illustration of a dorso-ventral section through the phragmocone showing pseudorthoceroid siphonal deposits, ×1. Venter on left. Étage E, Middle Silurian, from Locknow, Bohemia.

4. *Geisonoceroides woodæ* Flower, n. sp. 113

   Natural section through phragmocone of holotype, ×1½. See also pl. 7, fig. 10, pl. 9, fig. 4. Buffalo Museum of Science. No. E9013. *Pleurodictyum* bed, Wanakah member, Ludlowville shale, Hamilton stage, Middle Devonian; shore of Lake Erie, Wanakah, Erie County, New York.

5. *Geisonoceroides cylindricum* Flower, n. sp. 115

   Holotype, ×1 Buffalo Museum of Science, See pl. 6, fig. 7. Tichenor Limestone, Hamilton stage. Smoke Creek, Windom, New York.

6. *Geisonoceroides* cf. *cylindricum* Flower, n. sp. 115

   Margin of aperture of living chamber apparently complete. Referred with doubt to the preceding species, ×1. Buffalo Museum of Science. Tichenor limestone, Hamilton stage, South Shore cliffs, on Lake Erie, Erie County, New York.

7. *Bradfordoceras giganteum* Flower, n. sp. 160

   Holotype, ×½. Ventral aspect. Buffalo Museum of Science. A sandstone of the Conewango series, Upper Devonian, Allegheny State Park, New York.

8. *Bradfordoceras moderatum* Flower, n. sp. 159

   Holotype, ×1. Ventral aspect. Buffalo Museum of Science. Lewis Run sandstone, Conewango series, Upper Devonian, Lewis Run, Bradford County, Pennsylvania.

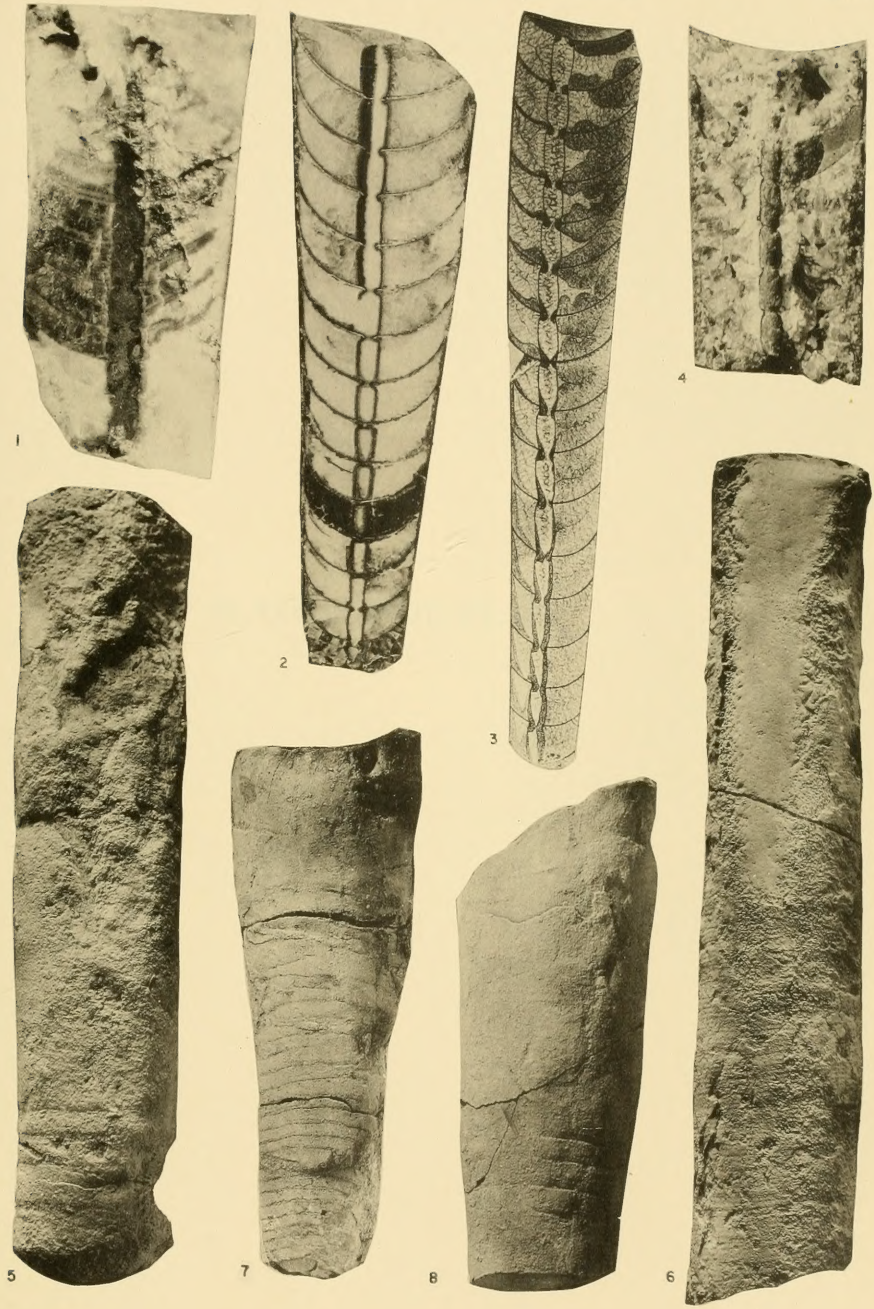
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PLATE IV (VOL. PL. 26)

EXPLANATION OF PLATE IV (26)

Figure *Page*

1-4. *Adnatoceras wellsi* Flower, n. sp. 123

Holotype: (1) ventral aspect, ×1; (2) left lateral aspect ×1; (3) adoral aspect ×1; (4) vertical section through siphuncle, ×2½. Pal. Res. Inst., No. 5849. West Brook member, Tully limestone, basal Upper Devonian, Borodino, New York.

5. *Mooreoceras*, sp. 151

Section of phragmocone showing siphuncular outline, ×2½. Section horizontal. Pal. Res. Inst., No. 5865. Salem limestone, Middle Mississippian, University of Indiana campus, Bloomington, Indiana.

6. *Dolorthoceras solitarium* Flower, n. sp. 105

Holotype: horizontal section, ×1½. See also pl. 1, fig. 9. U. S. National Museum, No. 96778. West Brook member, Tully limestone, basal Upper Devonian, northeast corner of the Pitcher quadrangle, New York.

7. *Diagoceras tullium* Flower, n. sp. 92

Holotype: ventro-lateral aspect, ×1. Pal. Res. Inst. No. 5875. Loose block of Tully limestone, basal Upper Devonian, east shore of Cayuga Lake near Portland Point, New York.

8. *Adnatoceras spissum* (Hall) 122

Hypotype: adapical portion, vertical section with venter on left, about ×2½. Pal. Res. Inst., No. 5840. See pl. 7, fig. 10. Pompey member, Hamilton stage, Middle Devonian, Pratt's Falls, Onondaga County, New York.

9. *Pseudorthoceras anomalum* Flower, n. sp. 143

Holotype: vertical or nearly vertical section, venter on left. Slightly more than ×2. The sides of the specimen are weathered below the plane of the section, obscuring the form of the cameral deposits. New York State Museum. Parrish limestone, Upper Devonian, Naples, New York.

10-11. *Dolorthoceras telamon* (Hall) 100

Hypotypes: (10) dorso-ventral section, venter on right ×2; Pal. Res. Inst. 5831. (11) exterior of phragmocone of another specimen ×1. Pal. Res. Inst. No. 5830. See pl. 2, fig. 10; pl. 8, figs. 9-10. Both specimens are from the Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

12-15. *Cryptorthoceras productum* Flower, n. sp. 132

Holotype: (12) adoral aspect, venter above. ×½; (13) ventral aspect, showing hyponomic sinus ×½; (14) adoral portion right lateral aspect ×1; (15) left lateral aspect ×½. Buffalo Museum of Science, No. E9013. Ludlowville shale, Hamilton stage. Bay View Creek. Erie County, New York.


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PLATE V (VOL. PL. 27)

EXPLANATION OF PLATE V (27)

Figure *Page*

1. *Anastomoceras mirabile* Flower, n. sp. 89

Holotype: internal mold ×1. See also figs. 4-7, below. Pal. Res. Inst., No. 5870. Helderbergian, New Scotland or Kalkberg (?) limestone. Lower Devonian, Albany County, New York.

2-3. *Anastomoceras rudis* (Hall) 90

Hyptoype: (2) weathered surface ×1; (3) enlargement of anterior end after grinding, showing traces of siphuncular outline and cameral and siphonal deposits ×1½. Pal. Res. Inst., No. 5872. New Scotland limestone, Lower Devonian, Schoharie, New York.

4-7. *Anastomoceras mirabile* Flower, n. sp. 89

Holotype: (4) anterior two siphuncular segments, showing *Dolorthoceras* type of siphonal deposits ×2; (5) enlargement of apical five siphuncular segments after grinding, ×2; (6) enlargement of septal foramen of fig. 4, showing septal necks and the point of fusion of adjacent deposits, ×14; (7) second segment from apex showing the wall of the central canal and the radial pillars, ×14. See fig. 1, above.

8,9. *Paraloxoceras konincki* Flower, n. sp. 153

Holotype: (8) dorso-ventral section showing siphuncle and siphonal deposits ×2½; (9) enlargement of a segment of the same specimen, showing the septal necks, the broad area of adnation and the radial canal penetrating the siphonal deposit, ×14. Univ. of Cincinnati, No. 22253. Visé limestone, Mississippian, Visé, Belgium.

10,11. *Bradfordoceras transversum* Flower and Caster 158

Holotype: (10) section of siphuncle, showing character of siphonal deposits, ×5; (11) enlargement, showing septal neck, area of adnation and connecting ring, ×20. Pal. Res. Inst., No. 5014. Lewis Run sandstone, Upper Devonian, Lewis Run, Bradford County, Pennsylvania.

12. *Mooreoceras*, sp. 152

Dorso-ventral section through siphuncle showing siphonal deposits on the ventral side (left) only. Note absence of connecting ring on dorsum. Ventral wall of conch lost. About ×6. Collection of Mr. Richard Schweers, Univ. of Indiana. From the Winterset limestone, Kansas City group, Pennsylvanian, Kansas City, Missouri.


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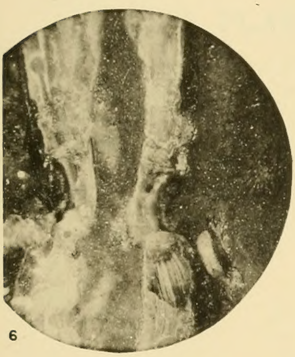
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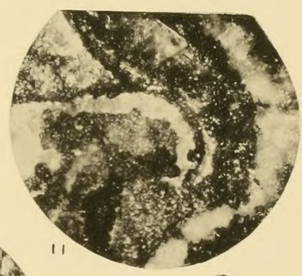
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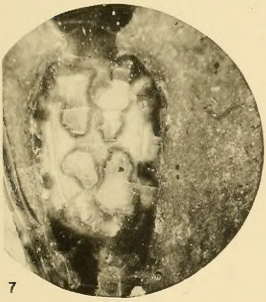
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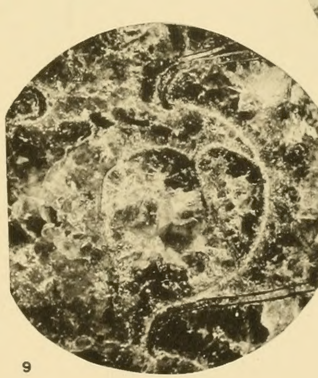
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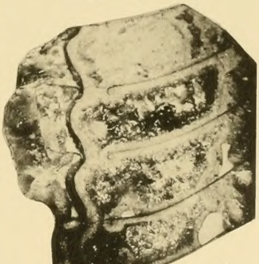
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PLATE VI (VOL. PL. 28)

EXPLANATION OF PLATE VI (28)

Figure *Page*

1. *Sceptrites obliquus* Flower, n. sp. 136

Holotype: lateral aspect, ×3/5. U. S. National Museum, No. 37228. Columbus limestone, Middle Devonian, Columbus, Ohio.

2. *Sceptrites claviformis* Flower, n. sp. 136

Holotype: lateral aspect, ×3/5. U. S. National Museum, unnumbered. Columbus limestone, Middle Devonian, Columbus, Ohio.

3. *Sceptrites sceptrum* (Hall) 134

Holotype: lateral aspect, ×½. Buffalo Museum of Science. Onondaga limestone, Middle Devonian, Federal Stone quarry, Lancaster, Erie County, New York.

4. *Sceptrites carteri* Flower, n. sp. 135

Holotype: lateral aspect, ×3/5. Collection of Mr. Alec Carter, to be deposited in the Buffalo Museum of Science. Onondaga limestone, Middle Devonian, Federal Stone quarry, Erie County, New York.

5,6. *Fusicoceras eriense* Flower, n. sp. 137

Holotype: (5) right lateral aspect; (6) ventral aspect. Siphuncle retouched. ×1. Buffalo Museum of Science. Wanakah member, Hamilton stage, Middle Devonian; Idlewood cliff, shore of Lake Erie, near Eighteen Mile Creek, New York.

7. *Geisonoceroides cylindricum* Flower, n. sp. 115

Holotype: lateral aspect, ×1. Buffalo Museum of Science. Wanakah member, Hamilton stage, Middle Devonian; Wanakah, New York. See also pl. 3, fig. 4; pl. 9, fig. 4.

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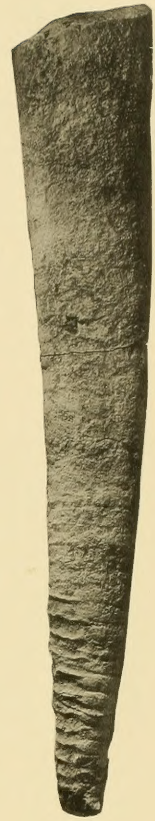

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PLATE VII (VOL. PL. 29)

EXPLANATION OF PLATE VII (29)

Figure *Page*

1. *Fusicoceras eriense* Flower, n. sp. 137
Holotype: enlargement of horizontal section through siphuncle ×2. See also pl. 6, figs. 5-6. Buffalo Museum of Science. Wanakah member, Hamilton stage, Middle Devonian; Wanakah, New York.

2. *Adnatoceras clarkei* Flower, n. sp. 127
Holotype: section, slightly oblique from horizontal, ×1½. New York State Museum. Parrish limestone, Senecan series, Upper Devonian; Naples, New York.

3. *Mooreoceras ruedemanni* Flower, n. sp. 149
Holotype: vertical section, venter on left, ×2½. The ventral wall is missing owing to solution of both the shell wall and the cameral deposits. See pl. 1, fig. 4; pl. 18, fig. 8. New York State Museum. Wellsburg Monothem, Chautauquan series, Upper Devonian.

4. *Dolorthoceras exile* (Hall) 98
Phragmocone and base of living chamber of a mature individual, ×1. Pal. Res. Inst., No. 5826. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

5,6. *Adnatoceras cooperi* Flower, n. sp. 124
Holotype: (5) showing proportions, ×½; (6) vertical section showing position and outline of siphuncle, ×1½. U. S. National Museum, No. 90758. West Brook member, Tully limestone, Upper Devonian, Tully, New York.

7. *Mooreoceras bradfordoides* Flower, n. sp. 147
Holotype: sectioned surface, slightly inclined from the vertical. Venter on right, ×2½. Cameral deposits are clearly shown, as are the outline and deposits of the siphuncle. New York State Museum. Wellsburg monothem, Upper Devonian, Austinville, Bradford County, Pennsylvania.

8. *Geisonoceras teicherti* Flower, n. sp. 164
Holotype: phragmocone sectioned showing organization of cameral and siphonal deposits, ×2/3. See pl. 9, fig. 19. New York State Museum. Onondaga limestone, Middle Devonian, western New York.

9. *Bradfordoceras fusiforme* Flower, n. sp. 161
Holotype: dorsal aspect, ×1. Buffalo Museum of Science. Lewis Run sandstone, Upper Devonian, Lewis Run, Bradford County, Pennsylvania.

10. *Adnatoceras spissum* (Hall) 122
Hypotype: a nearly complete unflattened individual, ×1. The basal portion of the living chamber has been partially restored. Ventral aspect. Pal. Res. Inst., No. 5840. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

11. *Geisonoceroides woodæ* Flower, n. sp. 113
Holotype: living chamber, dorso-lateral aspect. Buffalo Museum of Science, No. E9013. *Pleurodictyum* bed, Wanakah, member, Hamilton stage, shore of Lake Erie, Wanakah, Erie County, New York.

12. *Anastomoceras rudis* (Hall) 90
Hypotype: largest and most complete specimen observed, ×1. The living chamber extends for an additinoal 40 mm. in a flattened condition. Pal. Res. Inst., No. 5873. New Scotland limestone, Lower Devonian, Catskill, New York.


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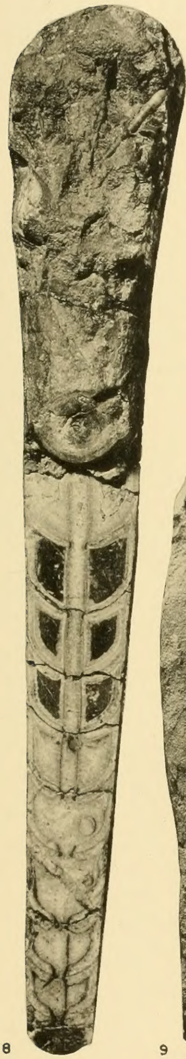
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PLATE VIII (VOL. PL. 30)

EXPLANATION OF PLATE VIII (30)

Figure *Page*

1. *Adnatoceras* cf. *neglectum* (de Koninck) 127
Vertical section, venter on left, ×2½. Univ. of Cinicinnati, No. 8776. Tournai limestone, Lower Mississippian, Tournai, Belgium.

2,3. *Dolorthoceras revertum* Flower, n. sp. 102
Holotype: adoral portion, ×1; (2) right lateral aspect, ×1; (3) dorsal aspect, ×1. Buffalo Museum of Science. *Pleurodictyum* bed, Wanakah member, Hamilton stage, Wanakah, New York.

4. *Adnatoceras cryptum* Flower, n. sp. 125
Holotype: right lateral aspect, ×1. Pal. Res. Inst., No. 5850. West Brook member, Tully limestone, Upper Devonian, Borodino, New York.

5. *Pseudorthoceras knoxense* (McChesney) 140
Vertical section through phragmocone, showing the relatively thin cameral deposits (light) on the dorsum (left), ×10. The deposits on the venter are poorly defined owing to crystallization (they are largely dark). Siphonal deposits are mature. Pal. Res. Inst., No. 5860. Hazelton Bridge limestone, Pennsylvanian, southwestern Indiana.

6. *Dolorthoceras tersum* (Hall) 97
Internal mold of living chamber, showing position and character of internal constriction, ×1. Pal. Res. Inst., No. 5823. Delphi member, Hamilton stage, Delphi Falls, Onondaga County, New York.

7. *Dolorthoceras exile* (Hall) 98
Hypotype: living chamber preserving the aperture, ×1. Pal. Res. Inst., No. 5827. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

8. *Mooreoceras ruedemanni* Flower, n. sp. 149
Holotype: lateral aspect, ×1. Same specimens as pl. 1, fig. 4; pl. 7, fig. 3. New York State Museum. Wellsburg monothem, Chemung stage, Upper Devonian, Austinville, Bradford County, Pennsylvania.

9,10. *Dolorthoceras telamon* (Hall) 100
Hypotype: living chambers, ×1; (9) a partially crushed specimen showing the surface of the shell; (10) an internal mold of a mature living chamber showing the gerontic constriction. Pal. Res. Inst., Nos. 5831, 5832. Delphi member, Hamilton stage, Delphi Falls, Onondaga County, New York.

11. *Pseudorthoceras knoxense* (McChesney) 140
Hypotype: dorso-ventral section not attaining the siphuncle, showing the extent of the ventro-lateral masses (on left side) beyond the middle of the cameræ, ×1½. Pal. Res. Inst., No. 5864. Jackborough limestone, Pennsylvanian, Jack County, Texas.

12. Cf. *Pseudorthoceras knoxense* (McChesney) 140
A pyritized specimen showing the septal furrow, ×1½. Pal. Res. Inst., No. 5863. Pennsylvanian, southern Indiana. Exact locality and horizon unknown.

