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PART I
Revision of *Buttsoceras*

PART II
Notes on the Michelinoceratida

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1962

STATE BUREAU OF MINES AND MINERAL RESOURCES NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

CAMPUS STATION **SOCORRO, NEW MEXICO**

Published October I2, 1962

For Sale by the New Mexico Bureau of Mines & Mineral Resources
Campus Station, Socorro, N. Mex.—Price $2.00

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PART I

REVISION OF *BUTTSOCERAS*

Abstract

New material of *Buttsoceras* increases its range from Alabama through southern New Mexico and into northern Utah; it appears confined to the very latest phase of the Cassinian. The genus possesses a nonsegmental lining in the siphuncle, thickening gently apicad like very slender endocones, which may terminate in a narrow tube that may be traversed by diaphragms. The inadequately known *Oxfordoceras* is not distinguishable from *Buttsoceras;* uncertainty surrounds the origin of its genotype. *Buttsoceras* shows fine lamellae in the lining of the siphuncle and thin homogeneous rings; it is referred to the Troedssonellidae of the Michelinoceratida, The study also involved some material referred to *Michelinoceras,* present with *Buttsoceras* in the Odenville and possibly in the Garden City Formation; M. primum, from the lower Cassinian part of the El Paso, is the oldest representative of the order Michelinoceratida so far recognized.

The family Troedssonellidae is revised to include *Buttsoceras*.

Introduction

This study is a reinvestigation of *Buttsoceras,* involving new and some old material. The genus was first distinguished as an orthocone generalized in most features, being a straight slender shell with transverse sutures and a subcentral tubular siphuncle, but set apart by the presence of a free tube within the siphuncle. This was, however, only one of several morphological surprises yielded by the study of the older cephalopods (Ulrich and Foerste, 1933). Ulrich, Foerste, Miller, and Unklesbay (1944) assigned *Buttsoceras* to the family Orthocerotidae, but they included a number of straight shells in the family, such as *Ellesmeroceras* of the Ellesmeroceratida and *Proterocameroceras* of the Endoceratida, which had little in common other than the demonstration of the fact that their siphuncles involved short septal necks, and a number of poorly known genera of straight shells. Flower (Flower and Kummel, 1950) placed *Buttsoceras* in a family by itself on the basis of the free tube and assigned it to the Ellesmeroceratida. It was later noted (Flower and Teichert, 1957) that a possible explanation of the free tube could be found in the calcification of the wall of the artery within the siphuncle, and that similar tubes had been found in some Discosorida as well as in *Harrisoceras* of the Michelinoceratida. It was, nevertheless, remarkable to find such a tube in a genus known only from the late Canadian, where at that time no evidence of other than three primitive orders, the Ellesmeroceratida, Tarphyceratida, and Endoceratida, had been found.

The new material which forms the basis of the present study shows the supposed free tube, which is perfectly visible and obvious in the suite of type specimens of *Buttsoceras adamsi,* to result from a peculiar preservation phenomenon. *Buttsoceras* actually develops within its siphuncle a lining, thickening gently apicad; under slight silicification, shell wall, septa, the exterior of the siphuncle, and the inner surface of the lining are replaced, but the main mass of the lining remains calcareous. Under leaching, such specimens present the aspect of a free tube within the siphuncle. The condition is analogous to that noted by Yochelson (1957) in *Palliseria,* in which the thick shell wall, being silicified on the outer and inner surfaces, presents the deceptive aspect of being composed of three original layers. It should be noted that the pre vious known material of *Buttsoceras* consisted exclusively of a suite of silicified specimens picked up on deeply leached outcrops of the Odenville limestone (see Butts, 1926).

The condition is shown strikingly by the specimen here described as the holotype of *Buttsoceras williamsi,* from the upper cherty beds of the Garden City Formation. It demonstrates the nature of the lining of *Buttsoceras* in a specimen very similar in general proportions to *Buttsoceras adamsi* itself, but though the specimen was partly silicified, showing silicification of the inner surface of the lining, it was found unleashed in limestone.

Material of *Buttsoceras adamsi* from the Odenville limestone was restudied, and several thinsections were attempted. In spite of the silicification and leaching to which this material had been subjected, some specimens were found corroborating the above interpretation. However, one of the sectioned specimens showed, not a lining within the siphuncle, but small annuli concentrated at the septal foramena, and it was evident that the suite of specimens, designated as unfigured plesiotypes, contained not only *Buttsoceras* but a species of *Michelinoceras.* The specimens consist of portions of phragmocones, none longer than 35 mm and most of them much shorter; surely such specimens, even when available in considerable numbers, supply a very insecure basis for critical decisions at the specific level. The present material contained at least two species which were so different internally that they could not be placed in the same genus or even the same family. This material suggested also that *Buttsoceras* had the thin, homogeneous connecting rings of the Michelinoceratida rather than the thicker, more complex, commonly layered rings found generally in the Ellesmeroceratida.