13. *Striacoceras typus* (Saemann) 13
Ventral aspect showing the three conchial furrows unusually well developed, ×1. New York State Museum, No. 12381/2. Cherry Valley limestone, Hamilton stage, Manlius, New York.

14. *Virgoceras cancellatum* Flower, n. sp. 162
Longitudinal section of adoral end of specimen, showing the pseudorthoceroid deposits in the orthochoanitic siphuncle, ×2½. Laurel limestone, Middle Silurian, Westport, Indiana. Pal. Res. Inst., No. 5868.

15. *Petryoceras thyestes* (Hall) 117
Hypotype: flattened individual showing characteristic appearance and proportions, ×½. Pal. Res. Inst., No. 5845. See also pl. 9, fig. 13. Sherburne sandstone, Upper Devonian, Taughannock Falls, New York.


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PLATE IX (VOL. PL. 31)

(*Continued from following page*)

Figure *Page*

17. *Dolorthoceras tersum* (Hall) 97

Hypotype: a nearly complete internal mold of a living chamber showing the internal constriction. Pal. Res. Inst., No. 5824. Delphi member, Hamilton stage, Delphi Falls, Onondaga County, New York.

18. *Dolorthoceras revertum* Flower, n. sp. 102

Holotype: section through siphuncle showing early (*Michelinoceras*) stage of the siphonal deposits, ×14. Buffalo Museum of Science, unnumbered. See also pl. 8, figs. 2-3. *Pleurodictyum* beds, Hamilton stage, from Wanakah, New York.

19. *Geisenoceras teicherti* Flower, n. sp. 164

Holotype: enlargement of apical end of the specimen shown on pl. 7, fig. 8, showing the continuity of the surface of the cameral and siphonal deposits, and the carbonaceous band representing the original position of the cameral mantle, in part. New York State Museum. Onondaga limestone, ''western New York.''

EXPLANATION OF PLATE IX (31)

Figure *Page*

1. *Sceptrites sceptrum* (Hall) 134
Hypotype: dorso-ventral section through siphuncle, ×1; same specimen as pl. 6, fig. 3. Onondaga limestone, Federal Stone quarry, Erie County, New York.

2,3. *Nautilus pompilius* Linnæus 12-15
(2) enlargement of a portion of the base of the ventral side of the living chamber showing the aponeurotic bands (below), which disappear beneath the mural part of the septum (central zone of figure) above which the free part of the septum is seen. (3) enlargement of dorsal wall of phragmocone, with septa removed, showing the septal furrows, ×2. Univ. of Cincinnati, No. B4390. Recent; Phillipine Islands.

4. *Geisonoceroides woodæ* Flower, n. sp. 113
Holotype: lateral aspect, natural color, showing traces of the original color pattern, slightly less than ×1. Note abrupt but irregular transition from dark on the left to light on the right of the specimen at the center. Buffalo Museum of Science, No. E9013. Same specimen as pl. 7, fig. 10 and pl. 3, fig. 4. *Pleurodictyum* bed, Wanakah member, Hamilton stage, from the shore of Lake Erie, Wanakah, New York.

5-7. *Bergoceras antilope* (de Koninck) 155
Reproduction of De Koninck's original figures. (5) exterior, ×½; (6) section, ×1; enlargement of two cameræ, ×½. (7) Visé limestone, Mississippian, from Visé, Belgium.

8. *Dolorthoceras tersum* (Hall) 97
Ventral aspect of a living chamber preserving the hyponomic sinus, ×1. Pal. Res. Inst., No. 5834. Pompey member, Hamilton stage, Pratt's Falls, Onondaga County, New York.

9,10. *Spyroceras oppletum* Flower, n. sp. 112
Holotype: (9) exterior, showing ornament, ×2½; (10) section through siphuncle, showing neanic *Dolorthoceras* siphuncular outline and siphonal deposits of the *Dolorthoceras* type, ×14. Pal. Res. Inst., No. 5867. West Brook member, Tully limestone, Upper Devonian, from Borodino, New York.

11,12. *Spyroceras crotalum* (Hall) 111
Hypotype: (11) phragmocone directly orad of the portion sectioned, ×1; (12) enlargement of early siphuncular segments showing neanic *Dolorthoceras* type of outline. Pal. Res. Inst., No. 5866. Pompey member, Skaneateles shale, Hamilton stage, Pratt's Falls, Onondaga County, New York.

13. *Petryoceras thyestes* (Hall) 117
Hypotype: a flattened specimen showing the ornament characteristic of the genus, ×2. Pal. Res. Inst., No. 5847. See also pl. 8, fig. 15. Sherburne sandstone, Upper Devonian, Taughannock Falls, New York.

14. *Cayutoceras casteri* Flower, n. sp. 156
Paratype: weathered section, showing siphuncular outline, ×1. Pal. Res. Inst., No. 5856. From a coquinite in the Cayuta shale, Upper Devonian, Bainbridge, New York.

15,16. *Dolorthoceras elegans* Flower, n. sp. 105
Holotype: (15) adoral portion of phragmocone, ×1; (16) vertical section through siphuncle, with venter on left, showing outline and the greater development of siphonal deposits on the venter, ×14. New York State Museum. Parrish limestone, Upper Devonian, from Naples, New York.

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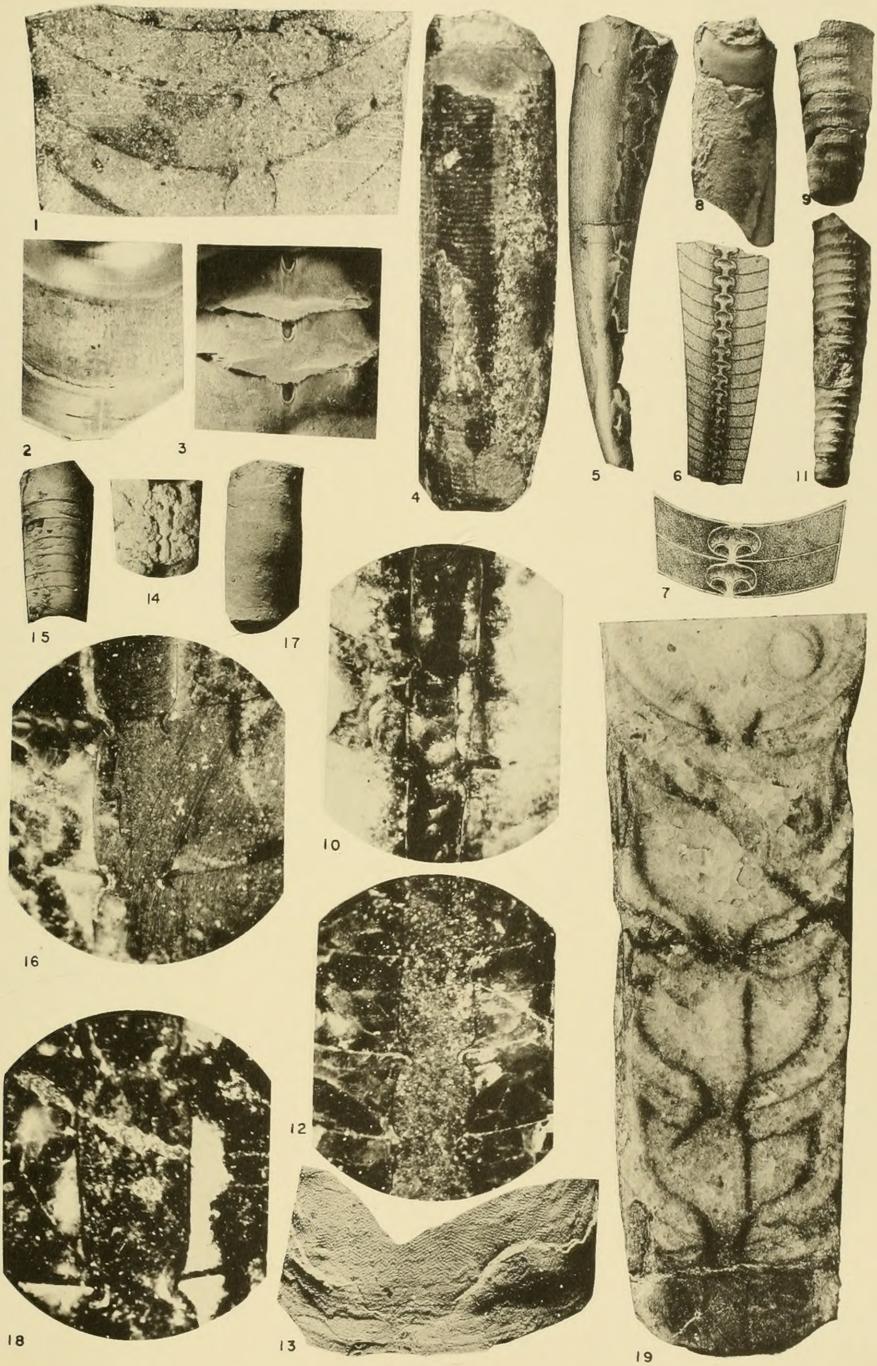
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PALAEONTOGRAPHICA AMERICANA

Volume 2, No. 11

PALAEONTOGRAPHICA AMERICANA

ILLUSTRATED CONTRIBUTIONS

TO THE

INVERTEBRATE PALEONTOLOGY

OF

AMERICA

VOL. II

NO. 11 : NOTES ON GIANT FASCIOLARIAS

By

BURNETT SMITH

September 23, 1940

Palæontological Research Institution
Ithaca, New York, U. S. A.

NOTES ON GIANT FASCIOLARIAS

By

Burnett Smith

INTRODUCTION

The purpose of the present paper is to call attention to some of the phases shown by *Fasciolaria papillosa* Sowerby (1825, Appendix p. xvi), or, as it is more generally cited in American literature, *F. gigantea* Kiener (1840, p. 5, pls. 10, 11). A synonymy for *F. papillosa* may be found in Strebel (1911, p. 7) who also gives a critical discussion of the nomenclatorial history of the species (1911, pp. 7-16). This will not be duplicated here for it is deemed sufficient to note only the more important points in the history.

Under the name *Fasciolaria gigantea* the species is well known as a prominent member of the Recent marine fauna of the southeastern United States. The same name occurs in lists of Pleistocene, Pliocene, and even Miocene fossils.

The work has been made possible through facilities granted and help given by officials of the Academy of Natural Sciences of Philadelphia, the Wagner Free Institute of Science of Philadelphia, Cornell University, and the Paleontological Research Institution at Ithaca, New York. The writer is indebted to Doctor Charles W. Merriam of Cornell and to Mrs. Ethel Ostrander Smith of Skaneateles, New York for the photographs used in illustrating the paper, to Professor Ernest Rice Smith of De Pauw University and to Mrs. Anastasia Beatty of Skaneateles, New York for use of interesting comparative material.

PRELIMINARY REMARKS

No figure accompanied the original description of *Fasciolaria papillosa* but it is safe to assume that Reeve (1847, pl. I, figs. 1a, 1b; pl. VII, figs. 1c, 1d) was acquainted with the species and that his figures of it are correct. Reeve, however, apparently did not appreciate the identity of Kiener's species with that of Sowerby for he figures a larger individual in the same work (pl. V, fig. 12) but calls it *F. gigantea*. The younger Sowerby (1887, p. 9, pl. I, figs. 1, 2; pl. IV, figs. 29, 30), on the other hand, understood this identity although he retained the specific name *gigantea*.

The figures so far cited are regarded as illustrating what is here called the typical phase of the species *Fasciolaria papillosa*. The term covers slightly more than does Strebel's "Hauptform". In this phase the protoconch is first smooth and then axially ribbed. It is followed by conch whorls which are gently angulated, spiralled, and provided with swollen axial ribs. These latter soon shorten and pass into nodelike concentrations in the shoulder region which in this paper will be called nodes for simplicity. The majority of shells retain these nodes more or less intact to the end of the ontogeny (Strebel, 1911, pls. I, II, figs. 8-11). Exceptionally a specimen exhibits a decided degeneration of these nodes late in the ontogeny. It is believed, however, that such degeneration can be viewed as an individual variation. The "Forma" *elongata* of Strebel (1911, pl. II, figs. 11, 11a), which he treats as the equivalent of a subspecies of *F. papillosa*, appears to conform to the typical phase in sculpture. The more slender proportions and other features noted by its author would hardly seem to warrent a separation from the typical phase. Old shells in the typical phase of *F. papillosa* are heavy and strong and the anterior canal is usually marked off from the outer lip of the aperture by a rather abrupt bend.

Even with some repetition it now becomes advisable to attempt an evaluation of the foregoing sculpture development in the typical phase of *Fasciolaria papillosa*. The swollen axial ribs are youthful conch features which pass into the nodes of maturity. As already mentioned this is a process of shortening and concentration in the shoulder region and the retention of these nodes into old age appears to be normal for the typical phase of the species. The loss or degeneration of this sculpture in the typical phase may well be regarded as a gerontic feature which perhaps in some cases is exaggerated by injury. In the ontogenetic sequence then the nodeless or virtually nodeless condition, if present, follows a noded stage. One is therefore justified in regarding individuals, races or subspecies with vestigial nodes or without nodes in the later whorls as having been derived from ancestors in which the nodes persist in force to the end of shell growth.

So much for this important ontogenetic change which may occur in the typical phase of *Fasciolaria papillosa*. It is now in order to inquire into cases in which the change just outlined seems widespread or has a semblance of being a racial character. Forms showing a racial tendency of this kind are very properly to be regarded as offshoots from the typical phase of *F. papillosa* or from some well-noded ancestor of the same.

The best known of these derivatives will now be taken up.

Many years ago Philippi (1851, p. 121, pl. III, fig. 2) published, with credit to Jonas, the species *Fasciolaria reevei*. In this form the nodes are well developed on the youthful and early adult whorls but later they degenerate markedly and may even be lost completely leaving the last whorl or more merely rounded and spiralled. The form is also more slender, smaller, and lighter than the typical *F. papillosa* and its secondary spirals are prominent. Its general characters are shown by Tryon's (1881, pl. 60, fig. 17) copy of the original figure and also by Strebel's (1911, pl. III, fig. 12) illustration but the nodes may be much less persistent than these figures indicate. The relationships and history of the "Forma" *reevei* are reviewed by Strebel (1911, pp. 7, 9, 15, 16) who gives it the equivalent of subspecific rank within the species *F. papillosa*. He appears inclined to question the determination of certain specimens assigned to *reevei* by Pilsbry (1902, p. 552). The present writer has examined Pilsbry's material and regards his determination as correct. Further notes on this subspecies have been made by Johnson (1919, p. 46; 1934, p. 127) and it is now recognized as one of the components of the fauna of the Gulf Coast of Florida (Perry, 1940, pp. 153, 154).

Turning now to the fossils it is found that Mansfield (1930, p. 63, pl. 6, fig. 1) describes the Florida Miocene subspecies *Fasciolaria gigantea harveyensis,* here called *F. papillosa harveyensis.* The measurement given for the type (73.5 mm., altitude) suggests an immature individual. Mansfield's text makes no mention of the degeneration of nodes so these may be persistent features. In such a case relationship to the typical phase would appear to be close.

Most paleontologists, however, seem to have followed Dall (1890, p. 104; 1892, pp. 212, 230, 231) in their treatment of the giant Fasciolarias. In this way peculiarities in sculpture have been viewed as individual characters and nothing more.

The present writer, on the other hand, is convinced that the institution of two additional subspecies of *Fasciolaria papillosa* will serve a useful purpose and descriptions of the following forms are now put forward.

SYSTEMATIC DESCRIPTION

Fasciolaria papillosa duplinensis Smith, n. subsp.

Plate 1, figures 1, 2

Summary of Characters.—Shell large but relatively slender for a giant *Fasciolaria;* whorls about eleven; initial whorl apparently smooth and rounded; earlier conch whorls gently angulated, spiralled, and noded; about eight nodes to a whorl; later conch whorls lose first the nodes and then the angulation and become rounded in outline. Their sculpture finally is virtually restricted to spiral ridges and depressions crossed by fine growth lines. Spirals very weak on anterior canal which is marked off from the outer lip of the aperture by a relatively gentle curve. Columellar plaits oblique and, as usual in *Fasciolaria,* three in number. The distal (most anterior) plait is the largest; the next, intermediate in size, and the barely perceptible proximal plait is smallest.

Holotype.—Cornell University, Ithaca, New York. Paleontological Collection catalogue number 32325. Miocene (Duplin formation). Strickland's marl pit near Magnolia, Duplin County, North Carolina. Collected in 1898 by the late Charles A. Tracy. Long dimension about 279 mm.

Early whorls of holotype gone, the whorls present being regarded as assignable to whorls 6 to 11 inclusive. Whorl 6 and about one-half of whorl 7 gently angulated, spiralled, and noded. Nodes disappear at about the middle of whorl 7. After disappearance of nodes the angulation persists but for less than one volution. By the middle of whorl 8 the angulation has also disappeared. From here on to the end of whorl 11 the volution shape is rounded and the sculpture consists of spiral ridges and depressions crossed by the fine growth lines already noted.

Paratypes.—Three specimens from Joseph Willcox, numbered 2578 in the Wagner Free Institute of Science of Philadelphia. They are from the Miocene of Duplin County, North Carolina and can safely be assigned to the Duplin formation. The specimens have respectively long dimensions of about 37, 181, and 205 mm. Together they give information on the early whorls (1 to 5) which are lacking in the holotype. The initial whorl is not well preserved but is rather surely smooth and rounded. Whorl 2 early exhibits a gently angulated, noded, and spiralled condition which persists into whorl 4 where the nodes begin to degenerate. The nodes disappear somewhat earlier than in the holotype. As in the holotype the angulation persists longer than do the nodes. The specimen of intermediate size has relatively sharp spirals but it is believed that this represents no more than individual variation. Other paratypes are found in the paleontological collection of the Academy of Natural Sciences of Philadelphia. Two specimens are numbered 1185 and are stated to be Miocene. Their long dimensions are approximately 114 and 130 mm. A specimen numbered 778 has a long dimension of about 138 mm. The Academy specimens are all from Joseph Willcox and the locality is given as Duplin County, North Carolina. No geological horizon is furnished for number 778 but there can be no doubt that it, together with the other Academy specimens, came from the Miocene Duplin formation. These shells show earlier whorls gently angulated, noded, and spiralled. There follows then a spiralled stage at first gently angulated but very soon becoming rounded.

Fasciolaria papillosa duplinensis can be rather confidently placed in the group of giant Fasciolarias typified by *F. papillosa* Sowerby. It differs from the typical phase in its apparently smaller size and more slender proportions and especially in its early loss of nodes. A loss or virtual loss of nodes may occur as a herontic feature in some individuals of the typical Recent form and also as a racial character in the Recent *F. papillosa reevei* but, as far as observed, such loss comes later in the ontogeny than it does in *F. papillosa duplinensis*. *F. papillosa duplinensis* is closest to the form immediately to be described (*F. papillosa acmensis*) but is lighter and more slender and has its anterior canal less abruptly marked off from the outer lip of the aperture.

Fasciolaria papillosa acmensis Smith, n. subsp.

Plate 1, figures 3, 4

Summary of Characters.—Shell large, heavy, and relatively stout; whorls ten to somewhat over eleven; first and second whorls unknown; earlier conch whorls gently angulated, noded, and spiralled; about seven nodes to a whorl. Later conch whorls lose first the nodes and then the angulation and become rounded in outline their sculpture, except for an occasional vestigial node, being finally restricted to spiral ridges and depressions crossed by fine growth lines. Spirals relatively weak on anterior canal which is marked off from the outer lip of the aperture by a rather abrupt bend. Columellar plaits three, oblique, the distal (most anterior) the largest, the next intermediate in size, and the proximal plait smallest and hardly recognizable as a ridge.

Holotype.—Paleontological Research Institution, Ithaca, New York. Number of specimen 3908. Number 871 Smith collection. Pliocene (Waccamaw formation). Acme, North Carolina. Collected by Burnett Smith in 1925. Long dimension about 251 mm.

Early whorls of holotype gone, those present being regarded as assignable to whorls 3 to 11. Whorl 3 is too poorly preserved for study. About one-fourth of whorl 11 is present. Whorls 4, 5, 6, and much of whorl 7 are gently angulated, noded, and spiralled. During the first half of whorl 8 the angulation disappears. From here on the volution shape is rounded and, except for a few vestigial nodes, the sculpture consists of spiral ridges and depressions crossed by fine growth lines.