It already seemed highly probable that *Buttsoceras* had a siphuncle which, in wall structure and the development of a continuous nonsegmental lining, was allied to that of *Troedssonella* Kobayashi (1935) known only from one species, T. *endoceroides* (Troedsson, 1932), but material so far found exhibited a lining and a siphuncle wall which were both considerably altered. The discovery of additional material of *Buttsoceras* in the highest El Paso of the Florida Mountains of New Mexico supplied additional and considerably less altered material which offered much better evidence of the relationship. Not only was the siphuncle wall less altered, but some of the material showed the lining to be composed of fine, closely spaced, thin layers, like the lining of *Troedssonella.* The material showed an additional feature, which had not been expected; namely, that where the lining is essentially fully grown, there remains only a small tube within the siphuncle and even this tube may be traversed by diaphragms. It thus became necessary to re-examine the concept that these singular cephalopods might be derived Endoceratida, a possibility which seems most unlikely from the present evidence. Certainly *Buttsoceras* and *Troedssonella* are to be placed in a single family, and as the family name Troedssonellidae Kobayashi (1936) has priority, it is desirable to suppress the family name Buttsoceratidae as a synonym.

Looking further afield, it is evident that there are no features by which the little known genus *Oxfordoceras* of eastern North America can be distinguished from *Buttsoceras. Oxfordoceras (?) atticus* was described as having a thick-walled siphuncle considerably removed from the venter of the shell. With the reservation that the thickening is probably produced by a lining like that of *Buttsoceras,* the structures are not distinguishable. Plainly, had *Buttsoceras* not been interpreted on the basis of what is now evidently the result of rather peculiar conditions of preservation, *Oxfordoceras* would never have been distinguished as a separate genus.

The discovery of *Michelinoceras* with *Buttsoceras* in the Odenville limestone raised the question as to whether the Troedssonellidae with a nonsegmental lining or the Michelinoceratidae with small annuli in the siphuncle were primitive, and also which is derived from the other. Stratigraphic evidence as to which is the older lineage is, of course, significant, and it has seemed worthwhile to include here a description of a *Michelinoceras* from the lower part of the Cassinian portion of the El Paso limestone, which lies well below the horizon yielding *Buttsoceras.* However, it must be noted that future finds may alter this situation, and in view of the surprises which the Canadian is still yielding in its cephalopods, the present stratigraphic evidence may not be conclusive.

It appears probable that *Buttsoceras* is a genus particularly characteristic of the closing phase of Cassinian deposition. The first known materials were those of the Odenville limestone of Alabama. Cloud and Barnes (1946) suggested correlation of the highest El Paso with the Odenville, the highest layers of the Arbuckle limestone of Oklahoma and the Black Rock limestone of Arkansas. Indeed, they tentatively identified *Buttsoceras* in the highest El Paso of the Beach Mountain section of Texas. Though the specimen is a small fragment, the writer would endorse the generic determination. No *Buttsoceras* has been recognized from the highest Canadian of the Arbuckle limestone nor from the Black Rock of Arkansas, but the additional finds of *Buttsoceras* in the highest El Paso limestone have supported the correlation of Cloud and Barnes, which was originally based primarily upon the associated brachiopods. The Garden City succession contains a series of beds ranging in age from early, possibly earliest, Canadian into post-Canadian beds formerly considered as possibly Chazyan (Ross, 1951), but now probably more properly interpreted as belonging in the Whiterock stage of Cooper (1956). That *Buttsoceras* occurs in the upper cherty member of the Garden City succession, but certainly in beds well below the top, is consistent with the suggestion that it is also confined to the very latest Canadian there. Unfortunately, the few specimens known at present, while certainly from the upper cherty beds, are without precise information as to exact elevation or as to associated faunal elements. It may be hoped that future field observations may establish the position of the genus in reference to the faunal zones, based primarily on trilobite associations, established by Ross (1951)•

Inquiry as to whether the synonomous *Oxfordoceras* is also from the highest Canadian yielded the information that *Oxfordoceras (?) atticus* is from the Corey limestone, above the Solomons Corners limestone which carries a cephalopod fauna similar to those of the Ft. Cassin and Smithville formations but below the Basswood Creek limestone, concerning the fauna and correlation of which almost nothing is known. Unfortunately, the precise geographic and stratigraphic origin of *Oxfordoceras billingsi,* the type species of the genus, is uncertain and requires further confirmation from the collecting of additional material (Alice Wilson, *fide Litt.),* as is noted more fully below.

As usual, many extensions of the present study were suggested which could not now be pursued. Further confirmation of the position of *Buttsoceras* in Utah, Quebec, and Ontario was desirable, but even had such field work been possible, there is no assurance that it would yield ready results. Possibly also, further investigation of the latest Canadian faunas elsewhere might yield additional *Buttsoceras.* More material of all the occurrences is needed for more satisfactory decisions at the specific level. In view of the importance of the revised interpretation of the morphology of *Buttsoceras,* its apparent importance in cephalopod taxonomy as well as a possible guide fossil to the closing phase of the Cassinian, it was felt that progress would be better served by the publication of the present results than by delay in the hope of obtaining such needed materials.

Acknowledgments

For help in collecting I am indebted to my wife, to Professor S. G. Williams, and to various associates and students. Dr. G. A. Cooper lent material of the Odenville *Buttsoceras,* as well as material from the Garden City limestone of Utah, which is incorporated in the present study. Dr. Preston Cloud lent the specimen which he had correctly identified as *Buttsoceras* from the highest El Paso of Beach Mountain, Texas.

Dr. Alice Wilson supplied information on the uncertainties surrounding the origin of *Oxfordoceras billingsi.* Additional information and some material requested in a search for possible further occurrences of *Buttsoceras* were supplied by Dr. T. H. Clark of McGill University, Dr. G. M. Kay and Dr. Norman Newell of Columbia University, and the American Museum of Natural History.

A Note on Specific Criteria

It must be noted that while *Buttsoceras* is a genus easily recognized, and one which promises to be significant stratigraphically, our present material is not really adequate for decision at the specific level, merely because the specimens are too fragmentary. Our two specimens of *B. williamsi* are essentially commensurate; the longest shows 70 mm of a phragmocone which, from its slender form, must have extended three times that distance apicad, and, allowing for the general delay of deposits beyond the rest of the phragmocone, must have extended forward for at least 5o more mm of phragmocone to which must be added a living chamber. Our one relatively complete Garden City specimen shows 90 mm of phragmocone within which cameral deposits are developed, thickening apicad, and apparently extending much closer than is usual to the living chamber, if we have interpreted the anterior aseptate part correctly; yet, the siphuncle is completely empty, and it is not certain whether pieces farther apicad would show a lining, which would require assignment to *Buttsoceras,* or whether annuli of *Michelinoceras* are developed there, or whether perhaps there are no deposits in the siphuncle at all. This is the type of *Michelinoceras (?) richardsi,* described below.

Proportions require the recognition of two species in the Garden City limestone, one certainly a *Buttsoceras,* the other of dubious position. Our El Paso materials are somewhat more fragmentary, but three good specimens embrace intervals of shell with diameters of from 13 to 21 mm. The specimens show some variations in proportion and may represent parts of more than a single species.

The Odenville material consists largely of small pieces of phragmocone, few of them 5o mm long and most under 4o mm. It was something of a surprise in going through the material to find representatives of a *Michelinoceras* as well as of a *Buttsoceras.* The *Michelinoceras* can be recognized by the smaller proportionate diameter of the siphuncle and the rather marked constriction of the siphuncle segments at the septal foramen; but there is no certainty that the deeply camerate M. *vandiverense* would not have at such a stage deep camerae and a large tubular siphuncle, such as is shown at portions of larger shell diameter. In inspecting the remaining fragments, all of which are apparently *Buttsoceras,* it is nevertheless apparent that there is variation in spacing of septa and in relative diameter of shell and siphuncle beyond what one would expect *(see* pl. 3, fig. 5-17). On the one hand, one is tempted to attribute this to variation of proportions in the species, but the *Michelinoceras buttsi* shows that previous latitude given in matters of proportion is too lax and clearly invalid, when it allows identification of representatives of two genera as a single species.

The alternative interpretation involves the admission that the small fragments of phragmocone from which *Buttsoceras* is known from the Odenville limestone are not really adequate for critical work at the specific level. There is little hope that collecting in the near future will result in the accumulation of either more complete specimens or, in the case of fragments, enough specimens to give a good sampling of proportions at various growth stages, and large suites of such fragmentary material are needed for accurate investigation at the specific level.

Buttsoceras Ulrich and Foerste

Genotype: *Orthoceras adamsi* Butts 19z6

Buttsoceras Ulrich and Foerste, 5933, Science, n. ser., vol. 78, no. 202, p. 288.
---- Ulrich and Foerste, 1935, Denison Univ. Bull., Sci. Lab., Jour., vol. 3o, p. 265.
---- Ulrich, Foerste, Miller, and Unklesbay, 1944, Geol. Soc. Amer., Special Papers, no. 58, p. 63.
---- Miller, 1943, Biological Reviews, vol. 18, p. 1 oz.
---- Flower and Kummel, 195o, Jour. Paleontology, vol. 24, p. 6o8. -
--- Flower and Teichert, 5957, Univ. Kansas, Paleontology Contrib., Mollusca, Art. 6, p. 27.

Butts (Geology of Alabama, 1926, expl. of pl. 18, fig. 22-23) illustrated *Orthoceras adamsi* and described it most briefly, noting that Foerste considered it probably a new genus but not going into further details.

Ulrich and Foerste (1933) proposed the genus *Buttsoceras,* noting the occurrence of an apparently free tube in the siphuncle, nowhere in contact with the siphuncle wall. Ulrich and Foerste (1935) presented a fuller description of the genus, noting the bilateral symmetry of the cameral deposits and again the presence of tubes in the siphuncle, not present in all specimens, apparently free from the wall and tapering apicad somewhat more rapidly than the exterior of the siphuncle. Ulrich and Foerste had both died before the final appearance of the monographic treatment of the Ozarkian—Canadian cephalopods, which was completed by Miller and various associates. Their revised description of the genus makes no mention of cameral deposits but instead notes "septa thickened except in the immediate vicinity of the siphuncle" and again emphasized the tube in the siphuncle.' They describe and illustrate three species which can be summarized as follows:

Buttsoceras adamsi (Butts)—A slender form, this type increasing only from 12 to 12.7 mm in 3o mm, four camerae in a length equal to the adoral shell diameter, siphuncle subcentral, tubular, rather small, containing a tube. The illustrations show several specimens suggesting some variation in septal spacing, depth of septa, and size and form of the siphuncle.