Paratypes.—A specimen approaching the holotype very closely is included in the collection of Professor Ernest Rice Smith of De Pauw University. It came from the lower Neuse River in North Carolina and is presumably Pliocene in age. The earlier whorls are broken away. The portion well preserved is estimated as composed of whorl 10 and about one-half of whorl 11. Whorl 9 is represented in fragmentary condition except for its columellar portion. The specimen differs from the holotype in having its anterior canal less strongly marked off from the outer lip of the aperture. This may be due to an injury whose repair caused the anterior canal to be slightly deflected in its later growth. The specimen, when complete, must have been somewhat larger than the holotype.

Another paratype is in the collection of the Academy of Natural Sciences of Philadelphia. The number is 141471. This single specimen, probably of Pliocene age, was collected by H. H. Du Bois and Chas. M. B. Cadwalader in 1926 from the beach at Hatteras, North Carolina. It is unfortunately much worn and nodes, if any, have disappeared from the early whorls. Coarse flat spirals approach those of the holotype. Growth lines indicate a constricted anterior canal as in the holotype. The last volution is estimated as composed of part of whorl 11 with possibly a third of whorl 12. The specimen, in its present condition, has a long dimension of about 364 mm. In life it must have been a fine example of the subspecies.

In sculpture, in early degeneration of nodes, and in the rounded outline of its later whorls *Fasciolaria papillosa acmensis* is very close to *F. papillosa duplinensis*. On the other hand, its heavy and relatively ventricose shell and constricted anterior canal make an approach to similar features of the typical Recent noded phase of *F. papillosa*. In a sense then *F. papillosa acmensis* is morphologically intermediate between the Duplin Miocene form and the Recent noded or typical phase of *F. papillosa*. It is not believed, however, that this apparent sequence can be explained as an evolutionary one. Persistance of nodes in the ontogeny appears to be a primitive feature. Their loss or degeneration seems not primitive. The evidence is interpreted as pointing to an ancestor or ancestors with nodes persisting virtually intact to the end of shell growth. It is not unlikely that Miocene and Pliocene forms were derived independently from some fully noded ancestor perhaps indistinguishable from the Recent typical phase or perhaps resembling *F. papillosa harveyensis* Mansfield.

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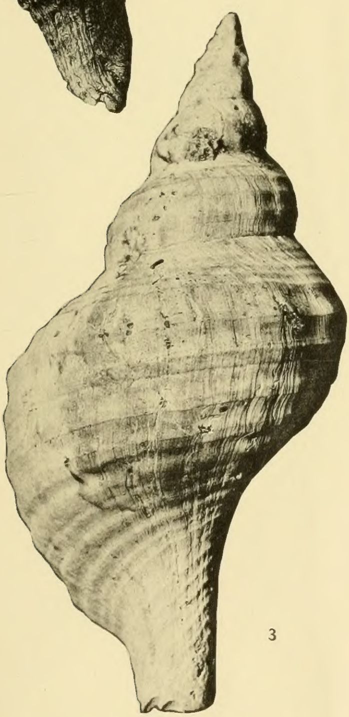
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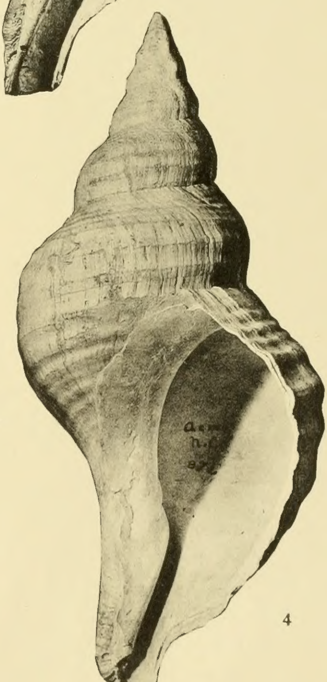
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VOL. II

NO. 12: THE TITUSVILLIIDÆ; PALEOZOIC AND RECENT BRANCHING HEXACTINELLIDA

By
Kenneth E. Caster

August 18, 1941

Palæontological Research Institution
Ithaca, New York, U. S. A.

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THE TITUSVILLIIDAE: PALEOZOIC AND RECENT BRANCHING HEXACTINELLIDA

By

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ABSTRACT

The Titusvilliidæ, chief family of Paleozoic branching Hexactinellida, is redefined in accordance with new Paleozoic findings and broadened somewhat in its scope to embrace certain Recent sponges. New subfamilies, Titusvilliinæ and Sclerothaminæ, are described to accommodate the two divisions of the family. All titusvilliid sponges are reviewed; the validity of the genera *Titusvillia* and *Armstrongia* is established by reëxamination of type materials; a new species, based on the supposed, 1920, hypotype of Clarke's *Armstrongia oryx*, is proposed, and the oldest representatives of the family are described as new genus and species, *Protoarmstrongia ithacensis*, from the Upper Devonian (Senecan) Enfield shale of Central New York State. The facieology of the Paleozoic representatives of the family is briefly summarized. The rare existing species is reviewed and the basis for the new family assignment is taken up in some detail.

FOREWORD

Branching siliceous sponges are great rarities in present seas and have been even rarer constituents of fossil faunas. Whether, in either instance, they are as rare as the published accounts would indicate, is worth a moment's speculation. The sampling of the statozoic fauna of the ocean depths has hardly begun, and to assume that the sporadic and fortuitous findings of the early expeditions give an accurate picture of the deeper benthos is fatuous. Of the nodose branching Hexactinellida here under consideration, a mere handful of specimens is known, but in view of new evidence of their racial antiquity as well as the element of chance in the few discoveries already made, their widespread presence in the Indo-Pacific, at least, seems quite probable.

Until 1939, only two types of fossil branching siliceous sponge were known. Of these *Ozospongia johnstoni* Clarke (1918) is apparently a unique and bona fide member of the Dictyospongiidæ* from the New York Devonian and need not concern us here. *Armstrongia oryx* (Clarke) (1918, 1920) and the better known close relative *Titusvillia drakei* Caster (1939, 1939A) are the nucleus of a very different morphologic group for which a separate family rating (Titusvilliidæ) has seemed advisable (Caster, 1939).

Clarke's *Armstrongia oryx* material came from the Upper Devonian (probably Conneaut stage, Chautauquan series) of Erie County, Pennsylvania, and the type material of *Titusvillia* from the Lower Mississippian (Waverlyan) of Crawford County, Pennsylvania. When the Mississippian material was described, the intimation was made that the family would probably turn up over a much wider

* Family spelling as recommended by Caster, 1939.

area and through a considerable thickness of Devonian and Mississippian strata, at least in the Penn-York Embayment. In a note accompanying Caster's supplementary paper (1939A), the presence of the family in the Conewango series, which intervenes between the horizons of the two previous discoveries, was pointed out, and the wider areal extent in the Mississippian confirmed. At that time, also, the discovery of much older representatives of the family in the Senecan series (Enfield formation) in the Finger Lakes area of New York was announced.

Why these fossils, now proving to be relatively common in the Upper Devonian-basal Mississippian terrane, should have been so long coming to light is probably best explained by the history of virtually every specimen thus far described. They were all originally collected as "worm burrows," and as such have received very little attention, since it has long been the common belief that these fossils are too lacking in distinguishing characteristics to make them stratigraphically useful. That they were collected at all has always been due to their curiously nodose condition. Now that their meaning is clear, they promise to be most useful indices. Each discovery in a new horizon has yielded a new species or genus. At the present time, the Paleozoic representatives of the family are known from Central New York to the inlier region of southwestern Pennsylvania, northwest to the extreme corner of Pennsylvania and apparently as far west as southern Illinois where certain scraps of characteristic nodose "burrows" have been found. Further details of the preservation and ecology of these organisms appear elsewhere in this report under the head of Environment.

SYSTEMATIC ANALYSES

Class **HEXACTINELLIDA** Schmidt

Order **HEXASTEROPHORA**

Family **TITUSVILLIIDÆ** Caster, 1939

The Titusvilliidæ is a family of exceptionally thick-walled hexactinellid and hexasterophorous sponges in which three zones of spicular differentiation are present in the mesenchymal region of the body wall. Near or at the exterior is a cortical or trabecular seminet (dictyonalia). The main mesenchymal or sarcode zone is usually represented among fossils by a mud filling of a felted spicular region in which remnants of a space-lattice of syncytial spicules are present. This probably represents the zone of flagellate chambers in the sponge wall. Lining the spongocœl* or paragastric cavity is an inner reticulum, the subgastral trabecular net, which is commonly intact. The central spongocœl (Hyman, 1940) in Paleozoic forms is usually somewhat less than half the diameter of the whole sponge. This cavity may be filled with spicular fibers, as in the existing representatives. The sponge grows as a supercolony of many branches which may be regularly disposed. Nodes or cups characterize all but the earliest representatives of the family. Titusvilliid morphology is summarized by text figure 1, below.

* Spongocœl [more properly derived spongiocœle]—*Eds.*

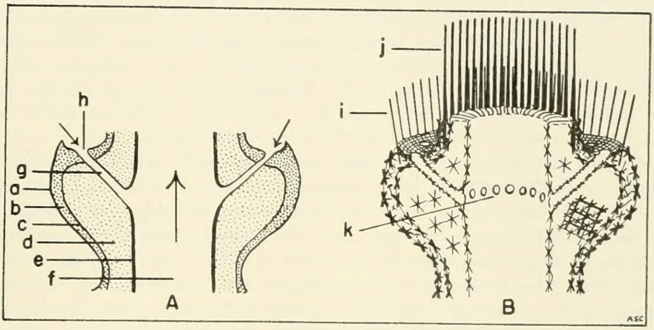

Fig. 1. Morphology of a titusvilliid sponge illustrated by an idealized vertical section through *Titusvillia drakei* Caster. A.—Generalized relationships of the wall of the sponge. B.—Inferred distribution of spicules over parts shown in A. *a*—External cortical semi-reticulum or trabecula of suppressed hexactins. This is the "epidermal" skeleton which preserved the form of the sponge in the fossil state to a greater or less degree. *b*—Outer limonitic zone of the fossil, apparently representing a pyritized spicular mat probably having at the core a trabecular space-lattice. Apparently this was the principal supporting skeleton of the fossil sponges. *c*—Surface of the "inner mold" of the fossil sponges. Probably represents the beginning of a free jelly, mesenchyme zone in the sponge; some suggestions of lattice work throughout, and many spicules. *d*—Main mass of the inner filling which was occupied by the inhalent tubules and probably by flagellate chambers. *e*—Paragastric trabecular net, or subgastric reticulum, which presumably lay at the contact of the mesenchyme and the gastral layer; this may be the homologue of the reticulum of the dictyosponges. *f*—Common canal, paragastric cavity or gastrocœle; main aporrhysal system. *g*—Inhalent, epirrhysal canal which no doubt led into flagellate chambers in life; walls apparently lined with a trabecular net of canalaria spicules. These regular radial canals known only in *Titusvillia* and *Armstrongia*. *h*—Inhalent pores as developed in *Titusvillia* and *Armstrongia* (?). *i*—Marginal prostalial spicules on rim of the cuplike nodes. *j*—Hypothetical oscular prostalia. *k*—Position of paragastric pores. All structures inferred from the holotype of *Titusvillia*. Proportions as in type material. Drawing by Anneliese S. Caster. After K. E. Caster, 1939.

Probably the most distinguishing character of the titusvilliid sponges, aside from their branching habitus, is the extraordinarily thick mesenchyme with its triple zonation of the spicular elements. This zonation is usually discernible even in mediocre specimens preserved in as unsatisfactory a medium as coarse sandstone. The thick-walled condition contrasts with the dictyospongiids wherein almost diaphanous walls were the rule. Only in very exceptional instances were Hall and Clarke (1898) able to detect a spicular space-lattice in their sponges, and this of no great thickness. The paragastrium or spongocœl of the dictyosponges was very large and cuplike, nearly of the same dimensions as the entire animal, unless we are gravely misled by the fossil evidence. In the fossil titusvilliids the paragastrium was a narrow tube in the center of the organism, often less than half the diameter of the whole sponge.

As might be expected, only indefinite suggestions of pore distribution and inhalent canal plan appear in the fossils. In *Titusvillia*, as seen in figure 1, there is fairly satisfactory evidence of a concentration of pores on the upper cup surfaces which, in turn, appear to have been connected with radial canals leading into the paragastric tube. This condition may have prevailed in *Armstrongia*, but the evidence is not so convincing as for the Mississippian genus. In the new genus and species to be described below, no such localization of pores or radial canals seems to have existed. Admittedly the preservation of the oldest form is less satisfactory than for *Armstrongia* and *Titusvillia*, but in the absence of regular nodes one would hardly expect a specialized epirrhysal system. Curiously, in the modern *Sclerothamnus*, where nodation is very complete, the parietal pores are diffuse. This is understandable only when it is recalled that its entire paragastrium is purportedly filled by an axial spicular rope, and all aporrhysal function of the paragastrium has apparently been foresworn in the interest of greater rigidity. As will come out in greater detail below, the most important difference between the Recent and Paleozoic representatives of the family lies in the invasion of the paragastrium by the skeletogenous elements of *Sclerothamnus*. Seemingly the gastral layer must be compensatingly distributed along the diffuse canal system in the body wall. *Armstrongia* and *Titusvillia* conform more closely to a primitive and traditional sponge plan. They no doubt suffered from inadequate support of their multibranched colonies, and lacked the resiliency which undoubtedly characterizes the modern derivatives. It is also questionable if the archaic tubular paragastrium of the Paleozoic sponges was not as hazardous as helpful in their neritic environment. This view is amplified in the ecologic discussion near the end of the paper.

Titusvilliidæ was proposed (Caster, 1939) as a monotypic, basal Mississippian family with the reservation (*idem*, p. 8) that *Ceratodictya oryx* Clarke (1918) of the Upper Devonian might be consanguineous when better known. This proved (1939A) to be an *ex post facto* prediction, since it was made in ignorance of Clarke's supplementary (1920) work on his species when he purported to establish its branching mode of growth, proposed for it the generic receptacle *Armstrongia*, and in all respects seems to have demonstrated its family relationship with *Titusvillia*. The oversight of *Armstrongia* was remedied by Caster (1939A) with a cursory comparison of the Mississippian and Devonian forms. The two genera seem to be warranted, but admittedly, had Clarke's genus been known, and if his implied relationships are correct, it should have received the patronymic. Partially compensating for the possible slight to Clarke is the fact that *Titusvillia* is far better known than *Armstrongia*. This is in part due to the nature of the material involved, but is largely attributable to Clarke's tacit assumption that *Armstrongia* was a dictyosponge. Certainly, had a new family been based on Clarke's description and illustration, it would have been most erroneously conceived, due to several fanciful assumptions on Clarke's part which only the reëxamination of his types brings out.

At this time the three genera, *Titusvillia* Caster (1939), *Armstrongia* Clarke (1920), and the new genus *Protoarmstrongia* Caster, their genotypes, and the new species *Armstrongia* (?) *clarkei* are the Paleozoic constituents of the family Titusvilliidæ. *Sclerothamnus clausii* of the Recent Indo-Pacific is apparently a living exponent of this ancient lineage. The morphologic differences between the Paleozoic and Recent representatives are of subfamily value.

Subfamily TITUSVILLIINÆ Caster, new

For the Paleozoic branching glass sponges of the titusvilliid pattern, the new subfamily TITUSVILLIINÆ is proposed. The characteristics of the new subfamily may be looked upon as an aggregate of the generic features of the three Paleozoic genera herein assigned to it: *Titusvillia* Caster, *Armstrongia* Clarke and *Protoarmstrongia* Caster, new. Text figure 1, above, summarizes the characters of the Titusvilliinæ, *ss.* Possession of a functional gastrocœle or paragastrium is the main morphologic distinction of the Titusvilliinæ. The systematic position of the existing sponge and its distinguishing characteristics are further discussed under the head of Biologic Relationships, below.

Generic criteria within the subfamily are visualized as: (1) variations in the mode of branching (whether regular or irregular); (2) frequency of branching; (3) shape of the individual nodes or cups; or (4) absence of them; (5) the consistency or inconsistency of any contour variations throughout the colony; and (6) the presence or absence of distal reorientation of the cups when linked with other features.

Genus TITUSVILLIA Caster, 1939

Genotype.—*Titusvillia drakei* Caster. Lower Mississippian (Tidioute shale), western Pennsylvania.

The genus *Titusvillia* was discussed in great detail in Caster's 1939 paper and therefore only an outline of essential characteristics is needed here. The original diagnosis brought out that the supercolony branches in a spiral manner at approximately 120° intervals from a "zigzag axis." The axis and branches are comprised of cup-shape nodes (as seen in text figure 2 and the plates of photographs in the 1939 paper). The cups are relatively constant in shape throughout the colony, but distally their orientation is reversed. An interpretation of this phenomenon was shown in text figure 3 (1939). Spicular generalizations were shown in text figure 1, (1939). Further generic details will come out in the comparison of *Titusvillia* and *Armstrongia* below, as they did also in part in the 1939A paper.

Titusvillia drakei Caster

Plate 4, figures 1-5

1939, Journal of Paleontology, vol. 13, No. 1, pp. 1-10; pl. 1, figs. 1-4; pl. 2, figs. 1-5; pl. 4, fig. 7; text figs. 1-3, 8.

This species is fully characterized in the original publication, and the diagnosis need not be reviewed here, except for the purpose of comparison with *Armstrongia*, below. The illustrations on Plate 4 are offered to further this comparison. They were originally presented in the description of *Titusvillia drakei* (1939).

Occurrence.—The holotype came from the Tidioute shale and sandstone member of the Lower Mississippian (Cussewago stage) exposed along Church Run in the village of Titusville, Pennsylvania. During the summer of 1939 new material was collected from the same formation along the Dennis Run road at Tidioute and on Yankee Bush Hill, just north of Warren, Pennsylvania. Titusvilliids, which were referred to this species when collected, have been found in the Knapp suite (just below the Tidioute member) at several points in McKean and Warren counties, Pennsylvania. The Knapp material now appears to represent a distinct variant, but better preserved specimens must be found before systematic description is warranted. Mr. Wilson M. Laird (personal communication, 1940) reports* finding titusvilliids in the Lower Mississippian (probably Knapp member of the Cussewago stage) in the inlier area of Chestnut and Laurel ridges in southwestern Pennsylvania.

Types.—Holotype No. 22130 in the University of Cincinnati Museum.

Genus **ARMSTRONGIA** Clarke, 1920

1920, New York State Museum Bulletin, Nos. 219-220, p. 143-146, pl. 1.

Genotype.—*Ceratodictya oryx* Clarke. "Upper Chemung (*i. e.* Chadakoin) six miles south of Erie, Pa." Parenthetical comment added.

Clarke's (1920) diagnosis of the genus *Armstrongia* is given below:

> In recently discussing the Devonian glass sponges, I described under the name of *Ceratodictya oryx* (N. Y. State Mus. Bull. 196, 1918, p. 180, pl. 2) a slim and strongly annulated form, expressing at the same time some hesitation in referring these short and simple twigs to the genus *Ceratodictya* which had been created some twenty years ago for the reception of much larger and more regularly developed reticula. Our knowledge of this sponge has been enlarged in a very interesting way through the acquisition of a slab of Chemung sandstone recently taken from the original locality of the species,† on the broad surface of which apparently two individuals of the sponge are laid out in impression, in what would seem to be approximately complete extent. While the structure of the branches indicates its specific identity with *C. oryx*, its extraordinary branching form and accessory structures show that this sponge has nothing to do generically with *Ceratodictya*.
>
> In the figure here presented of this slab the relief is given rather than the natural impression, the picture being made from a cast of the original. It will be seen that we have here to deal with a diffusely-branched sponge whose form and direction of branching is approximately determinable from the form of the annulation. These have a normal expression of ensheathing rings with their steeper slopes directed backward, or toward the root. This index is not easy to follow in all parts as occasionally the annulations show little difference in lower and upper curves. On this slab there seems to be more than one colony represented, possibly three in all; but one is conspicuously shown, displays the form of structure at the joints and indicates that branching is very diffuse. The surface of these annulated branches shows fine striations on the sandstone matrix in the inter-annular spaces, but little can be seen of spicular tufts projecting from the annuli.
>
> Other structures are indicated: Several of the branches show terminal sheaths or smooth conical extensions running out into a blunt truncated apex. Two or three of these are in place and several others are scattered over the surface of the slab. They suggest the non-reticulated tuft or undifferentiated felt of spicules which is common enough at the root of many living hexactinellids. The position of these, however, is obviously not basal. Position, mode of branching and some other features indicate that these sheaths or tufts are terminal

* While this paper was in press a preliminary report of Mr. Laird's work in southwestern Pennsylvania appeared, (Laird, 1941).