B. ? *odenvillense* n. sp.—This is a form known from fragments of siphuncles with some adhering portions of septa. The siphuncle segments are at least as broad as long, and the material suggests certainly a species with a proportionately much larger siphuncle than that of *B. adamsi.* The material shows, again, a free tube tapering more rapidly than the enclosing siphuncle.

* Oddly, since it became evident (Flower 1936, 1939) that the conclusion of Miller, Dunbar, and Condra that cameral deposits were formed at the bases of the living chamber could not be true, further observations by Miller have involved little more than vague expressions of doubt as to the organic nature of these structures. Today, this seems as intelligent as scepticism concerning the spherical shape of the earth.

B. ? *vandiverense* n. sp.—This species is based upon a single specimen, showing a very slender shell, camerae much deeper than in the other forms, one and a half camerae in a length equal to the adoral shell diameter, sutures slightly oblique, a large tubular subcentral siphuncle which contains, surprisingly, no tube but instead annular deposits, somewhat flattened and seemingly pressed against the wall of the siphuncle. They note the absence of the tube, supposedly diagnostic of *Buttsoceras,* but fail to mention that annuli such as this species shows are generally characteristic of a host of Michelinoceratidae of dominantly younger age; Barrande has figured numerous examples from the Silurian of Bohemia, and the Silurian *Harrisoceras,* though its annuli are more inflated into the cavity of the siphuncle, is not dissimilar and was reported as showing in some specimens not only similar annuli but also an unsupported tube in the siphuncle.

It is at this point that contributions to our factual knowledge of the genus rested for some years. The statement (Flower, 1946, p. 78) that *Buttsoceras* contains diaphragms is a clerical error; the genus in mind was *Robsonoceras.*

Flower, in Flower and Kummel (195o), erected the family Buttsoceratidae characterized by the free tube within the siphuncle. As was later stated (in Flower and Teichert, 1957), it seemed that the best explanation for this tube was the calcification of a central artery, analogous certainly and homologous possibly with the central canal of the Actinoceratida but unsupported by other structures. Such a free tube appears in *Harrisoceras* of the Michelinoceratida and in occasional Discosorida, being known in isolated examples in *Westonoceras,* prevalent in *Madiganella,* and present in the one illustrated specimen of *Pseudogomophoceras rigidum* (Barrande).

As already noted, our new material requires drastic revision of these views. *Buttsoceras* may now be defined as follows: Slender orthocones, subcircular in section, with a large central or only slightly eccentric siphuncle, tubular, the wall with the thin rings and short straight necks of the older Michelinoceratida; a lining within the siphuncle consists of lamellae which are continuous for their length, from the adoral contact with the siphuncle wall to an indefinite and unknown apex, where presumably they may fill the siphuncle or leave a small tubular cavity; probably the latter condition is general. This cavity may, in advanced growth stages, develop diaphragms. Deposits are developed in the camerae, markedly concentrated ventrally and showing lobation certainly bilaterally symmetrical. Both episeptal and hyposeptal deposits develop. The shell surface is reported as showing fine transverse markings in the genotype. Specimens showing the surface are most fragmentary, and that no hyponomic sinus has been noted is probably not very significant.

As noted below, some of the original material assigned to *Buttsoceras* shows instead of a continuous lining small annuli in the siphuncle, belongs to the Michelinoceratidae, and is referred to *Michelinoceras*. This includes *B. vandiverense* and a new species found in the original suite of specimens from which, apparently, both the holotype and the hypotypes of *B. adamsi* were selected. This is *Michelinoceras buttsi,* described below.

It seems appropriate to discuss at the generic level some features shown by the various species of *Buttsoceras*. That only one specimen shows fine growth lamellae in the lining of the siphuncle is clearly attributable to alteration which affects most of the specimens so far observed; there is no good basis for assuming such structure to be restricted and every reason to attribute its general absence to replacement.

Only one of our specimens, the holotype *B. novemexicanum,* shows the lamellae in the lining; a single paratype shows the cavity reduced to a narrow tube which is crossed by diaphragms. The rarity of this condition may be more apparent than real, due to limitation of the parts shown by the series of phragmocone fragments with which it is necessary to deal.

The paratype of *B. williamsi* shows a narrow, somewhat irregular tube, and the specimen fails to show diaphragms crossing the tube; though the specimen shows a rather advanced stage of alteration, the absence of diaphragms is probably real. This specimen also shows the tube rather irregular, but there is no clear evidence of radial elements extending from it. Oddly, one specimen of *Buttsoceras adamsi* (Ulrich, Foerste, Miller, and Unklesbay, 1944, pl. 24, fig.), suggests radial tubes penetrating the lining of the siphuncle, a feature which may be adventitious, as it has not been observed in other specimens but is worth noting in view of the need for fuller observations in regard to such possible structures.

Our material has been all sadly fragmentary, and the fragments are inadequate to explain one obvious anomaly: how could cameral deposits develop with a camera isolated from the vascular structures of the siphuncle by a lining? No certain answer is possible from the present material, but there is a second anomaly which may have a bearing on the matter, suggesting as it does that cameral deposits may be actively secreted only orad of the development of the lining. This condition is shown by Plate 3, figure 21, in which cameral deposits develop plainly orad of any lining of the siphuncle. A similar condition is suggested by Plate 3, figures 18-20, but this form, a distinct species by its proportions, is not even certainly attributable to *Buttsoceras,* and in the absence of a demonstrable lining, the generic assignment must remain uncertain until more complete material can be studied.

The material here described suggests that the possibly isolated siphuncles of *Buttsoceras* might be mistaken for endoceroid fragments. Rather extensive collecting in the highest El Paso which has yielded *Buttsoceras* in southern New Mexico has, however, failed to yield any such specimens; the locality and horizon in the Florida Mountains from which our material came have yielded some small shells of the aspect of *Protocycloceras* in the association, but no endoceroids or isolated endoceroid siphuncles whatsoever have been found in these beds. One cannot speak with certainty concerning the occurrences in northern Utah, but it is perhaps significant that the available cephalopod material from the Garden City limestone has failed to yield any real or apparent endoceroid siphuncles from the main part of the upper cherty member from which *Buttsoceras* is derived, excluding the top 20 feet where chert is rare or absent. This horizon is quite clearly above that which yielded the *Buttsoceras*. Likewise, no apparent endoceroid endosiphuncles have been reported from the Odenville limestone.

Buttsoceras williamsi Flower, n. sp.

Pl. 2, fig. 1-8, 10-12

This is a *Buttsoceras* with siphuncle segments nearly as wide as long, the siphuncle definitely eccentric, apparently ventrad of the center, below the point of greatest shell width, septa quite shallow in curvature, depth about one-seventh the shell diameter and half or slightly less the length of a camera or siphuncle segment.

The holotype is a portion of phragmocone 7o mm long embedded in matrix; its orientation was somewhat uncertain, the anterior end being seemingly slightly distorted; the specimen was cut in two and the halves cut longitudinally in different directions. In a length of 7o mm, the shell expands from 15 mm apically where the section is round, the siphuncle 6.o mm across, 5.5 mm from the assumed venter, *7* mm from the dorsum; to the adoral end where the section seems slightly distorted, but the siphuncle is 6.5 mm across, the shortest distance from the wall is 4 mm, the greatest 1 o mm. Apically, two and a half camerae occupy a length equal to the adoral shell diameter; adorally, three camerae occupy a corresponding length. Siphuncle segments are nearly as broad as long; apically, the length is slightly greater than the width; adorally, the width is 0.5 mm greater than the length. A characteristic feature of the species is the rather shallow curvature of the septa, equal to or slightly less than half the length of a camera or siphuncle segment.

The type was cut transversely in the middle, and longitudinal sections were taken of the two parts in planes of different inclination. The two surfaces of the adoral part, shown in Plate 2, figures 1 and 2 with enlargements of the siphuncle in figures 6 and *7,* show a lining in the siphuncle, gently thickening adapically. In figure i the section is central, and the lining can be seen, slightly thicker ventrally than dorsally, with the cavity within partly occupied by calcite. The surface of the lining is clear, very faintly segmental, conforming to the very slight contractions of the siphuncle at the septal foramina, but growth lines are suggested rather than shown, for the material of the lining has been extensively replaced and original textures are altered. The opposite surface of this cut, shown in figures 2 and *7,* is eccentric and does not reach the internal cavity of the siphuncle. Here the lining is seen with a dark outer portion, a light adjacent portion, and a darker inner portion which in the plane of this section is expanded in each segment. The apical portion shows the siphuncle interior so replaced that interpretation is difficult; the plane of the section shown is essentially central, and adorally one could interpret the outer dark portion as the lining and the inner part as an inorganic filling, but apically the distinction is not clear; it is evident that with advanced replacement the distinction between organic and inorganic calcite is obscured.

A second specimen shown in Plate 2, figures 10-12, supplies some additional information. This specimen is a fragment of siphuncle 55 mm long, with septa attached and portions of the shell wall preserved. The weathered surface shown in figure i o is nearly horizontal and the dorsum has been removed; the siphuncle lies ventrad of the center, and the maximum shell diameter is not shown. Segments increase in length from 5 to 5.1 mm and in width from 5.5 to 7.o mm. At midlength the shell shows a width of 16 mm, apparently not quite complete; the septa are shallow in curvature as in the holotype.

A portion of the siphuncle was ground down, and two illustrations are given showing surfaces at two very slightly differing depths. In figure 11 is seen an adoral part, cut slightly below the remainder and etched; silicious bands strongly suggesting annular structure in the lining are present, and though they may outline organic structure, they have certainly exaggerated any original annular condition which may have existed. The remainder of the surface shows a lining that is greatly thickened so that the cavity within it is a narrow tube, the course of which is slightly irregular in the adoral portion, though straighter apically. Clearly the tube is free from diaphragms. There are suggestions of annular structure in the lining, but precise analysis is impossible from the evident advanced condition of replacement. In figure 12, the anterior end is identical, but the lower three fourths has been ground very slightly lower and the plane of the section passes apically just below the central tube. Here again are seen suggestions of annular entities in the deposit and much the same irregularities in the tube.