† Despite this statement, note that Clarke gives the original locality (1918) of *Ceratodictya oryx* as 6 miles south of Erie, Pa., whereas he reported this new material as coming from 9 miles south of Erie.

to the branches and represent compacted growth ends. This consideration, not very easy to substantiate perhaps among living sponges, is helped by the fact that the slab shows practically as many such sheaths as there are branches. Some are in place and some apparently detached but there are many more than the number of sponges would require as root-ends.

In addition to these structures the slab shows some flat concentric disks which would seem to be in all probability a part of these organisms. These disks are depressed at the center and their concentrically lined surface is like that of an epithecal base of a *Chaetetes* or *Pleurodictyum*. Such circular bases are not, however, foreign to the living glass sponges and the association makes it probable that these disks have served such a function here.

In seeking comparisons among the living Hexactinellids with this singular branching Devonian sponge we find a suggestive species in the *Sclerothamnus clausi* (Marshall) as depicted in Schulze's *Report on the Hexactinellida* of the Challenger Expedition (p. 337, pl. 98). To institute more closely this comparison between the two branching sponges the Challenger species is here copied. Here the annular tufts appear to be not always circular but at times continuous and spiral though the branching is unlike that of the Devonian species, but so seldom does branching occur that the two forms are comparable on that basis alone.

As we can no longer associate this species with the genus *Ceratodictya* it is now proposed to term this sponge *Armstrongia*, in recognition of the intelligent interest taken in the collection of these Devonian sponges, by Mr. E. J. Armstrong of Erie, Pa., and the notable additions to our knowledge of them which his specimens have contributed. This slab, which was found loose, is from the upper beds of the Chemung group, 9 miles south of Erie, Pa., and carries on its back abundant specimens of a large *Leiorhynchus*, probably *L. mesocostalis*.

In summary then, the morphologic features which Clarke recognized as specifically and generically important in his genus and species are: (1) "diffusely-branched" habitus; (2) annulations having the normal expression of ensheathing rings with their steeper slopes usually directed toward the base; (2a) occasionally the annulations show little difference in their upper and lower curves; (3) the surface of the annulated branches show "fine striations" (direction?) on the matrix in the interannular spaces; (4) suggestions of spicular tufts projecting from the annuli; (5) terminal felted sheath or growth-end running out into a blunt truncated apex occurring on the branches; (6) flat disks with a central, concentrically striated depression occur with the specimens and are interpreted as attachment disks.

Discussion.—Through the courtesy of the Director of the New York State Museum, Dr. C. C. Adams, the New York State Paleontologist, Dr. Winifred Goldring, and the Technical Assistant, Mr. Clinton F. Kilfoyle, latex molds of Clarke's types have been furnished. After a most careful study of the original materials the conclusion that Clarke's collections may not be conspecific seems inescapable. This means that we have the anomalous situation of a genus based almost entirely on morphologic characters present on material not conspecific with the genotype. The two collections presumably came also from different Devonian horizons.

What is *Armstrongia*? This question is answerable only on the basis of the genotype which is considered below. There is excellent chance that the genotype is a branching sponge in generic features similar to Clarke's 1920 material, but there is room for considerable doubt in the matter. Strictly speaking, *Armstrongia* is a receptacle for the two twiglike ceratodictyoid specimens described by Clarke as *Ceratodictya oryx*, and until branching habitus is established for that species by new materials from the type locality "six miles south of Erie," paleontology is stalemated in its investigation of *Armstrongia, ss.*

Let us assume as a working hypothesis that Clarke was correct in considering his 1918 and 1920 materials congeneric, and for the present accept the generic receptacle *Armstrongia* as he proposed it. However the nomenclature may work out, this fact is assured: there is a distinct titusvilliid genus represented in Clarke's 1920 material, and that genus is different from the Mississippian *Titusvillia* or the Senecan *Protoarmstrongia* later to be described in this report. Whether or not that genus is *Armstrongia, s.s.*, only time will tell.

With these assumptions in mind, how does Clarke's 1920 material agree with the foregoing generic description? In the first place, for Clarke to describe either the 1920 specimen or his drawing of it as "diffusely-branching" is misleading. The specimen appears to be regularly ramose in the titusvilliid manner; the branches appear to leave a zigzag axial portion at approximately 120° intervals, although the vertical component of the spire varies from place to place in the colony. The nodes of the 1920 specimen are intermediate in shape between *Armstrongia oryx* and *Titusvillia*. As Clarke indicated, they are variable and often asymmetrical. They do not attain a definite cup-shape, however, and do show a ceratodictyan crown duplication in many parts of the colony. The rubber molds fail to show the "fine striations" which Clarke mentions. The absence of any evidence of the reticular net in Clarke's material is disappointing. Nothing has been observed in the rubber molds which would support his view of spicular tufts protruding from the nodes, but no doubt this was the condition, since it would be in keeping with most fossil and Recent siliceous sponges.

The so-called "terminal felted sheaths" which Clarke made much of and showed in his 1920 figure (restoration) appear to be based on a misconception. No such structures apparently exist on the slab. In several instances small particles of the subgastral trabecula appear to protrude beyond the cortical net, but none bears any close similarity in form to the felted cones which Clarke showed. In nearly all specimens of the titusvilliid sponges, small sections of the paragastric net protrude beyond the external net, but never yet has a specimen been found which certainly shows the natural termination of a branch.

The "centrally depressed disks" which Clarke described from his 1920 slab may be attachment "buttons" as he suggested, but they appear to have the same explanation as similar disks associated with other titusvilliids, where they are interpretable as cross sections through branches of the colony. The central depressions are apparently caused by the central paragastric tube, and concentric lines correspond to edges of trabecular fibers. There is a fair chance that some attachment disk will be discovered for the titusvilliids, however, since many existing Hexactinellida of branching habits fasten themselves in this manner to some solid object on the sea floor. On the other hand, no large hard anchors suitable for this type of attachment have yet been found in association with any of the titusvilliids. Fossil and Recent forms appear to have lived either in mud or fine sand, and this suggests a basiemphytic anchorage by pleuralia basalia spicular masses.

Only the species *Armstrongia oryx,* the genotype, can now be safely assigned to the genus *Armstrongia.*

Armstrongia oryx (Clarke)

Plate 1, figures 5, 6

Ceratodictya oryx Clarke, 1918, New York State Museum Bulletin, No. 196, pp. 117-186, pl. 1-6.

Non Armstrongia oryx (Clarke) 1920, Clarke, New York State Museum Bulletin, Nos. 219-220, pp. 143-146, plate.

Clarke never emended his original specific description of *Ceratodictya oryx* except in the questionable generic manner reviewed under the discussion of *Armstrongia,* above. His species analysis follows:

The specimens at hand are long, slender, twiglike skeletons, with very prominent horizontal rings, all of which in the best preserved of the two examples, appear to be duplicate on the periphery; this is to say, these rings stand out prominently and abruptly; they are compressed, and the surface is grooved in such a way medially, as to make each ring a duplicate one. On the second and longer specimen this duplication is not obvious, or at least it is no more than suggested, but the preservation of this individual is bad and the absence of the crown groove may be due entirely to this fact. These annulations are separated by smooth and subcylindrical surfaces, which are rather long, as they have fully twice the width of the annulations themselves, and this is rather more than the other species of the genus. As preserved, the specimens show a sinuous or gracefully curved stock or twig, very slender and scarcely tapering from one end to the other, so that the original sponge must have been of extraordinary length in proportion to its diameter. The shortest specimen measured 100 mm. and carries 12 annulations; the longer specimen is 180 mm. and carries 23 more or less recognizable annulations. The average diameter of the shorter and better preserved specimen is 15 mm.

Type.—Syntypes: New York State Museum, Nos. 2071/1,2.

Occurrence.—Clarke (1918) described the occurrence as follows:

The matrix of this specimen is Chemung sandstone of somewhat coarse grain, and no trace is left of the reticulum. The larger specimen is buried in the sand, but the smaller is represented only by an external mold. The block which carries the smaller specimen has also a very indistinct trace of either another individual or the continuation of the first, bent at a very sharp angle. The locality is given by Mr. Armstrong as "about 6 miles southeast of Erie, Pa."

Mr. Armstrong's material must have come from either stream rubble or glacial drift, and apparently has never been traced to outcrop. It undoubtedly came from the "Portage Escarpment," and at the distance cited south of Erie quite probably was derived from either the Canadaway or lower Conneaut groups of the Chautauquan series. This makes the position far above the true Chemung group. The horizon is probably somewhat lower than that of the 1920 material described below.

Armstrongia (?) clarkei Caster, new species

Plate 1, figures 1-4

Armstrongia oryx (Clarke), 1920, Clarke, New York State Museum Bulletin, No. 219-220, pp. 143-146, plate.

Non Ceratodictya oryx Clarke, 1918, New York State Museum Bulletin, No. 196, pp. 177-186, pl. 1-6.

In the description which follows it will be necessary to refer to Clarke's 1920 illustration of the holotype slab and especially to the plates of illustrations accompanying the present paper. Text figure 2, below, will serve as an orientation guide in referring to all illustrated material. As will be seen from this figure,

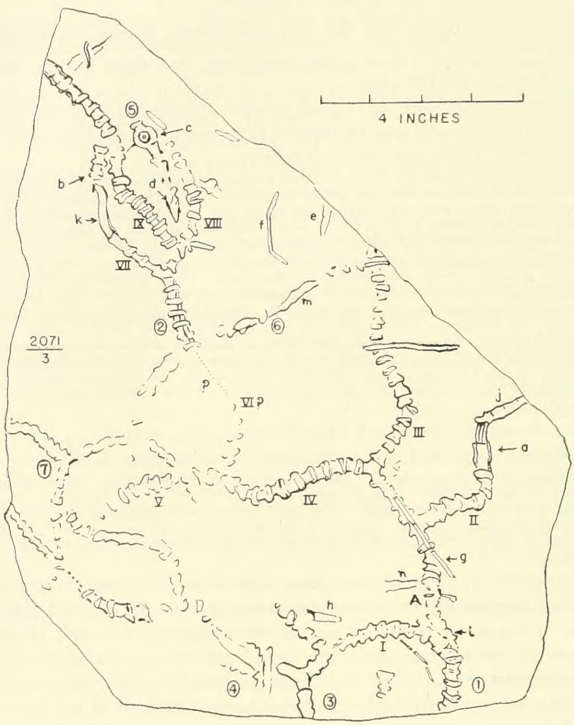

Fig. 2. Finding-sketch of the holotype of *Armstrongia* (?) *clarkei* Caster, new. The slab from which this sketch is drawn was illustrated (Clarke, 1920) as a hypotype of *Armstrongia oryx* (Clarke). The symbols identify details of the specimens which are discussed in the text and illustrated on the plates. There are seven separate branching elements (1-7), which are either separate individuals or disjunct portions of one; branches of each element are numbered from base outward (I-II-III, etc.); letters refer to structural details discussed in the text and shown by photographs. Interpretation of the relationships of various parts is indicated by dotted lines; these will be seen to deviate somewhat from Clarke's reconstruction of the same slab in his 1920 paper. Drawing prepared from a latex rubber mold of New York State Museum type No. 2071/3 which was prepared by Mr. Clinton P. Kilfoyle through courtesy of Dr. Winifred Goldring, New York State Paleontologist. Drawing by Anneliese S. Caster.

the separate branching elements on the type slab have been given Arabic numbers; branches of these parts have been designated by Roman numerals, proximad to distad in sequence. Asterisks and letters refer to minor details which are either discussed in the text or illustrated on the plates.

Clarke's description of this slab has been cited already under the diagnosis of the genus *Armstrongia*. The following comments are offered in the light of broader understanding of titusvilliid sponges.

The type slab shows a nodose and sparsely ramose sponge, the branches of which leave the undulatory or zigzag axial portion at approximately a right angle to the vertical. Each branch extends horizontally for an inch or thereabout before upwardly geniculating at nearly 90°. The colony appears to be subequal in diameter throughout, but suggests the probability of slight basal expansion. The diameter through nodes averages 1 cm., and from 7 to 8 mm. through constricted internodal portions. The annular nodes are subequally spaced, and as seen by the diameter measurements, are elevated from 2-3 mm. above the internodes. In shape the nodes vary considerably, from rugose and irregular to duplicate (crown-grooved) ceratodictyan annulations and include an occasional asymmetrical subcuplike node. The ceratodictyan nodes tend to be slightly asymmetrical also.

Two reticula are clearly present; a narrow subcylindrical tubule lies within an outer nodose one. Sometimes the inner, paragastric net lies free of the outer one for short sections.

Six or seven disjunct sections of branching sponge occur on the holotype slab. These are either separate individuals, or what is more likely, dissociated sections of one original colony. The principal section or colony (1) shows in addition to the basal axial part, three (II-IV) or four (I?) well-marked branches and two (V-VI?) less distinct ones. If the indefinite impression labeled "VI?" is really a branch of colony 1, then colony 2 is a continuation of the first colony as Clarke supposed in his restoration (1920). The fossil does not offer sufficient evidence to warrant the condition shown by Clarke's illustration (supposedly an accurate drawing, not a reconstruction). The branches of colony 2 are numbered VII-IX, as though we are sure colony 2 was a continuation of the first colony.

At point *i* on the basal axial section of colony 1, doubt arises whether branch I was really ever connected to colony 1; it seems rather to be connected in a normal manner to colony 3, and furthermore, two branches seem to be lying one partially upon the other at point *i* (Plate 1, fig. 4). The section of axis marked *A* on colony 1 may be the base of one fragment, whereas the section which Clarke showed as the base of this colony is quite possibly a pendant or downwardly bent part of branch I in colony 3. Certainly the angle between the base of *A* and branch I is too small to agree with the nearly 90° angle of branching seen elsewhere in the colony, and branch I meets the axis of colony 3 at nearly a right angle. The basal disputed section is comprised of asymmetrical nodes of which the basal two are cup-shape. The fourth node from the bottom shows strong vertical ridges (corrugations) on the proximal (?) slope.

Axis sector *A* (Plate 1, fig. 4) bears irregular annulations only. The junctions of branches II and III with the axis (Plate 1, fig. 1) are apparently undistorted. These branches and also branch IV demonstrate the apparently normal condition of bending. In branch II some of the cups seem to show axial corrugations extending over the crests of the annulations. The region *a* on branch II (Plate 1, fig. 1) is a very fine demonstration of the tube-within-a-tube construction of the reticular nets in the Titusvilliidæ. Here the latex mold brings out the external reticular mat (presumably of limonitic spicular elements) in contact with the matrix, but exfoliated on the crest of the branch to expose the thick concentric lamina of fine mud which fills the flesh zone of loosely scattered and felted spicules; this is in turn broken away to expose the innermost filling of the paragastric tube. The branch continues to the edge of the slab as a partial external imprint (*j*) which does not in the least resemble Clarke's drawing of it as an inflated termination. The tubule filling *g*, which runs along the crest of the axis from near the origin of branch III, has the appearance of a section of the paragastric reticulum which had broken through and lay free of the outer net. This condition has been observed several times in other specimens of these branching sponges. A similar filled-tubule impression (paragastric fragment?) apparently crossed branch III a little beyond the midpoint.

The junction of branches III and IV with the axis (IV is probably the axis continuation) is very characteristic of both *Titusvillia* and *Armstrongia*. Lateral oscular gemmation would seem to explain this mode of branching. Both branches III and IV carry nodes with steeper proximal slopes; several of the nodes have suggestions of duplicate crests, but none is truly cup-shape. Branch III extends to the edge of the slab without modification. Branch (or axis) IV probably originally continued to the edge via the indeterminate branch V. There is no evidence of branching from the uncertain ramus V. As mentioned before, it is doubtful if the erosional depression shown as branch VI? really represents the position of a sponge branch, although Clarke reconstructed an axial sector in this depression. The point would be immaterial were it not for the generally erroneous concept which Clarke's interpretation and integration of the fragments creates.

The rami of colony 2 are crowded together and deformed so that the angles between them are probably smaller than in life. The diameter of this colonial fragment is slightly less than that of the other sponges on the slab. The annulations of colony 2 (Plate 1, fig. 2) are more like those of *Armstrongia oryx, s.s.*, being rugose annuli for the most part rather than asymmetrical cuplike nodes. The basal part of the colony (upper left of fig. 2, Plate 1) preserves the impression of the paragastric tube as well as the outer reticulum. The uppermost node of this sector is cuplike, but is oriented downward, and carries axial corrugations onto the crest of the nodes. The dichotomy of branches VII and VIII is almost normal. Branch VII shows widely spaced annuli near the base, and near the middle (*k*) all but the filling of the "sarcode" zone has been lost. Here again we do not have the natural end of a branch as Clarke thought, for the outer trabecular net continues beyond *k* to point *b* (fig. 2), where it comes to lie along branch IX. This obviates the curious swelling on branch IX which Clarke showed. Branch VIII is not overly distinct, but appears to continue (as shown on figure 2 by dotted lines) past the point *c*, opposite colony 5, where it is represented only by the paragastric tubule. Branch IX cannot be demonstrated to connect with branch VIII, but the angles of the first nodes on the two branches after the projected junction strongly suggest former connection. Branch IX carries *oryx*-like rugose annulations, and continues to the edge of the slab without change.

In the midst of colony 2, between branches VIII and IX, is another fragment of nodose sponge, colony 5. This begins with the "disk" *c* (Plate 1, fig. 2) and is intermittently preserved to near the crotch of VIII and IX. The disk is concave, concentrically striated, and centrally deeply excavated. Clarke thought of this as an anchorage structure, which it may have been; but it would be strange indeed if great branching sponges of this sort did not have a much larger disk of cementation, and stranger still if these sponges did not anchor themselves by prostalial ropes after the usual manner of the mud-dwelling Hexactinellida. The outside diameter of the "disk" is not greater than the maximum diameter of the cups in the larger part of the colony. The larger central concavity corresponds in diameter to the non-nodose sections of the sponge, and the central deep depression is of about the average diameter of the paragastric tube. It seems just as probable that we see here a vertical exposure of a broken sponge branch. The triangular terminus of this fragmental branch, *d* on the diagram, (Plate 1, fig. 2) appears to be only a section of paragastric tube, and not the oscular felt that Clarke thought it was.

We need not consider in much detail the detached and poorly preserved portions labeled 3, 4, 6 and 7. It is essential, however, to understand their relation to other fragments, thus dispelling the illusion of "diffusely-branched" attributed by Clarke to the sponge. General relations are shown by figure 2. Colony 3 bears three or four short branches; colony 4 begins proximally with the paragastric tubule and the outer lamella showing very well, and then leads indistinctly into two rami indicated on the finding-diagram. Although colony 6 is exceedingly indefinite, it appears to extend across the base of colony 2 and possibly across colony 7. At the point *m* Clarke interpolated one of his terminal felted tufts, which like all the others appears to be based on a section of paragastric reticulum; the branch seems to continue toward the right to the edge of the specimen. The trend of colony 7 is shown by figure 2; it seems to cross branch V of colony 1 rather than join it as Clarke showed. Probably small portions of other colonial fragments are represented by the paragastric tubules *e, f, h* and *n*. Nowhere on the specimen can an osculum be demonstrated.

Topotype material at hand does not offer any supplementary structural data on this interesting sponge, the while corroborating many of the points already brought out.

Types.—Holotype: New York State Museum No. 2071/3; paratype (topotype?) material, unnumbered, University of Cincinnati Museum.

Occurrence.—According to Clarke (1920), Mr Armstrong collected the holotype slab "nine miles south of Erie, Pa." This is apparently the vicinity of McKean, Pa. The paratypes were all collected in a ravine on the Laird farm in the village of McKean. Apparently most of the streams in that vicinity, cutting ravines in the Chadakoin escarpment, expose the sponge beds. Drift specimens in stream courses are commonplace about McKean. The age is probably Conneaut.

Genus **PROTOARMSTRONGIA** Caster, new

Genotype.—*Protoarmstrongia ithacensis* Caster, new species. Enfield stage, Upper Devonian.

Since the genus *Protoarmstrongia* is monotypic, the characteristics of the genotype may be considered for the present as both generic and specific.