All sections of both holotype and paratype show short straight septal necks and connecting rings which are thin and apparently homogeneous. Though both specimens show the lining in the siphuncle, the holotype, in which the lining is relatively thin anteriorly, shows no trace of cameral deposits, though incipient deposits could be present but could be obscured in recrystallization of organic calcite in the apical camerae. The paratype is a portion farther from the living chamber, farther from the anterior thinning end of the siphonal lining, and vestiges of cameral deposits thicken the septa slightly on either side of the siphuncle.

Discussion.—Though as was noted above the available specimens of *Buttsoceras* are such scraps as to be generally indecisive at the specific level, it is evident that the holotype and paratype represent a single species with the siphuncle large, segments about as broad as long, with rather distant septa distinctive in their shallow curvature. It is also evident that the lining in the siphuncle appears in camerae void of cameral deposit, and the lining must thus have extended farther forward in the phragmocone than did the cameral deposits. The lining thickens apicad only most gently, and its end result, in apical portions where further growth seems impossible, is a slender, rather irregular tube in which diaphragms are not apparent.

Irregularity of the tube suggests the possibility of radial tubes extending to the siphuncle wall and possibly supplying a connection of the siphonal blood system with the camerae, but there have not been found clear radial canals in the lining.

The species is known from the Garden City limestone. The holotype came from a loose piece picked up in Green City Canyon, where only the higher beds are present above. The piece contained considerable black chert, and the specimen itself is partially silicified; it came clearly from the upper cherty member and, clearly, from below the highest 20-35 feet in which the chert is largely wanting. It is, thus, certainly from below zone L, but it is impossible to say whether it came from zone J or from zone K. For the paratype no precise position in the Garden City is known, but its silicified condition and the lithology of the matrix suggest certainly a position in the upper cherty member. It is from the Garden City limestone, from Mill Creek, T. 12 S., R. 42 E., northwest of Liberty, Montpelier quadrangle, Idaho.

Types.—Holotype, collection of the writer, no. 295; paratype, U.S. National Museum, no. 14902.

Buttsoceras novemexicanum Flower, n. sp.

P1. r, entire; Pl. **2,** fig. 9; Pl. 3, fig. 21

The *Buttsoceras* from the uppermost layers of the El Paso is quite similar in aspect to *B. williamsi,* and at first the writer had thought to include these forms under that species. However, there are differences in proportion of gross shell parts; these seem minor in relation to a differential development of cameral and siphonal deposits.

Shells are subcircular, the siphuncle slightly ventrad of the center; spacing of septa is similar to *B. williamsi;* they tend to range closer in early stages, however, and curvature of septa is nearly equal to the length of a camera. Siphuncles are larger in proportion to the shell diameter.

In several individuals in which the linings are developed, it is clear that cameral deposits are evident in parts of the phragmocone where the linings are thin, whereas such deposits seem greatly delayed in development in *B. williamsi.*

The several specimens from which this species is known are described separately below.

Holotype, no. 38o (pl. I, fig. 1-9).—This specimen is a portion of phragmocone of a *Buttsoceras* from the highest El Paso. It is 6o mm long, circular in section, increasing from 15 to 18 mm in diameter in 5o mm. The adoral end is incomplete from weathering, and a good part of the dorsal shell wall was gone before it was buried. At the base, the siphuncle is 6 mm high, 3 mm from the venter, and an estimated 6 or 7 mm from the dorsum; a break at about midlength shows the siphuncle 6 mm across, 2.5 mm from the venter, 7.5 mm from the dorsum; and at the adoral end the siphuncle is 7 mm across, 3 mm from the venter, and apparently 8.5 mm from the dorsum.

Throughout, three camerae occupy a length equal to the adoral shell diameter. Sutures are transverse. Sections show the septa shallow in curvature, rather steeply inclined between the siphuncle and the venter, relatively horizontal immediately dorsad of the siphuncle. The depth of the septum is about equal to half the length of a camera, and one sixth the shell diameter.

The siphuncle wall shows short straight septal necks and thin homogeneous connecting rings. The specimen was sectioned longitudinally in two parts; the planes of the two sections differ in direction by about 20 degrees, so the apical and adoral parts are not strictly conformable as shown in our illustrations (pl. 1, fig. 4-7). It must also be noted that the very center of the siphuncle was lost in sectioning, so the greatest diameters of the siphuncle and of the cavity within it are not shown. The siphuncle is occupied by a lining thicker ventrally than dorsally; adorally, the cavity remaining is about three fourths of the siphuncle height; this is reduced to about one fifth the siphuncle height apically, but it was probably slightly larger in the median plane. Lamellae of growth are apparent in much of the lining; they are largely parallel, showing lamellae which are continuous and clearly nonsegmental, though there is a faint indication of the growth lines curving slightly as they approach the siphuncle margin at their anterior ends, such curvature occurring orad of each septal foramen and suggesting some relationship between these lamellae and the annular deposits of the Michelinoceratidae. Apically, the lining is recrystallized, and textural details are lost. No diaphragms cross the apical part of the cavity.

The lower part of one side was used for making a thinsection, shown in Plate 1, figures 8 and 9. Unfortunately, in preparation and mounting, the portion of phragmocone shown ventrad of the siphuncle in figure 6 was lost.

On the ventral side of the siphuncle episeptal deposits are clearly developed, but hyposeptal deposits are thin and obscure. Ventrally, the deposits seem lobed, the lobes extending somewhat laterally outside the plane of the section, for in figure 7 are shown considerable masses of material lying against the outside of the siphuncle, not apparent in the same form in figure 6. On the dorsal side of the siphuncle, septa are incomplete, but the preserved parts are thickened and strengthened by thin deposits, probably both episeptal and hyposeptal.

Paratype, no. 381 (pl. 2, fig. 9).—This is a portion of a phragmocone 55 mm long, incomplete dorsally anteriorly and ventrally apically, but expanding from 15 to 17.5 mm in that length. Apically, we can restore outlines enough to show the siphuncle 5 mm across, 3 mm from the venter, and 5.5 mm from the dorsum; adorally, the siphuncle 5.5 mm across is 4.5 mm from the venter, 5 mm from the dorsum. As in the preceding specimen, camerae are very nearly three in a length equal to the adoral shell height (31/2 apically), septa are rather steep between the siphuncle and the venter, but show steeper inclination on the dorsal side of the siphuncle than is shown by the previous specimen. As shown in the figure, the adoral part of the section shows evident inorganic calcite in some adoral camerae, most marked on the venter, and though the specimen shows the lining in the siphuncle thicker than does the preceding form, the deposits of the camerae are surprisingly thinner. The lining within the siphuncle has lost fine textural detail through recrystallization. It is thick, leaving, in a surface as perfectly central as could be obtained, a cavity only 2 mm high adorally, thinning gently apicad. The lower third of the cavity is filled with calcite, terminated adorally by a diaphragm, and a second diaphragm is seen farther apicad. Vexingly, additional diaphragms were apparent when the section was first cut but were lost in grinding down very slightly to obtain a smooth surface.

Paratype, no. 382 (pl. 1, fig. 10-12).—This is a specimen consisting of a portion of phragmocone 70 mm long, increasing from 15.5 mm at the base, where the siphuncle is 5 mm across, circular, and 2.5 mm from the venter, 7.5 mm from the the dorsum. At the adoral end only the siphuncle is preserved, which is 7 mm across, circular except for a flattening on one side which is the more odd as its position is dorsolateral and definitely askew in relation to the symmetry of the shell. There the shell would be 21 mm across. The specimen was broken longitudinally when collected; in the figured section, one surface was ground and it shows the siphuncle essentially in a median section except at the base. Curiously, in the lower third of the specimen the plane of the siphuncle is slightly below the plane of the section, but at the extreme apex the apparent narrowing of the siphuncle is the result of curvature above the plane of the section.

In the surface shown the left side is ventrolateral, the right dorsolateral. Adorally, three camerae occupy a length equal to the adoral shell width, but in the apical portion there are two and a half in a similar length. Septa appear more strongly inclined forward from siphuncle to shell wall than in the other El Paso specimens, but even so, the depth of the septum is about equal to half the length of a siphuncle segment. Basally, siphuncle segments are about equal in width and length; adorally, the length is slightly greater.

Cameral deposits are developed, thicker on the left, the ventrolateral area, than on the right, the dorsolateral side, as one might expect. Their pattern is in general consistent with that shown by the other specimens. The usual adoral thinning is evident. The siphuncle contains a lining, thin adorally so that the cavity within is about two thirds the diameter of the siphuncle, but thickens apically far more gently than shown in the other specimens. In the lower two camerae the plane of the cavity passes above the plane of the section, so is not shown. In the next anterior three camerae are apparent irregularities in the form of the lining, which are not real but due to the fact that the plane to which the specimen was ground does not quite reach the slightly irregular surface along which the specimen was originally broken. The lining of the siphuncle is white calcite, as are the cameral deposits, but the material of both is altered, and original textures are lost. The cross section at the base of the specimen (pl. 10, fig. 12) suggests symmetry of the cameral deposits as well as marked ventral concentration. The midventral region is to the lower left and shows a narrow external emargination of the deposit. Both this and the anterior cross section of the siphuncle show the position of the break, the position of which dictated the surface shown in figure 11.

It should be noted that this specimen is materially larger in cross section than the other specimens, and thus represents a later growth stage. It differs further in the slight curvature of the siphuncle normal to the plane of the section, and in that the lining is of much more uniform thickness throughout the specimen, thickening only most gently apicad. It seems reasonable that these differences may be a combination of slight distortion, and different growth stages, but it should be noted that it is not impossible that this form may prove, with more material, to be distinct from *B. novemexicanum.* On the other hand, it is quite possible that the lining forms a relatively short cone in early stages, but is so prolonged in later stages as to be nearly cylindrical.

Buttsoceras cf. novemexicanum Flower
Pl. 3, fig. 21

This specimen, shown in Plate 3, figure 21, is a considerably weathered portion of a phragmocone 7o mm long showing a tubular siphuncle increasing from 5 to 7 mm in width in the adoral 55 mm, the siphuncle being lost in the apical fourth. The shell width is 20 mm where the siphuncle is 6 mm across, and there three camerae occupy a length equal to the adoral shell width. The siphuncle is filled with granular matrix and is free of organic deposits. To the right of the siphuncle the septa are reinforced by both episeptal and hyposeptal deposits which thin adorally, but the episeptal deposit at least is apparent in the most adoral camera. The exposed surface is plainly ventrolateral. On the opposite side, the dorsolateral, septa are only incompletely preserved, but plainly those septa visible in the apical part are reinforced by thin cameral deposits. Septa agree with the previously described forms in curvature.