The new genus is proposed for the earliest stage yet discovered in the evolution of the titusvilliid sponges. Here we see the generalized ancestral form possessing, in a diffuse and prenuncial organization, all of the traits which later became standardized in the genera *Titusvillia* and *Armstrongia*. We find also some traits omitted in these genera, which are apparently reassumed or retained in the Recent *Sclerothamnus* of the Indo-Pacific terminus of the titusvilliid line.

Had not the more advanced Paleozoic titusvilliids been discovered first, and the essential structures of the family demonstrated, the alignment with the siliceous sponges of this meandering, irregularly branching, desultorily nodose organism, might never have been discovered. We find in *Protoarmstrongia,* however, the fundamental titusvilliid plan of spicular organization, including two tubular nets, or mats, one within the other. The total thickness of the spicular and flesh zone in this form appears to be much greater than in either of the succeeding Paleozoic genera. The paragastric tube is of somewhat larger proportional diameter than in the later titusvilliids, the outer reticulum has more the appearance of a felted zone of spicules than a true reticulum. The outer sponge tubule, and therefore the sponge as a whole, is of an undulatory nature, irregularly narrowing and swelling, occasionally in asymmetrical bulges, and rarely appears to have eccentric annular nodes. Cups are unknown. The branching seems to be biramous and at rather infrequent intervals. The branches grew to considerable length.

Protoarmstrongia ithacensis, Caster, new species
Plates 2 and 3

Although hundreds of specimens of the new sponge are at hand, virtually all of its features are seen on the extraordinary holotype slab, a sandstone block of diamond shape, 20 by 15 inches, from which most of the photographs illustrating the species were taken. The slab as a whole is shown reduced on Plate 2, fig. 1. Text figure 3, below, shows the disposition of the sponge branches on the holotype slab, and serves as a finding-diagram for the identification of the photographs on plates 2 and 3. A paratype slab of roughly triangular outline, 25 by 32 by 35 inches, is also briefly discussed. A scaled sketch of the second slab is shown as text figure 4.

As differentiated by the patterns on text figure 3, the holotype slab is seen to embrace portions of six or possibly seven separate ramose sponges. What may have been the life relation of these fragments one to another is indeterminable. In text figure 3, the portion judged to be the main axis of each fragment is lettered *A*. That sector of the axis judged to be nearest the original place of attachment (the proximal sector) carries the designation *A1*, the second segment of the axis *A2*, etc. In a similar manner the branches are numbered distally, the earliest branch being I, the second II, etc. This system of numbering is similar to that used by the author in discussing *Titusvillia* in 1939.

The photograph of the holotype slab (Plate 2, fig. 1) shows reticular rami ly-

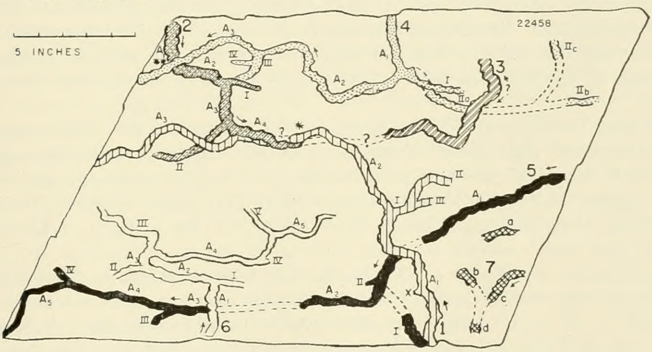

Fig. 3. Finding-sketch of the holotype flag of *Protoarmstrongia ithacensis* Caster, new species. From the Enfield shale, (Upper Devonian) near Ithaca, New York. Scale indicated. Arabic numerals (1-6) refer to the six distinct fragments or colonies represented on the slab. The indistinct fragments, 7a, b, c, d, are possibly portions of a triturated seventh branch. The six principals are further distinguished by patterns. Dotted lines indicate the presumable continuations of branches. The arrows indicate the presumed distal direction of each fragment. The branches I, II, etc. are numbered accordingly. All areas on the slab which are judged to be of primary importance are shown by the plates of photographs. University of Cincinnati Museum Type No. 2248.

ing through several inches of sandstone matrix. This condition seems to reflect the semirigidity of the skeleton, as does also the fact that both inner and outer reticula are ordinarily preserved and in essentially their original relationship. Mud fills the sarcode between the two reticula and also the central paragastric cavity. In preparing the specimens for exhibition, and in searching for additional nets, the flattened tubules were given added relief by chiseling, and therefore the types give an undue impression of elevation to the various branches. Many branches and several colonies were discovered by deep excavation of the type slab; for example, nearly all of colony 2 was thus discovered.

The first impression of any of the large type slabs, with their matted, chaotic masses of intertwining sponge skeletons, is that of exceedingly abundant branching and great irregularity of organization. This is largely an illusion which is dispelled by carefully tracing the course of any of the larger strands. This has been done for both of the large prepared slabs at hand, and the results are shown on the finding-diagrams. In reality, the skeletons are only, sparsely branching. Rami usually arise by dichotomy at less than 90°, which suggests the possibility of the origin of new branches by terminal (oscular) fission. To be sure, an occasional, seeming lateral branch occurs, but these are rare, and in no instance has it been possible to make sure such strands are not disjunct sponge skeletons. The dichotomous habit of branching at an acute angle is in contrast to the right angle condition of *Armstrongia* and *Titusvillia*, where lateral oscular gemmation seems to have prevailed. In *Protoarmstrongia* it has been impossible to differentiate branches from axes; all are branches of similar contour and size differing only in their remoteness from the unknown basal anchorage, or initial sponge mass. Detailed description of the holotype slab follows:

Colony 1.—By consulting text figure 3 it will be seen that this colony extends from the lower right corner of the holotype slab diagonally toward the upper left. It is comprised of a long axial portion (A1, A2, A3) and only one short (incomplete) secondarily biramous branch (I, II, III). At the asterisk (*), axis A2 passes along and *under* branch III of colony 2 (Plate 2, fig. 2). The axis of the first colony extends for some distance beyond the junction as A3 and crosses branch II of colony 2. Great pains were taken in preparing the specimen to discover the possible existence of any additional branches other than the short stumps (i, ii, iii). Deep excavation revealed no additional ones. It is possible that the fragment labeled 7 may have been attached to the A1 axis, but the indicated direction of the "cups" on the 7c fragment would militate against this idea. About 15 distinct nodes occur on axis of A1 colony. (Plate 2, fig. 4). Nodes are also present for a short distance on the proximal part of A2. The nodes at point "x" are most cuplike. The enlargement of this point (Plate 3, fig. 4) brings out the incipient cups rather well. No other specimens among hundreds collected show "prenuncial" cups as well as this. The 1.8 cm. diameter of the basal portion of A1 is the largest on the type slab and nearly maximum for any specimen. The enlargement of point "x" shows a suggestion of vertical fascicles of spicules which recall the strengthening seen so often on the narrower parts of the cups in *Titusvillia*. The central parts of branches I and III (Plate 2, fig. 4; Plate 3, fig. 2) show the imprint of the inner (paragastric) reticulum. This can also be seen in the axial segment A2. Alignment and node orientation of colonies 1 and 3 suggest the onetime continuation of colony 3 with A3 of 2.

Colony 2.—This fragment extends from the upper left corner of the slab toward the lower right. It seems to cross the first colony, as discussed above, at a point marked with an asterisk. The base of the fragment appears to be at the upper left. Two branches and three axial segments are distinguished. Dotted lines on figure 3 indicate the possibility of connection of colony 4 to axis A3 of this colony. Axial segment A1 appears to have been of slightly greater diameter than the rest of the fragments; this is in part an illusion due to the crushed condition of the outer reticulum in A2 where the diameter preserved is essentially that of the paragastric reticulum. No outer net is preserved on branch I, At the double asterisk (**), A3 of the 4th colony crosses the axis of the second. Details of the crossing are shown on Plate 3, fig. 6. A3 of the second colony is crushed, but the initial orientation of the nodes seems to continue here. Branch II crosses the A3 extension of colony 1, and A4 lies along the A3 axis of the first colony as previously indicated, Plate 2, fig. 2.

Colony 3.—This is a relatively well-preserved colonial fragment near the center of the type flag. In the wider part, it shows rather satisfactory retention of outer reticular detail. In the narrower portions, the detail of the paragastric net can be obscurely distinguished. The orientation of this fragment cannot be determined in the absence of the conventional criteria. The end toward the upper part of the slab sinks vertically into the sandstone, while the opposite end (? in fig. 3) seems to align rather well with the broken termination of A4 of the second colony, but could also be aligned with segment A3 in the first colony. The relations of colony 3 are adequately shown by figure 1, Plate 2, and figure 6, Plate 5.

Colony 4.—This fragment has about the same orientation as colony 2. The basal portion extends to the upper edge of the slab. Obscure cups and nodes are present, and their direction seems to oppose that of colony 1. Four branches are preserved, and it appears likely that other branches came off originally in the long sinuous portion A2. Certain spicular details are preserved on A1. Branch IIa seems clearly to have been attached to A1 in the manner indicated by dotted lines (Plate 3, fig. 5). IIb may or may not have been connected to IIa with which it shows alignment. The bearing of IIb to IIc is purely speculative. Branch IV (Plate 3, fig. 6) shows only the paragastric reticulum, and may be the central cylinder of branch III rather than a distinct ramus. The crossing of A3 and the A1 section of colony 2 is seen on Plate 3, fig. 6.

Colony 5.—This segment runs from the right middle along the full lower length of the slab. It is the longest fragment on the holotype flag, and in some respects the finest specimen. Nodes or swellings are especially well developed, and their orientation relatively distinct, as can be seen on the A1 portion shown as Plate 2, fig. 3. Orientation of the cups and the varying diameter of the colony point to the right end as basal, and the narrowing branching portion on the left, as distal. Axial fragments A1 and A2 are clearly continuous in the matrix under A1 of colony 1 (Plate 2, fig. 4). Alignment suggests that A3 continues deeply in the matrix under A1 of colony 6. Axis A3, A4 (top of fig. 1, Plate 3) and A5, as well as the branches show only paragastric characters, and these in no detail.

Colony 6.—This specimen originates to the left of center on the lower margin of the slab and extends upward with the most abundant and regular branching of any specimen on the type slab. Axis A1 (Plate 3, fig. 7) shows the most perfectly developed outer reticular contour. The nodes on this segment are oriented in opposite directions at the two ends. Branch I preserves the paragastric net only; A2 shows both reticula near the middle of the segment; branch II seems to leave the main axis about 120° from the first branch, and branch III seems to leave at about 120° from branch II. Axis A3 is flexed and distorted. Branches IV and V and the remainder of the axis show few details, but the suggestion of regularity in branching which their presence offers is most important. Most features of the colony, excluding characters distad of A4, are shown on Plate 3, fig. 1. Those distad of A4 appear on Plate 5, fig. 5.

The *c* branch of colony 7 is shown on Plate 3, fig. 3. Both reticula appear, and cuplike nodes are well marked.

Text figure 4, below, shows the general distribution of *Protoarmstrongia* fragments on the largest of the paratype slabs of this curious fossil from the type locality. The interlacing ramifications of many branching fragments suggested mud crack patterns to students of sedimentation who casually examined the type in the quarry. We are indebted to Drs. K. V. W. Palmer and R. H. Flower for procuring the specimen which has been prepared with some pains in the Cincinnati laboratory to bring out details of the complex tangle of sponge branches. Although the reticular minutiæ have been largely destroyed by weathering, the branching is very well demonstrated. Here, for the first time in the family, secondary and tertiary branching is clearly to be seen, and also for the first time, bifid mode of branching is known. It came as a surprise to discover that a very large part of the tangled mass on the slab is assignable to one continuous ramifying piece of glass sponge. This individual is shown on figure 4 by vertical ruling. The base of the large sponge fragment appears to sink in a vertical spiral near the center of the slab (at number 1 on the drawing). On the spiral portion the reticular net is moderately well preserved. This sector has the largest diameter of any fragment on the slab. The basal portion of the colony seems to split, as though by terminal fission, and eventually each branch splits and re-splits in the same manner. Fragments of four other branching sections of glass sponge occur also on the slab (2-5). The scheme of branching and the proportions are carefully depicted on the sketch, but since reticular details are not so well preserved as on the holotype, no photographs are given.

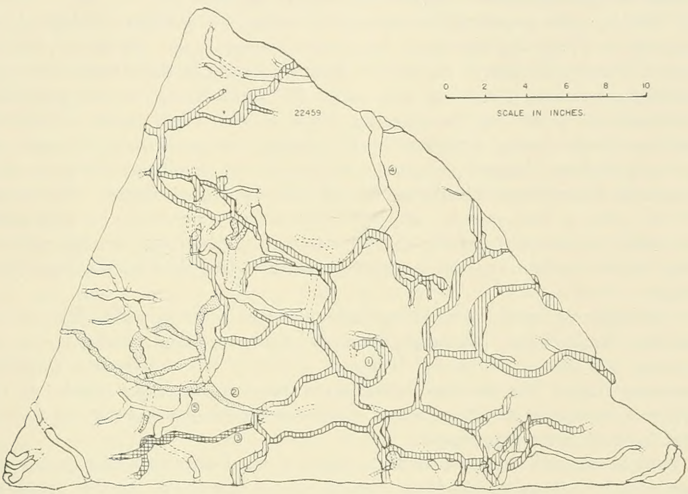

Fig. 4. Sketch showing disposition of skeletal strands on a paratype slab of *Protoarmstrongia ithacensis* Caster. Six separate skeletal fragments appear on the sandstone specimen, of which the sponge numbered 1 and distinguished by vertical ruling is the largest. This is also the largest specimen of a fossil branching sponge known. The intricate entanglement of the branches was exposed by deep chiseling, which in some places has followed sponge masses as much as 2.5 inches below the original surface of the slab. Collected by Drs. K. V. W. Palmer and R. H. Flower from the Enfield stage of the Upper Devonian, Hungerford quarry, near Ithaca, New York. University of Cincinnati Museum type No. 22459.

Mode of life.—There seem to be three possible modes of growth of this extensive branching glass sponge: (1) benthonic growth, upright habitus, basiemphytic attachment; (2) benthonic with basiemphytic attachment, but existing ephebically as a recumbent, tangled mass of sponge strands, flexibly shifting position on the bottom with current or wave motion; (3) drifting sponge, possibly attached to *Callixylon* or other kinds of early woody logs.

The sponge fossils offer no cogent structural answer to the question of how they grew, since we have no natural terminations, distal or proximal, on any of the specimens yet recovered. It seems quite likely that the great quantities of sponge strands in the Hungerford quarry indicate a biocœnose, especially when we note the excellent state of preservation of an adjacent fauna in the preserving sandstone of neotremate and atremate brachiopods, coiled nautiloid cephalopods, brittle stars, fragile crinoids and aberrant sea urchins, as well as multitudes of diminutive dictyosponges (*Ithacadictya cornelli* Caster). This fauna occurs always a few inches above the branching sponges. The fact that the sponge strands pass through a considerable thickness of the embedding sandstone, penetrating the bedding planes, suggests entombment in place.

This is rather impelling intimation of benthonic and emphytic habit for the organisms. Now the question: did these sponges grow upright or recumbent? The strange lack of evidence of basal thickening of the skeletons, the exceedingly extensive dichotomy and especially the twisting, snarled condition of the strands as we find them, passing deeply into the rock, suggest a more or less recumbent, tangled existence for the sponge. It would seem that only by growing in dense "hedges" where mutual support was possible, could these very long strands ever have held themselves upright to any great degree. Of course, if they lived in this manner, we might expect their remains to be even more abundant than they are in the Enfield sandstone. Assuming that the sponges were buried in place, our discoveries may prove to be only a fair ecologic sampling.

Condition of burial.—The Hungerford quarry is also the locality from which the tiny dictyosponge, *Ithacadictya cornelli* Caster (1939), comes. In describing that species, the general facieology of the site has already been discussed in some detail. The bearing of this environment to the facies pattern of the Upper Devonian of the Penn-York Embayment was shown in a general way by text figure 7 of the 1939 report.

All of the very abundant sponge remains in the Hungerford quarry are preserved in an olivaceous sandstone layer from 2-3 feet thick. In this sandstone the bedding planes are irregular, noncontinuous, and occasionally on weathering reveal suggestions of current cross-bedding. Carbonaceous films of triturated plant tissue sometimes occur and delimit planes or surfaces along which fracture occurs. The sponges also serve as lines or rather zones of weakness in the massive sandstone, and are damaging imperfections for which the material has been discarded. An occasional sprinkling of mud pellets occurs in the sand, usually diffusely distributed, but sometimes they concentrate in a zone of short lateral extent which renders the rock unserviceable. The sponges are always preserved in a partially inflated condition of the skeletal mats, and consistently show a filling of very fine mud rather than of the sand in which they are buried. The fine mud of the interior of the sponges and the mud pellets of the sandstone are usually of a greenish color when newly quarried, but oxidize to a pinkish hue long in advance of the arenaceous matrix. The presence of pink-weathering mud pellets in an olivaceous sandstone is usually indicative of a shoreward subfacies of the Smethport magnafacies in the Penn-York Embayment of the Upper Devonian. (See Caster, 1934, 1934A, 1935, for facies nomenclature in the Upper Devonian of the Penn-York Embayment.)

Did the fine mud penetrate the sponges in life or after death? While it seems very probable that the organisms were rather suddenly engulfed by the sand in which we find them, and even though there is abundant opportunity for particles to penetrate a sponge by means of pores and oscula, it seems hardly likely that sponges could have withstood turbidity long enough for the entire paragastrium to be charged as we find it. Further, the spicular elements were deeply embedded in flesh during life. It is the flesh zone and central paragastric canal that are filled with mud rather than pores, canals, etc., which would have been the principal recipients of the fill during life. From the fact that in many instances the paragastric tubule has broken through the outer spicular tube, and lies free, sometimes for a considerable distance, and usually has been shifted from its original central position in the skeleton, it seems probable that this central cavity was filled in advance of the spicular, mesoglœal zone made vacant by the decay of flesh.

Protoarmstrongia probably grew upright at first but later toppled in a loose tangle on the sandy bottom. Perhaps storm currents carried the mud and sand in murky roiliness along the bottom; the finer sediment entered the inhalent pores of the sponge, collected in the canals, and especially in the paragastric central tube, slowly strangling the organisms, until at length suffocation was complete.

The cilia of the inhalent canals would be the most effective means of sweeping the fine sediment into the central gastric chamber, where sedimentation would occur if the exhalent current were insufficient for the task of removal.* Only the heavier sediment, the sand, was deposited around the strangling sponges; the fine sediment was carried on (by-passed) out toward deeper or quieter water. Death accomplished, decay soon followed, but the matted spicules of the sarcode resisted disintegration, and remained as a fine-meshed glassy filter which admitted fine particles to the erstwhile sarcode zone while the whole sponge mass was gradually engulfed by the shifting sands.

Sometimes the mud-filled central tube broke through the outer meshes, as gravity pulled it downward, to break the spicular ties which once held it in an axial position. Gradually the fine, by-passing sediments percolated through the spicular felt and filled the sarcode cavity nearly as completely as the flesh did in life. When completely buried, the mud-filled spicular tubes, outer and inner, retained a semblance of their life aspect. Spicular elements were apparently gradually replaced by pyrite, the almost universal preservative of sponge skele-

* As in the existing Hexactinellida (*See* Hyman, *e. g.*, 1940, pp. 303, 304) the titusvilliids undoubtedly passed a vast quantity of water through their bodies in quest of food and oxygen, and likewise as readily succumbed to turbidity and silting.

tons in the Embayment. It is possible that the pinkish color of the weathered sponges might be in part a reflection of the pyrite once present. More often, though, the spicular elements are still partially preserved as typical yellowish limonite coating about pink mud filling. Since the apparently inorganic mud pellets associated with the sponges in the matrix are also pink when weathered, other explanations must be sought to account for the ferric color.

It is now well known that the Enfield sands and shales assume a pinkish and then reddish color with increase of ferric iron content when traced eastward (sourceward) only a few miles from the Hungerford quarry. This ferric iron increase is typical of the shoreward, but still marine, subfacies of the Smethport magnafacies. The assumption of a red or olivaceous color in a constant direction, however, is not as consistent a phenomenon as some would suppose. Occasionally the direction of color or coarseness change is reversed for a short distance. This is seemingly attributable in part to localized or temporary current shift. Commonly in the Smethport magnafacies, a greenish sand, carrying mud pellets of pinkish or even red color when slightly weathered (or even quite fresh) will give way seaward to a pinkish or pinkish-weathering alternation of fine sand and mud ("pink rock stage"). Clearly in most of the red sediments, especially sands, of the Upper Devonian in New York and Pennsylvania, only a fraction of the sediment is or becomes red. This is the finest divided material which serves to stain less weathered constituents having quite different colors. The Hungerford quarry sand quite possibly represents a small offshore bar formed by the reworking of slightly antecedent reddish mud and quartzose sand accumulations which had not yet been associated long enough to stain the larger particles, especially the quartz grains. When agitated and carried seaward the coarser particles traveled along the bottom whilst the finer, reddish muds, or oxidized muds not yet red, were perhaps in suspension, or what is more likely, were carried along eventually to by-pass the coarser sediments. Entrapped first by the paragastrium of the living sponges, and then by their sievelike skeletal felts, our only evidence of the by-passing finer materials in the sandbar or shoal deposits is those organic fillings. This speculative account is in keeping with the sedimentary relationships often observed at many horizons in the Smethport magnafacies, though never before has evidence of by-passing been recorded, apparently, by fossil media.

Some additional broad facieological considerations of the occurrence of siliceous sponges were brought out in the 1939 paper. With the discovery of this oldest titusvilliid in the Smethport magnafacies development of the Enfield stage, the Embayment history of the branching glass sponges seems to conform to that of the dictyosponges. In both, there seems to have been a tendency to migrate toward deeper, and, therefore, presumably less silt-contaminated water. From Enfield time to Lower Mississippian nearly all of the Hexactinellida of the Embayment outdistanced off-lap by two magnafacies belts. In other words, the glass sponges known to us indicate that during the closing phase of the Upper Devonian they were progressively shifting toward the deeper inland sea at a rate somewhat faster than their general environment was migrating with marine regression. Of course we do not know if this trend has any long-range significance. These facts we do know, however: siliceous sponges are almost unknown in epicontinental deposits after Mississippian time, and to-day occur for the most part at considerable depths, the optimum depth being between 500 and 1000 meters, though there are both shallower and deeper exceptions to this.

The sandstone carrying *Protoarmstrongia* would ordinarily pass for barren. It is only on quarry discards which are from localized pockets, so to speak, that the rather large complement of fossils turns up. It is curious that not a single large slab carrying remains of the branching sponges has shown evidence of other kinds of life, though the massive sandstone a few inches above, and the shale below, are often very fossiliferous. .

From the fact that several of the large slabs show the branching sponges passing vertically through to the basal part of the sandstone, and that these sponges usually occur not far from the base of the member, the possibility is advanced that the sponges lived attached probably by basal tufts of spicules to the *mud* bottom, which is represented by the fine bluish shale underlying the massive sandstone. This would correlate rather well with the existing branching sponge *Sclerothamnus*, which is known in the few instances of its recovery only from mud (volcanic mud in this case) bottom (80-360 fathoms).

No sponge skeletons have been recovered in the shale underlying the sandstone in the quarry, but the immediately underlying shale is not often exposed at the workings. We may have here the explanation for the lack of data on mode of anchorage of the sponge. The matter is raised at this point in considering life associations, for if the sponges were anchored in the blue mud, then the fauna of the sandstone is a thanatocœnose in its relationship to the sponges. The associates of the sponges in life in this case should be viewed rather as the organisms of the mud, which would include great numbers of delicate crinoids, auluroids, spirifers, and nuculoid pelecypods. The only other choice is to consider the branching sponges as diastemic in their true relation to underlying mud and entombing sand.

The sandstone fauna includes, in addition to the small and sometimes abundant dictyosponge, *Ithacadictya cornelli* Caster (939) and an undescribed larger species recently acquired, also numbers of new linguloid and orbiculoid brachiopods. Crinoid stems are locally common. Crinoid "heads" have been found in the sandstone, and also brittle stars, though both are more common in shale and sandstone layers a few feet below. An undescribed perischœchinoid, closely allied to Olsson's *Lepidechinoides ithacensis*, has also been found in the sandstone. "*Spirifer mesistrialis*" occurs through the quarry, but is not abundant in the sponge-bearing sandstone. Among the commonest fossils in the sponge sand are flabellate algæ, being described by Dr. L. C. Petry of Cornell University, and triturated wood (*Callixylon?*). A few leaf fragments have been found, and occasional stems. Lepidodendroid scraps also occur. Some discard blocks show many true trails and burrows. Two coiled cephalopods of large size were collected from the sandstone during the summer of 1940.

Types.—Holotype: University of Cincinnati Museum No. 22458; paratype: 22459, and also many unnumbered slabs and hand specimens in the University of Cincinnati Museum and at the Paleontological Research Institution, Ithaca, New York. Considerable topotype material presented by the writer in 1935 is presumably still in the Cornell University collection. Collectors will find much topotype material still available at the Hungerford quarry.

Occurrence.—As intimated above, *Protoarmstrongia ithacensis* comes from the base of a massive olivaceous to bluish sandstone, averaging about 3 feet in thickness, in the Hungerford quarry, on the Ellis Hollow road, town of Ithaca, New York. This is about 2 miles ESE of Cornell University, where much of the stone from the quarry has been used in the modern building program. Branches of the sponge can be seen in the walls of Myron Taylor Hall and in bridges and masonry walls on the various trails about the campus in Cascadilla and Fall Creek gorges. The horizon is in the lower part of the Enfield stage of the Senecan series. The sponge is probably of much wider distribution, at least in Central New York, for "nodose worm burrows" are recalled among the discards of many a field excursion along the "Portage Escarpment" in the Ithaca region.

GEOLOGIC DISTRIBUTION OF THE TITUSVILLIIDS

The geological distribution of the Titusvilliidæ (Titusvilliinæ) is as follows:

	1	2	3	4	5	6	7	8	9	10
Armstrongia oryx (Clarke)						x	x		.	.
Titusvillia drakei Caster	x	x	.			.	.		.	.
Titusvillia drakei Caster var.			x			.	.		.	.
Armstrongia clarkei Caster						x	.		.	.
Protoarmstrongia ithacensis Caster									x	x?

The numbers correspond to the principal units in the Upper Devonian and Lower Mississippian stratigraphic column in western New York and northwestern Pennsylvania. They are as follows:

1. Corry sandstone (Mississippian)
2. Tidioute shale (Mississippian)
3. Knapp sandstone (Mississippian)
4. Oswayo shale (Conewango series, Upper Devonian)
5. Venango stage (Conewango series, Upper Devonian)
6. Chadakoin beds (Conneaut stage, Chautauquan series, Upper Devonian)
7. Canadaway stage (Chautauquan series, Upper Devonian)
8. Chemung-Portage stage (Chautauquan or Senecan series, Upper Devonian)
9. Enfield stage (Senecan series, Upper Devonian)
10. Ithaca stage (Senecan series, Upper Devonian)

It should also be borne in mind that fragments of titusvilliids have been found in the Middle Mississippian of Illinois (Caster, 1939A) and that nodose "worm burrows" occur at many places through the Upper Paleozoic, and presumably higher.

EXISTING TITUSVILLIIDS

No fossil glass sponges of branching habitus appear to have been described from strata younger than the Lower Mississippian. Among the rarest of existing Hexactinellida are certain branching forms, chiefly from the depths of the Indo-Pacific, which are rather inadequately known. Clarke (1920), by inunendo, suggested that one of these existing forms, *Sclerothamnus clausii* Marshall (1875), either is related to his genus *Armstrongia* of the Devonian or else sheds isomorphic illumination on the mode of growth and environment of that form. It is sad that Clarke, with his great knowledge of fossil Hexactinellida, did not follow up this clue which now, despite our still meager knowledge of the existing sponge after twenty years, seems so very profitable.

Information on *Sclerothamnus* comes from three literature reports of the organism. In 1875 Marshall applied the name *Sclerothamnus clausii* to fragmental specimens from an unknown source. Murie in 1876, unaware of Marshall's description, applied the name *Dendrospongia steeri* to branching sponge material from an uncertain locality, between the Philippine Islands of Cebu and Negros at presumably 80-100 fathoms depth. Schmidt, in 1887, corrected the nomenclature when reporting on fragments of Marshall's sponges dredged by the Challenger Expedition off Timor at a depth of 360 fathoms from volcanic mud bottom. The basis for considering the assignment of this sponge to the Titusvilliidæ will appear in the generic and subfamily discussion which follows.

Subfamily SCLEROTHAMNINÆ Caster, new

The ensuing discussion of *Sclerothamnus* will bring out the grounds for concluding that the family attributes of this unique sponge lie with the Titusvilliidæ of the Paleozoic rather than with any of the families of existing glass sponges. *Sclerothamnus* has possibly no paragastric cavity, and perhaps therefore no paragastric reticulum. It possesses many (diffuse?) parietal pores and "oscula" and has a curious fasciculate core of acicular spicules which bow outwards to form the spiral band or bead which gives the sponge a nodose appearance. These divergent characters appear to be post-Paleozoic acquisitions or modifications of the titusvilliids which warrant recognition as a subfamily. The subfamily SCLEROTHAMNINÆ is therefore proposed to embrace the existing sponges of this advanced mien. Whatever the final disposition of this unique branching sponge of to-day, it is so very different from all known Recent forms that a separate subfamily or even family, if Titusvilliidæ proves unacceptable to parazoölogists, is very much in order. The new subfamily, being monotypical, partakes of the attributes of its genus and the genotype which are discussed in the following pages. The Paleozoic representatives of the family have already been assigned to the Titusvilliinæ, whose characteristics are a synthesis of those of the comprising genera *Titusvillia, Armstrongia* and *Protoarmstrongia*.

The relationship of *Sclerothamnus*, and, therefore, of the subfamily Sclerothamninæ, to other glass sponges assigned with it by Schulze (1887) to his "Tretodictyidæ," is discussed under the heading of Comparisons in the species analysis, below.

Genus **SCLEROTHAMNUS** Marshall, 1875

Genotype.—*Sclerothamnus clausii* Marshall. Indo-Pacific, Recent seas.

The genus *Sclerothamnus* Marshall, 1875, was reviewed by Schulze in the Challenger Report (1887, p. 337) in which he pointed out that the name—

Sclerothamnus clausii was applied by Marshall to a bushy-branched Hexactinellid obtained from an unknown source. It measured 50 cm. in height, while the cylindrical branches, which were repeatedly forked, had a diameter of 3.5 cm. toward the extremities and of 13 cm. at the basal ends. In the tolerably uniform framework of siliceous beams, which consisted of fused hexradiate spicules with tubercled external surfaces, Marshall thought he perceived a continuous connection between the axial canals, which exactly met one another in the fusion of adjacent hexradiate spicules, and thus remained in open communication. The broad (5 mm. in diameter) and narrow (1 mm. in diameter) canals which traverse the branches of the sponge often anastomose with each other, and open outwards by orifices of variable size. Many of these excurrent passages, moreover, possess a fringe in the form of a freely projecting cuff, but on the whole the canal system seems to be indistinctly and irregularly developed in the dense tissue.

"Among free spicules, Marshall found (1) large knobbed hexradiate forms which fuse to form the continuous framework; (2) very small fine, regular hexradiate spicules; (3) broom-forks with 5 clubs, beset with delicate warts on each of the expanded portions, while their stalk, which is covered with similar warts down to a slight swelling, terminates in a sharp point; (4) longer broom-forks, with four long clubs, in which the stalk, like the spicular shaft, is beset with fine recurved hooklets."

(These were reillustrated in the Challenger Report).

In 1876 Murie published a paper on new Hexactinellida which were obviously referable to the sponge which Marshall had described the year before. In this work Murie gave the best illustrations of the curious sponge that we yet have. According to Murie, Professor Steere had procured the sponge from Philippine fishermen "between the strip-like and parallel islands of Negros and Cebu, on the opposite eastern side of the island of Cebu, where hitherto no sponges are said to have been got from the sound or channel above mentioned." The sponge came from a depth of 80-100 fathoms. Murie named the sponge *Dendrospongia steeri* in honor of its discoverer.

In its dried condition the sponge was some 80 cm. high and showed branches "as thick as one's finger." Schulze (1887) went on to say:

According to Murie's description and figures, "the general surface exhibits several broad but very shallow impressions or concavities which traverse the stem obliquely. The distinguishing feature of the branches is a series of tufts or rosettes, so continuous and interwoven as in the main to present a whorl running successively around from base to apex, composed of a bunch of long parallel-placed spicules which issue from the axis of the branch at an oblique angle, and slightly spread out at their free ends. The spiral hollow between the frills shows a delicate gossamer lacework composed of minute spicules, forming a rectangular chequer.''

The principal fibrous bands of the network beams, which is composed of fused hexradiate spicules, run, according to Murie's representation, in a longitudinal direction in the axial part of the branches, but bend laterally in a bow-shaped curve towards the exterior, and terminate freely in the more radially directed, obliquely projecting fibers of the spiral frill. All were covered with short mucronate spines.

Among the spicules which he isolated, Murie described (1) long acerate, fusiform, inequilateral spicules of two sizes, large and small, both covered with spines all sloping in the same direction; (2) two forms of scapuline spicules, the larger with a straight shaft, and with microspines and indistinct capitate terminal rays, from two to four in number, the smaller with two to four rays opposite to one another, and expanding laterally like petals.

In regard to the position of these scapuline spicules, Murie records Carter's conjecture, illustrated by a woodcut, that they may have lain parallel to the surface in the dermal layer, and may have been crossed in such a way that square meshes were formed. He found (3) two forms of rosettes, of which the smaller bore six straight, smooth rays, rising at right angles from the center, and each terminating in a little discoid swelling bearing 4-8 rays, spread in what Carter terms a fleur-de-lis. Each ray terminates in a swelling which is expanded into a circular convex head, bordered by four opposite and recurved spines. The larger rosettes are very rare, and the globular still more so. Each of the six short, stout rays terminates in a quadrangular, or, more frequently, pentangular cap or head, with free convex surface. He also notes (4) single hexradiate dermal spicules, which form by the overlapping of their horizontal rays the squares of the skin. The outermost tip of the anterior ray frequently bears the small rosette above described.

The most important peculiarities of the new form have been summarized by Murie in the following brief diagnosis: ''Hexactinellid sponge characterized by its dendritic or scrubby contour, occasionally attaining a height of 3 feet or possibly more. Branches forking or dichotomous, with continuous whorled series of spicular tufts from base to apices. Skeleton only known; basework composed of relatively stoutish glassy fibers of coalesced hexradiate or spinomucronate spicules, disposed in tolerably compact trabeculae. Main direction of fiber longitudinal to axis in parallel straightish or slightly bent lines, where continues into exterior whorls; in crossing fibers more irregular as are the very numerous excretory canals. Oscula and pores of moderate size, distributed all over the free surfaces. Flesh spicules abundant and of scapuline, acerate and rosette shapes. A dermal veil of slender, interwoven hexactinellid spicules probably clothes the major portion, or possibly the entire sponge.

In a postscript, Murie finally calls attention to the fact that his *Dendrospongia steeri* may be identical with *Sclerothamnus clausii* Marshall, described a year before, so that Marshall's name may be accepted as having priority.

The structural characteristics of *Sclerothamnus* and the subfamily based thereon are shown in part by the figures of *Sclerothamnus clausii* from Murie's report and Schulze's report on the glass sponges recovered by the Challenger Expedition which are reproduced below on Plate 5, figs. 1-4.

Sclerothamnus clausii Marshall

Plate 5, figures 1-4

Sclerothamnus clausii Marshall, 1875, Zeitschr. f. Wissen., Bd. 25, Supp.
Dendrospongia steeri Murie, 1876, Linnean Soc., Trans. (Zoöl.), ser. 2, vol. 1.
Sclerothamnus clausii Marshall, Schulze, 1887, Sci. Results Challenger Exped., Zoöl., vol. 21.

This species was discussed by Schulze (p. 339) as follows:

Of this remarkable bushy-branched species which differs essentially in external appearances from all known Hexactinellida, only two skeletal fragments belonging to a dead specimen were trawled by the Challenger Expedition in the neighborhood of Timor (Station 194A, Lat. 4° 31′ 20″ E.) from a depth of 360 fathoms on volcanic mud. These are small, irregularly rounded, somewhat bent, and slightly knee-shaped branches of the thickness of one's finger, and from 12-115 cm. in length. The outer portion has been destroyed by abrasion or otherwise. The tolerably compact fibrous framework exhibits, in longitudinal section, strands of fibres for the most part longitudinally directed, or arched toward the exterior and laterally curved. They terminate freely on the outer surface while between them other fibres extend approximately at right angles. The entire disposition of the dictyonal framework, and especially the above-mentioned direction of the fibres, corresponds exactly with the structure of the framework described by Murie . . . Moreover, the results of microscopic examination of the beams of the framework are in complete accordance with the description by Marshall and Murie. All the beams of the network, the meshes of which are not always quite regular, though generally square, are more or less richly beset with prongs which are either low and pointed, or large, broader and more acute. The whole framework is traversed by round canals from 2-3 mm. in width, which open out laterally.

In the comparatively large, well-preserved specimen studied by Murie, ring-like or spiral wreaths were found to originate laterally on the branches of the stock, while between these, bands of approximately uniform breadth occur. It is only in these wreaths that the extremities of the laterally bent longitudinal fibers of the dictyonal framework project freely. Although, moreover, in the case of the specimen examined by Murie, only the deepened furrows were covered with a dermal lattice-like network of delicate hexacts, forming square meshes, he still regarded it as possible that the entire surface of the whole sponge was covered with such a dermal network.

Since I was able in the British Museum to examine some microscopic preparations which were probably made from Murie's original specimen, and to compare the loose spicules preserved in great abundance and partly in their natural position, with those which could be discovered here and there in the fragments from the Challenger Expedition, I was able to demonstrate the most complete agreement between the two forms. The identity of the two species is therefore indubitable . . .

The detailed descriptions of Murie and Schulze bring out the many characteristics shared by these unique Recent sponges and the Paleozoic titusvilliids. It seems almost inescapable that *Sclerothamnus* is a derivative of this ancient line, despite several specialized traits. More is the wonder that it deviates so little! Spicular comparisons between fossil siliceous sponges and existing forms are none too satisfactory even under the best conditions of preservation. In the case of the titusvilliids, where all material recovered thus far has been preserved in sandstone, nontrabecular details are wanting. Fortunately, the trabecular skeleton furnishes excellent morphologic data, which within the group seem to be fully as important systematically as the skeletal minutiæ customarily employed by students of the usual Hexactinellida.

Comparisons.—Despite the great time-gap which separates the Lower Mississippian *Titusvillia* from the aberrant Indo-Pacific *Sclerothamnus,* the following morphologic details shared by them seem to indicate family kinship: (1) both grow as branching, bushy colonies of essentially the same size and proportions; (2) the component parts, nodes and internodes (spiral keel and interspiral concavity) are alike in shapes assumed and in relative dimensions and distribution; (3) both show "forking and dichotomous" branching which results in a colony of a few, relatively long branches; (4) the spiral condition does not prevail throughout the entire existing sponge for nodes of both the ceratodictyoid and cuplike form are present; (5) thick, strong internal spicular support makes possible extensive upright growth; (6) a common paragastrium possibly exists throughout the Recent sponge as in all of the fossil representatives, albeit much smaller in the existing species; (7) external reticular chequer or reticulum is present on the internodes of both, and probably over the nodes of the Recent forms as in the fossil ones; (8) internodal parietal pores occur in the Recent sponge, in essentially the position where the pores seem to be concentrated on the disk of the cup in *Titusvillia, i. e.,* internodally.

The differences between the sponges are of a very different degree. Perhaps the most outstanding difference lies in the possibility that the entire central region of *Sclerothamnus* is filled by the axial fascicle of acicular spicules, whereas in the fossil forms the support is concentrated in the body wall region. But Murie has cast doubt on the postulated complete filling of the central zone by the spicular sheaf. Certainly the Challenger illustrations clearly indicate a true paragastrium in the more proximal portions of the colony. No paragastric reticulum has been described for the Recent sponge, but this is due in part to the inadequacy of our knowledge of the interior zone of the sponge, and in part to the assumption which Schulze and others have made that there is a solid axis throughout. Wherever a paragastrium exists, it is safe to predict the eventual discovery of a chequer.

It is very clear from the illustrations of *Sclerothamnus* given on Plate 5, fig. 1, that the basal zone of the sponge was hollow, and that the outer mat of spicules was of such rigidity that it has ruptured longitudinally since death. This ruptured condition is seen so frequently in the Paleozoic sponges that it takes on great systematic importance. There is even a suggestion of a free paragastric tubule in the basal branch of the large specimen illustrated on Plate 5.

It is unfortunate that the students of *Sclerothamnus* have stressed so much the so-called spiral growth of the nodal keel of the distal branches. In reality, it seems unlikely that the Recent sponge exhibits any appreciably greater tendency to grow spirally than did the Paleozoic antecedents. In both *Armstrongia* (*Armstrongia?*) and *Titusvillia* the spiral tendency of the brachiation has been discussed. An occasional Paleozoic branch suggests the spiral growth of one cup into the contiguous ones, and the preservation of much of the Paleozoic material in the form of external molds precludes determination of whether or not the fragment was nodose or spirally keeled. Certainly many annular nodes are shown in the illustrations of the Recent sponge, and also a very large percentage of the nodes, both annular and spiral, are duplicate (ceratodictyoid), *e. g.*, the first branch of the right stalk of the colony shown on Plate 5, fig. 1.

Incidentally, the Recent sponge shows no felted terminations of the branches, such as Clarke postulated through erroneous interpretation of paragastic chequers, for the Devonian forms. Until better material of *Sclerothamnus* is acquired, we must not rely too much on the frayed skeletons for life appearance of the sponge. An outer reticulum may have held the nodes and keels in a cuplike or regular ceratodictyoid form.

Since the basal portions of the colony have not been preserved in any of the fossil sponges, detailed comparisons with the extreme base of the large *Sclerothamnus* specimen are inadvisable. It may be of considerable recapitulative importance, however, that the basal zone of the Recent sponge recalls *Protoarmstrongia* in its irregular nodation and open paragastrium. Irregular branching seems also to prevail here. More distally the branching appears to be in the *Armstrongia?-Titusvillia* spiral manner, but this is soon suppressed, and the few branches continue to grow to considerable length without further splitting. The spiral branching appears concomitantly with annular nodes. In distal portions, where the paragastrium appears to be filled solidly with the spicular sheaf, the nodes become spirally disposed. Spiral nodation (keeling) may be a final resolution of a suppressed tendency toward spiral branching.

Schulze's "Tretodictyidæ"

Now let us look to the other branching Hexactinellida assigned with *Sclerothamnus* by Schulze (1887) to his typeless* family "Tretodictyidæ." The family was described as being "with irregularly arranged afferent and efferent canals which penetrate the body wall, and especially the more or less thickened dictyonal framework, not transversely, but obliquely, or in a longitudinal direction, or even in a coiled course." While this family diagnosis appears to be in part tailor-made to embrace the not demonstrably related genera desired to be assigned to it, it does on the other hand principally rehearse the generic and specific features of *Sclerothamnus clausii* which is known in greater structural detail, through Murie's work, than are the other genera assigned to the family. This combination of features has not yet been demonstrated in any other existing genus of sponge.

Schulze's "family" included the genera *Hexactinella* Carter, 1885 (*Tretodictyum* Schulze, MS. *ante* 1887, and plates, 1887); *Cyrtaulon* Schulze, 1887 (new name for *Volvulina* Schmidt, 1880, due to preoccupancy of the name for a gastropod, 1865); *Fieldingia* Seville-Kent, 1870; and *Sclerothamnus* Marshall, 1875 (*Dendrospongia* Murie, 1876).

Schulze's "family" appears now to have been merely a convenient receptacle for a heterogeneous group of sponges not readily assignable in 1887 to any of the families of hexactinellid sponges then known. It is questionable if the genera attributed to the "Tretodictyidæ" are of family affinity. Since we know that the essential peculiarities of branching *Sclerothamnus* are characteristic of the line as far back as the Upper Devonian, when they were as distinct from the rather large hexactinellid fauna of the Paleozoic as the Recent form is unique to-day, we need not hesitate very long in casting out from any family to which *Sclerothamnus* is assigned, any sponges not bearing its essential earmarks.

* Schulze (1887, p. 327) assigned four genera to his family "Tretodictyidæ." The numbering of his genera indicates that there were five originally, doubtless including his undescribed *Tretodictyum*. He indicated, however, that his unpublished manuscript-genus *Tretodictyum*, type of the family, had proved to be identical with Carter's (1885) *Hexactinella*. In the final report, Schulze attributed to the latter genus all the species which he had previously assigned in manuscript to his new genus. Why Schulze retained the typeless name *Tretodictyum* after this explanation is not clear. Perhaps he thought it would be convenient to the student in using the plates which had apparently been engraved with the manuscript name *Tretodictyum* instead of *Hexactinella* before he learned of Carter's work. Seemingly Schulze should have proposed a family based on *Hexactinella*, or some one of the four genera which he included in his typeless family.

There appears to be no evidence that either *Fieldingia* or *Cyrtaulon* is a branching sponge. There is naught in the analyses or illustrations of these genera that would ally them with *Sclerothamnus* or the titusvilliids. The little we know of *Fieldingia* suggests the possibility that it is based on an immature fragment, the adult form of which is either unknown or not as yet correlated with it. Neither Schmidt's *Cyrtaulon* from the Gulf of Mexico nor the specimen cited in the Challenger Report from Little Ki Island in the Pacific, is ramose and they appear to be of a very different structural plan from either *Hexactinella* or *Sclerothamnus*.

Hexactinella (*"Tretodictyum"*) is a genuinely branching sponge. Three species were mentioned in the Challenger Report. Of these we may temporarily disregard *H. ventilabrum* for it is based on very inadequate material and apparently does not branch. *H. tubulosum* and *H. latum* are branching sponges. Schulze's (1887, p. 328) diagnosis of *Hexactinella* follows:

> The walls of each of the cup-shaped or tubular specimens are transversed by canals, which are not exclusively disposed at right angles to the bounding surface.
>
> The dictyonal framework is principally composed of radial, longitudinal, straight or slightly bent fibrous, reticulate plates, about 1.5 mm. in breadth. These are separated from one another by spaces of similar form and breadth, but are at the same time bound together laterally by numerous transverse beams. A more irregularly developed fibrous network with round openings extends in some species over the outer, in others over the inner (gastral), surface of the dictyonal framework, and thus conceals either on the outside or inside the above-mentioned longitudinally directed radial plates and their cleft interspaces.
>
> The dermal and gastral skeletons consist of pentacts or hexacts and numerous scopulae of various forms. In addition to the delicate uncinates, numerous oxyhexasters, discohexasters and more rarely oxyhexacts and discohexacts appear in the parenchyma.

It is problematical if the flabellate *H. latum* is really generically related to the tubular *H. tubulosum* which has a decidedly ramose aspect. But since it is further highly questionable if the branching, but not nodose, sponge is related more than possible in an ordinal manner to *Sclerothamnus*, it, too, can be dismissed from the current discussion. *H. tubulosum* may shed some homeomorphic light on the possible manner in which the branching form of the titusvilliids arose. The relatively enormous gastric or paragastric cavity may extend through the whole branching colony, and is in this respect reminiscent of the Paleozoic titusvilliids. The presence of an "irregularly developed fibrous network" sometimes over the exterior and sometimes over the inner, gastric, surface is also extremely interesting and worth further investigation.

It appears therefore that most or all of the genera included in the "Tretodictyidæ" aggregate are separate genetic lines. *Sclerothamnus* appears to be a relict of the Paleozoic horde of "zoölogical primitives." The consonance of this appearance with fact depends in some degree on results yet to be gleaned from the neglected "Problematica" of "nodose worm-burrow" mien which in all likelihood thread the miles of marine strata bridging the gap in titusvilliid history from Mississippian to the present.

ORDINAL RELATIONSHIPS

It will be noted that in the systematic section of this paper no ordinal headings are employed. This omission is due to two reasons: (1) there are insufficient data at hand to make ordinal assignment reasonably certain; (2) it seems questionable if satisfactory orders have yet been defined in the Hexactinellida.

Zittel (1887, and subsequently in his textbook) restricted the order Lyssacina to sponges in which the spicules generally remain isolated, or are connected only by protoplasm (or occasionally by secondary silica, Hall and Clarke, 1898). He restricted the Dictyonina to those sponges in which the spicules are fused, axis to axis, to form a lattice, the canals of each spicule being distinct, however. The assumption was that these characteristics are of systematic importance worthy of ordinal ranking.

Schulze (1887) came to the conclusion, after reviewing virtually all Recent siliceous sponges for the Report of the Challenger Expedition, that the dictyonine condition has been independently attained by several lines of hexactinellids, and that the so-called order Dictyonina is polyphyletic. He considered the term of great descriptive value, but of no systematic worth. Zittel apparently never seriously considered this opinion.

Schulze placed great stress on free spicular details and prepared a rather telling analytical (though questionably phylogenetic) "tree" of spicular relationships among existing hexactinellids. He thought that the dictyonine state was independently attained among the "Uncinitaria" four or five times; in the nonuncinitarians, once (Meandrospongiidæ). What he termed a "pseudo-dictyonalian" condition exists in the Euplectellidæ among the nonuncinitarians. Schulze did not consider fossil hexactinellids in his classification, but apparently the Dictyospongiidæ would have been placed near the base of his tree among free-spiculed forms. The Titusvilliidæ, on the other hand, would apparently have been considered as aligned with the "Scopularia" and "Uncinitaria" and, like *Sclerothamnus,* would have been described as dictyonine.

Reëxamination of all of the fossil material of the Titusvilliidæ in the light of the reticular plan found in the presumed derivative *Sclerothamnus* leads to the conclusion that in the fossils a condition exists quite different from that found in the lyssacine dictyosponges. Caster showed in 1939 that the reticula of *Titusvillia* (and also *Armstrongia*) are chequers of a curious textilelike quality, single layered, and netlike. From some sections of the holotype of *Titusvillia* it seemed (1939) that a slight terminal overlapping of the radii of reticular spicules occurred, especially on the vertical axes, whereas the horizontal axes appeared to meet end on in a dictyonine manner. In *Sclerothamnus* the reticulum is of the dictyonine type wherein the axes meet in both directions, though the canals of adjoining spicules are not continuous. It now appears that in the Titusvilliidæ (Titusvilliinæ) we may have the oldest example of an approach toward the true dictyonine condition among the Hexactinellida.

The imperfection of the dictyonalian structure in *Titusvillia* seems to support the contention of Schmidt (1880) and Schulze (1887) that the lyssacine condition is most primitive and that the dictyonine condition is attained therefrom. We have no knowledge of the spicular plan in *Protoarmstrongia*, but the general absence of a distinct reticular pattern on any of the abundant material suggests rather strongly that the chequer was still more imperfect than in *Titusvillia*.

Schulze's discount on the ordinal importance of the lyssacine and dictyonine conditions appears to have considerable merit. Certainly when we see existing forms, such as *Hertwigia* (cited by Schmidt, 1880), the branched base of which is first dictyonalian, later transitional, and finally, toward the upper and external portions, becomes lyssacine, it seems that the traits are thoroughly interwoven. It is likely, however, that the lyssacine condition is the most primitive, since nearly all existing glass sponges appear to begin life as lyssacines. Schmidt (1880) stressed the evidence of lyssacines and dictyonines growing together in former (especially Mesozoic) epoch just as they do to-day. The titusvilliids and dictyospongiids represent a similar association in the Paleozoic.

THE ENVIRONMENT OF THE TITUSVILLIIDÆ

The Paleozoic environments of the Titusvilliidæ and the Dictyospongiidæ are very similar. Up to the present it has been supposed that both lived in a muddy or sandy bottom, well within the zone of clastic contamination, and, judging from the associated biota, in relatively shallow waters. However, it seems worthwhile reëxamining this view in the light of the occurrence of the titusvilliids.

Caster (1939) gave a facies summary of the two groups as known in the Penn-York Embayment of Upper Devonian and basal Mississippian times. The available data seem to show a seaward migration of the sponges, which somewhat exceeded the rate of seaward encroachment of the strand during that off-lap phase of geologic time. Whether the seaward and presumably deeper adaptation of the sponges is indicative of a long-range environmental change or not cannot be evaluated on present evidence. This we do know, however, after the Mississippian, glass sponges are great rarities in the fossil record. This has usually been correlated with the assumption that during the late Paleozoic and Mesozoic the sponges were becoming adapted to the relatively inaccessible deep sea environment which they as a group inhabit to-day.

Judging from the preservation of the titusvilliids, it seems highly likely that they established themselves on muddy bottom during a quiescent period of the shallow sea. The abundance of skeletal material in certain beds intimates luxuriant colonial existence. Probably titusvilliid colonies could establish themselves only during the brief on-lap interlude of the oscillatory but generally regressive history of the Embayment. Since their skeletons have not yet been discovered in the mud, it is worth considering if they lived where we find them during the mud-accumulation phase. We know them only as thanatocœnose in the sandstones overlying the muds. Nowhere have the sponges been seen in sandstones which merge transitionally with underlying shales. This leaves us with the intriguing possibility that the titusvilliids (and also the dictyospongiids) may be diastemic in their relation to both mud and sand, in a sense bridging the nonconformity between the two sedimentary phases. While it is highly unlikely that the muddy bottom sank to profound depths whilst the sponges established themselves, it is not impossible that the vertical oscillation of the bottom of the Embayment may have been on occasion far greater than has been usually supposed. The commonness of sharp, erosional and nonconformable contacts of the sandstones on the shales strongly points to rapid changes of some magnitude as a usual feature of the regressive phase in the Embayment.

The sedimentary cycle insofar as it is related to the titusvilliids may have been as follows:

(1) Moderately deep, offshore marine waters in which fine clastic silts and muds accumulated; mud-loving organisms and pelagic and nektonic forms preserved in moderate profusion.

(2) Relatively sudden regional and differential sinking of the bottom; sedimentation essentially halted due to the failure of clastic supply; progressive invasion of the mud bottom by benthonic biota including siliceous sponges; essentially a nonrecorded interlude in the sedimentary cycle —a diastem.

(3) Sudden shallowing of water and renewal of clastic sedimentation of much coarser grain than during stage (1); strangulation of the static benthos by silts; lodging of fine, by-passing silts in the spicular skeletal mats of the dead sponges; burial of the silt-heavy skeletons by the sands.

(4) Submergence; gradation of sands into muds of progressively finer type, and eventual reëstablishment of the statozoic benthos on mud bottom in essentially clastic-free water, in accord with stage 2, above.

The Challenger Report brought out very vividly that, despite their deep water occurrence, the modern siliceous sponges decrease both in species and numbers as their distance from land increases. They occur in tropical, north and south temperate zones. The south Pacific and Indian oceans have the largest faunas, but they exist in considerable numbers in all seas and oceans. The North Atlantic is poorest in number and variety of Hexactinellida. According to data given by Schulze (1887) and Walther (1893) siliceous sponges live to 3000 fathoms; maximum distribution being 95-300 fathoms, though goodly numbers are taken between 300-700 fathoms. Schulze reported that no siliceous sponges were taken in less than 95 fathoms. In depths of 95-100 fathoms only lyssacine sponges were taken; from 101-1000 fathoms the dictyonine sponges equal or even slightly sur-pass the lyssacine, but the dictyonine sponges are far excelled by the lyssacine at all depths over 1000 fathoms.

The variety of bottom on which existing Hexactinellida live is very great: five species are reported from sandy floor; two from gravel and stones; six from "hard ground"; seven from coral mud; fourteen from volcanic mud; one from green mud; two from red mud; thirty-two from "mud, including blue mud"; eleven from red clay; thirteen from *Globigerina* ooze; seven from pteropod ooze; two from radiolarian ooze; nine from diatomaceous ooze. The "blue-mud" bottom which so many sponges seem to prefer, appears in the Challenger records to have ranged from 95 fathoms to 265 fathoms; the depths of 129-140 fathoms, however, being the depth of half of the species recorded as taken from blue mud bottom.

Obviously much is yet to be learned of the ecology of the siliceous sponges in modern seas. The existing *Sclerothamnus* is too poorly known to yield much useful data for our immediate purpose. It was taken on one occasion at a depth of 360 fathoms from volcanic mud by the Challenger Expedition and is supposed to have come from 80-100 fathoms from unknown, but probably volcanic mud, bottom in another instance.

CONCLUSIONS

The following conclusions have been reached in this discussion of the Titusvilliidæ: (1) The Titusvilliidæ are represented to-day by the genus *Sclerothamnus* of the Indo-Pacific ocean; (2) the family is assignable to neither of the orders Lyssacina nor Dictyonina, since the earliest representatives seem allied to the discrete-spiculed lyssacines, the intervening forms seem to be of an intermediate type, and the existing forms are in part dictyonine; (3) the "orders" Lyssacina and Dictyonina are unnatural and presumably polyphyletic as Schmidt and Schulze long ago concluded; (4) Schulze's family "Tretodictyidæ" of existing sponges is also apparently polyphyletic, and disuse of this typeless "family" designation is highly to be desired; (5) new subfamilies of the Titusvilliidæ are necessary—Sclerothamninæ for existing representatives and Titusvilliinæ for the fossil forms known thus far; (6) a new species, *Armstrongia clarkei* seems to be represented by Clark's 1920 supposed hypotype of his *Ceratodictya oryx*; (7) Clarke's diagnosis of this "hypotype" specimen shows certain discrepancies from the specimen itself; (8) a new genus and species, *Protoarmstrongia ithacensis*, representing the oldest known titusvilliid, occurs in the Enfield formation (Upper Devonian) of the Ithaca, New York, region; (9) the titusvilliids are morphologically very distinct from the hitherto-known Hexactinellida of the Paleozoic; (10) the biotic environment of the Paleozoic titusvilliids and possibly also of the dictyospongiids may be diastemic in relation to their fossil occurrence.

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* Since Norman Newell called attention to the paleontologic possibilities of self-vulcanizing liquid rubber emulsions (Journal of Paleontology, Dec. 1939) the material has been used in the paleontological laboratories at the University of Cincinnati with great success. Molds and casts of concealed interiors, overhangs, etc., are easily made by films of latex rubber. Plaster casts of great fidelity can then be made from the rubber impressions if it seems advisable. The absence of grain in the latex film greatly increases the fidelity of casts to originals. The material used was purchased from the Self-Vulcanizing Rubber Co., 605 West Washington Blvd., Chicago, Illinois. More recently we have used with unusual success a rubber emulsion prepared by the American Anode Co., 60 Cherry Street, Akron, Ohio, under the name "Clear Molding Compound", No. 10099-A, after a formula prepared in collaboration with Mr. Von Feurer, Preparator at the Carnegie Museum. This latter material is less liquid and much easier to apply without the danger of tiny bubbles. Very faithful enlargements have been made by soaking the rubber molds in kerosene and making plaster casts from the expanded molds in accordance with procedures worked out by Mr. Von Feurer.

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PLATES

PLATE I (VOL. PL. 33)

EXPLANATION OF PLATE I (33)

In referring to the figures 1-4 of *Armstrongia clarkei* Caster, see finding-diagram of the holotype specimen illustrated as text figure 2, page 14. See also J. M. Clarke's restoration of this specimen (1920).

Figure *Page*

1-4. *Armstrongia clarkei* Caster, n. sp. 13

From the Upper Devonian, 9 miles south of Erie, Pa. (Chadakoin formation probably) collected by E. J. Armstrong. Photographed from a latex rubber mold of the type specimen No. 2071/3, New York State Museum.

Fig. 1. Shows central part of the holotype slab, illustrating portions of colonies 1 and 3; colony 1: zone *i* where branch 1 and main axis of colony 1 meet; paragastric fragment *n*; disrupted paragastric tube *g;* branch II of colony 1, with the important double reticular zone *a;* biramous relation of branches III and IV; colony 3: branch I, paragastric fragment *h*.

Fig. 2. Shows colonies 2 and 5 on upper part of holotype; inverted in relation to text figure 2. Colony 2: axis with paragastric tube preserved inside the outer spicular felt; zone *k* showing the inner net and zone *b* showing branch VII lying along branch IX; branch X may be in connection with either branch VII or IX as the photograph brings out very clearly; ceratodictyan nodes of branch IX well shown. Colony 5: with zone *c*, either a "hold fast" (Clarke) or a cross section of a vertical sponge tubule at a point of branching; *d* a paragastric remnant, not a swollen termination of a branch.

Fig. 3. Detail of the junction of branches VIII and IX of colony 2.

Fig. 4. Detail of the junction of colonies 1 and 3.

5-6. *Armstrongia oryx* (Clarke) 13

From the Upper Devonian, 6 miles south of Erie, Pa. (Canadaway formation probably) collected by E. J. Armstrong. Photographed from latex molds of the syntypes in the New York State Museum. Fig. 5, No. 2071/2; fig. 6, No. 2071/1.

All Illustrations Natural Size

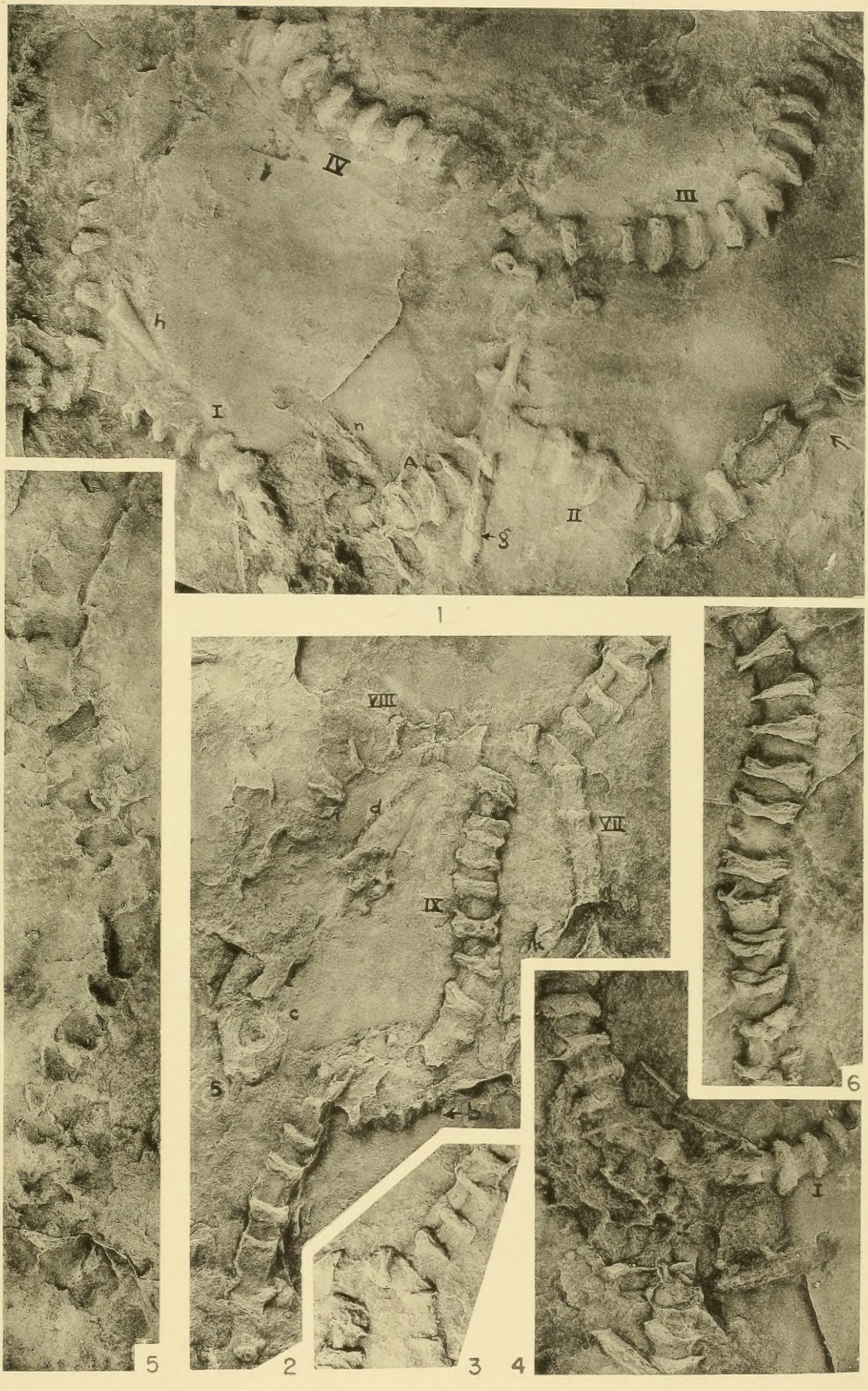
IV
III
h
I
n
A
g
II
1
VIII
d
VII
IX
k
c
5
b
6
I
5
2
3
4

PLATE II (VOL. PL. 34)

EXPLANATION OF PLATE II (34)

In consulting the photographs on this plate use text figure 3, page 19, for orientation.

Figure		*Page*
1-4.	*Protoarmstrongia ithacensis* Caster, n. sp.	19

From the Upper Devonian, Enfield shale and sandstone (Senecan series) the Hungerford quarry, Town of Ithaca, New York. Holotype flagstone slab, University of Cincinnati Museum type No. 22458. See also Plate 3.

Fig. 1. Holotype sandstone slab showing 7 colonial fragments of archaic branching sponge. Compare with text figure 3, page 19. Approx. 1/4 natural size.

Fig. 2. Showing detail of the junction of colonies 1 and 2 at the zone marked with an asterisk on text figure 3, and the entwining of the A_3 axis of colony 1 with A_4 and branch II of colony 2; $\times 1$.

Fig. 3. The A_1 sector of colony 5 showing some of the best development of cuplike nodes on the holotype slab. Note ceratodictyan duplication in lower part of photograph; $\times 1$.

Fig. 4. Basal part of colony 1 and adjacent colony 5. Reversed orientation when compared with text figure 3; point x of the diagram is well shown, and also the paragastric nature of branch III. See also Plate 3, fig. 4; $\times 1$.

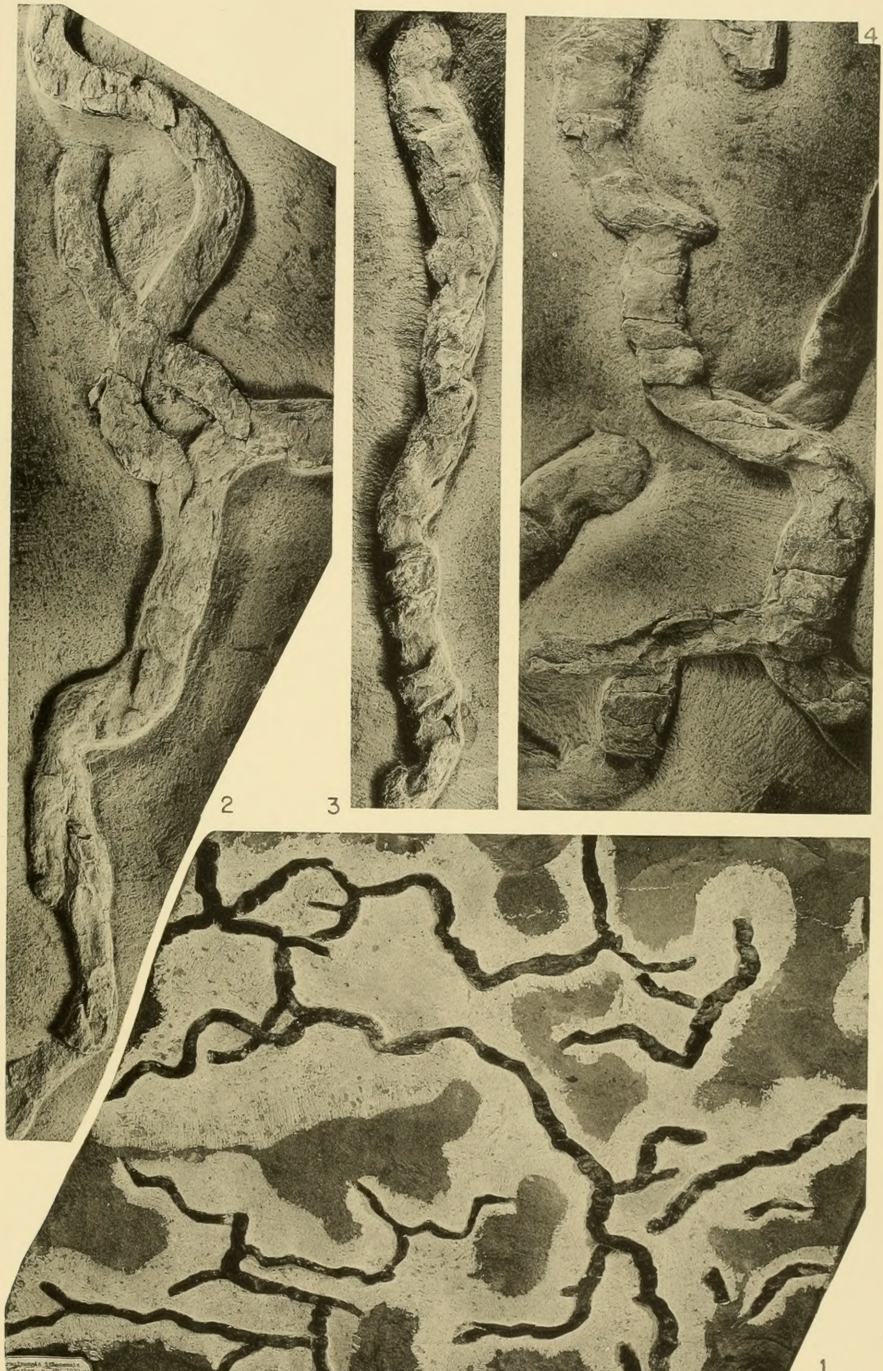
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PLATE III (VOL. PL. 35)

EXPLANATION OF PLATE III (35)

See also text figure 3, page 19, for relationship of the parts here illustrated to the whole holotype slab, which is also illustrated on Plate 2, figure 1.

Figure *Page*

1-7. *Protoarmstrongia ithacensis* Caster, n. sp. 19

Fig. 1. Detail of colony 6 and adjacent part of colony 5. Orientation reversed in relation to text figure 3; ×1.

Fig. 2. Enlargement of branches I, II, III of colony 1 and contiguous part of A_1, colony 5, showing several nodes. Terminus of branch II unknown since branch sinks vertically in the matrix at distal exposure here; ×1.

Fig. 3. The *c* section of supposed colonial fragment 7; shows collapse of the outer reticulum due to absence of paragastric filling; ×1.

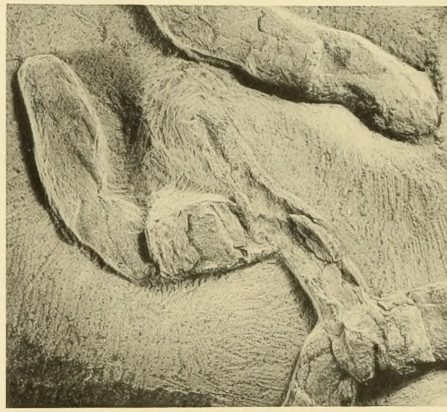
Fig. 4. Enlargement of basal part of colony 1. See also Plate 2, figure 4. The outer limonitic crust of spicular felt shows very well; ×2.5.

Fig. 5. Basal portion of colony 4; reversed orientation in relation to text figure 3, ×1.

Fig. 6. Basal portion of colony 2 and its relationship to A_3 and branch III of colony 4. The crossing over of A_3 shows very clearly; ×1.

Fig. 7. Basal section of colony 6 and contiguous A_3 of colony 5. Note the nodes; ×1.

1



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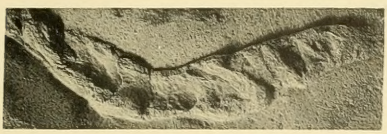

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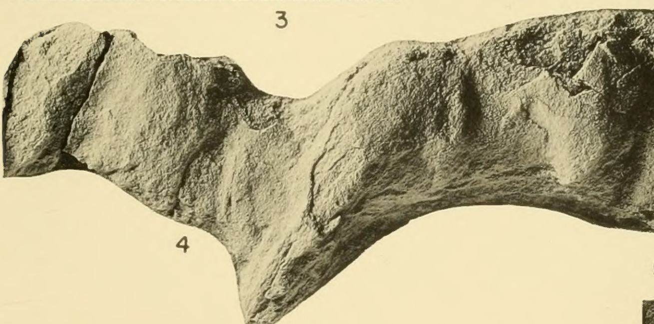

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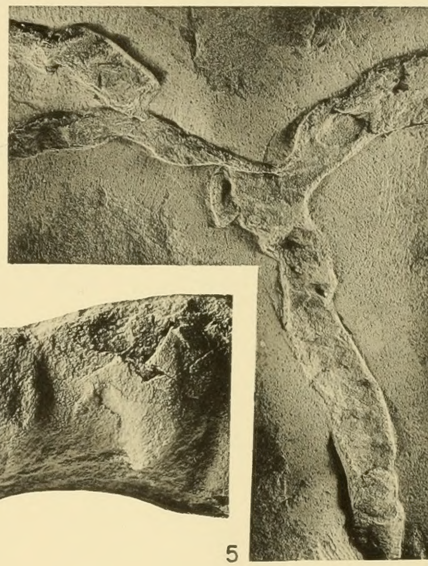

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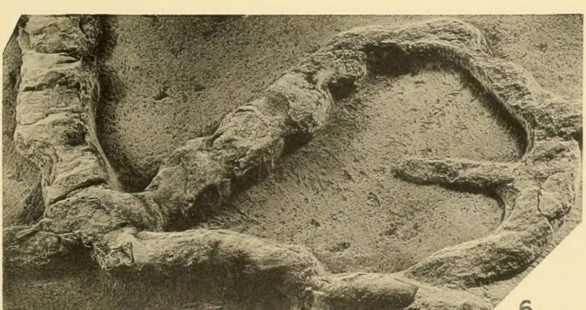

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PLATE IV (VOL. PL. 36)

EXPLANATION OF PLATE IV (36)

In examining the photographs in detail, reference should be made to text figure 8, page 19, in Caster's 1939 description of *Titusvillia.*

Figure *Page*

1-5. *Titusvillia drakei* Caster 9

From the Tidioute member of the Cussewago stage, Oil Lake series (Lower Mississippian) Church Run, Titusville, Pa. Holotype, University of Cincinnati Museum No. 22130.

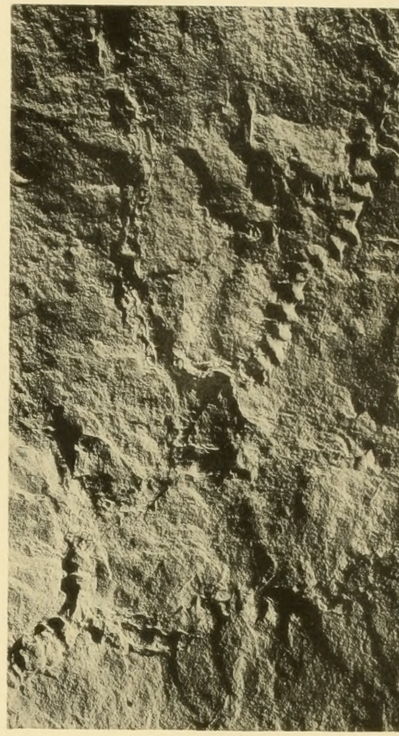
Fig. 1. Major part of the holotype slab, showing the attitude of the rami to the axis.

Fig. 2. Portion of branch V of the holotype. Lighting reversed to create illusion of convexity to external mold, thus bringing out the cuplike nodation of the sponge; ×3.

Fig. 3. Middle section of branch IV, showing natural vertical section through outer reticulum and mud filling of sarcode zone. Paragastric tubule shown indistinctly. Cup-shape nodes of outer reticulum well shown; ×1.

Fig. 4. Distal fragment of branch III, showing external mold of the outer reticulum and a short section of the paragastric tubule in its central position and also lying free of the outer tubule. This condition is highly characteristic of the Paleozoic titusvilliids; ×1.3.

Fig. 5. Enlargement of the continuation of the paragastric tubule shown in fig. 4. Arrows indicate nodes on the paragastric filling which correspond in spacing to external cups. At each paragastric node radial tubules communicated with the exterior, apparently always on the disc of the cup; ×3.



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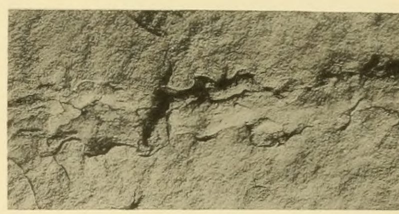

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PLATE V (VOL. PL. 37)

EXPLANATION OF PLATE V (37)

Figure *Page*

1-4. *Sclerothamnus clausii* Marshall 31

Modern hexactinellid sponge from the neighborhood of the Philippine Islands, from a volcanic mud bottom 80-100 fathoms deep, between the islands of Negros and Cebu. All illustrations from the Challenger Expedition Report.

Fig. 1. Schulze's reillustration of Murie's *Dendrospongia steeri*, best known example of *Sclerothamnus clausii;* note the similarity of branching and form to the Paleozoic titusvilliids. Note that most of the nodes (spiral band in reality) are ceratodictyan double nodes rather than cups; ×1/4.

Fig. 2. Detail of another fragment of the Recent sponge (Challenger Expedition material from off Timor?). Shows nature of branch endings. This is supposedly an abraded specimen from which the outer reticulum has been worn away except for the internodes; ×½.

Fig. 3. Detail to show the parietal pores in the internodal zone. Since all specimens recovered thus far have been abraded, it is not known if the pores extend to the nodes as well; ×1.

Fig. 4. Sketch from the Challenger illustration showing the fascicle of axial spicules and their outbending to form the nodes; ×½.

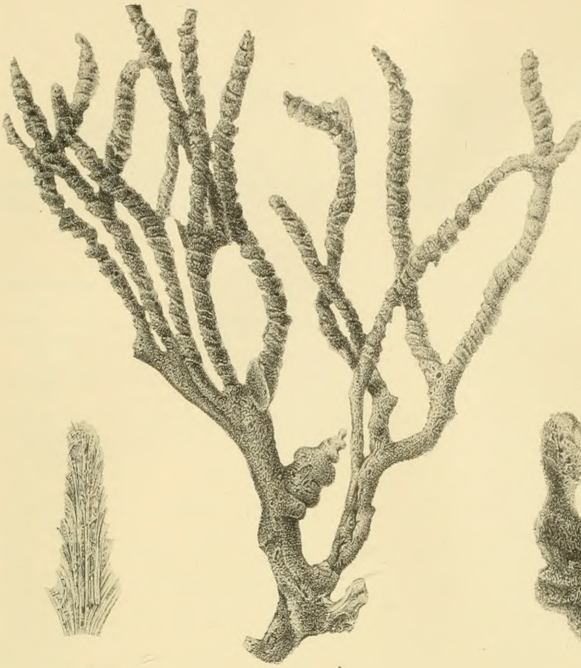
5-6. *Protoarmstrongia ithacensis* Caster 19

See also Plates 2 and 3.

Fig. 5. Terminus of A_4 and branches IV, V, and axis A_5 in colony 6 of the holotype; ×1.

Fig. 6. Termination of colony 3 with adjacent IIa of colony 4; ×1.5.

3



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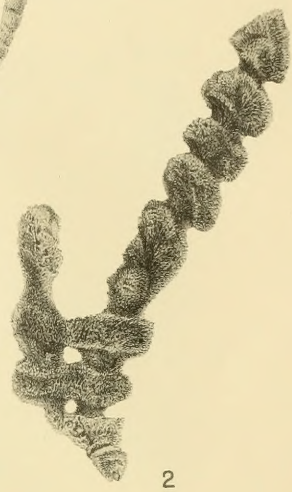

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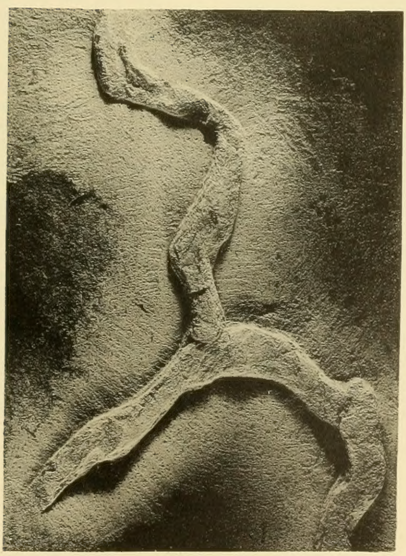

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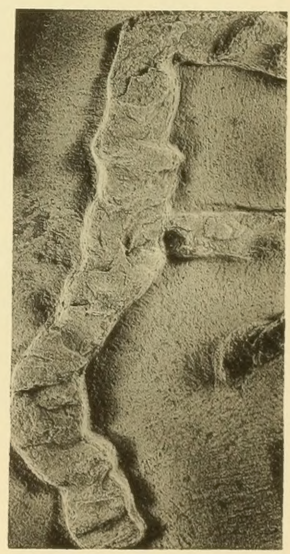

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