Discussion.—This specimen is puzzling in that it shows a portion of phragmocone with the siphuncle empty, but cameral deposits well developed. Proportions would suggest that it is probably conspecific with the previously described forms, but in those specimens the thick lining in the siphuncle and the thin cameral deposits show a different growth of these parts.

Figured specimen.—From the highest 20 feet of the El Paso limestone from the east side of the Florida Mountains, New Mexico; no. 383.

Buttsoceras adamsi (Butts)
Pl. 3, *fig.* 1, 2, 5-17

Orthoceras adamsi Butts, 1926, *Geology of* Alabama, Ala. Geol. Surv., Special Rpt. 14, p. 99, 100; pl. 22, fig. 22, 23.
Buttsoceras adamsi Ulrich and Foerste, 1933, Science, n. ser., vol. 78, p. z88.
– -- Ulrich and Foerste, 1936, Denison Univ. Bull., Sci. Lab., Jour., vol. 3o, p. z65.
–--- Miller, 1943, Biological Reviews, vol. 18, p. 102.
–--- Ulrich, Foerste, Miller, and Unklesbay, 1944, Geol. Soc. Amer., Special Papers, no. 58, p. 63; pl. 24, fig. 1-4, 6-11, *not* fig. 5.

The original description of this species was made only in the most general terms, but a figure was provided by which this cephalopod, peculiar to the Odenville of Alabama, and without forms of closely similar proportions in the Canadian or Ordovician of the region, could be recognized. If no exhaustive comparison with other *"Orthoceras"* was made, the work was not by any means unique in this respect; indeed, the same could be said of the species described by Hall and Barrande and numerous others. Subsequent references prior to **1944** deals primarily with the peculiar tube within the siphuncle and with the recognition of the genus *Buttsoceras.*

It was not until 1944 that the species was reasonably well illustrated, but, anomalously, only one of the figures shows the free tube within the siphuncle at all clearly, and only one other specimen was figured even suggesting the structure.

In a survey of the suite of specimens from the Odenville limestone, Ulrich, Foerste, Miller, and Unklesbay found two other species which they regarded as distinct; one, *B? odenvillense,* though known from fragments only, certainly has a much larger siphuncle, and there is no good reason to question the generic assignment. The other, *B.? vandiverense,* has annuli in the siphuncle, is a *Michelinoceras,* and cannot be placed in the same genus or family as *Buttsoceras.*

In surveying the suite of specimens from which the types were selected, it is evident (I) that the specimens are largely small fragments, largely of phragmocones, from which it is not possible to restore the proportions of a whole mature shell and (2) that commensurate specimens show considerable variation in spacing of camerae and the proportion of siphuncle and shell diameter. One of the most extreme of these specimens was sectioned, and proves to be a *Michelinoceras;* it is described in the present work as *Michelinoceras buttsi.* However, even in the remaining specimens there is considerable variation in size of siphuncle and depth of camerae. To this situation there are two answers: (1) the species is variable and such features are unreliable as specific criteria, and (2) the Odenville has yielded fragments of phragmocones of a number of species which, from their fragmentary nature, have been included in a single too-broadly-defined species. The writer's experience would endorse the second possibility. True, variation in proportions exists in orthoconic cephalopods; it has been demonstrated in *Striacoceras typos* (Saemann) of the Cherty Vally limestone (Flower, 1936). However, the unreliability of assumptions that in the present instance an association indicates a species is shown by the inclusion in the material identified as *B. adamsi* of not only *Buttsoceras* but also a *Michelinoceras.* It seems far wiser to admit that the present scraps are really inadequate for the proper distinction of species, a matter which has nothing to do with the validity of the species concerned but rather with the subjectiveness of species concepts, which becomes a greater hazard as the fragmentation of material obtainable increases.

On Plate 3, figures 5-17 are shown a series of *Buttsoceras* from the suite of Odenville specimens identified as *B. adamsi* and indicated as plesiotypes, from a suite of specimens no. 109489 in the U.S. National Museum. These are not previously figured specimens but were included in the study; indeed, some were marked to be figured by Foerste. Figures 13-15 are of particular interest in that the cameral deposits are shown. They are shown also, though not so clearly, in the other specimens, but selection of specimens here was designed to show variation in proportions suggestive of the presence of possibly more than one species. In particular, figures 11-12 show a specimen with extremely long camerae, contrasting with slightly earlier and later growth stages, shown in figures 6, 8, and i 0, in which septa are proportionately much closer. The cross sections show also variation in relative size of siphuncle and shell.

The types of *B. adamsi* are in the U.S. National Museum; all are from the Odenville limestone of Alabama; detailed localities and numbers of figure specimens have been given by Ulrich, Foerste, Miller, and Unklesbay (p. 64). The specimens here figured are nos. 14905-14911.

STRATIGRAPHY OF *BUTTSOCERAS*

The first known occurrence of *Buttsoceras* is that of the Odenville limestone, the highest Canadian of Alabama. It seems possible that *Buttsoceras* may prove to be a genus particularly widespread in the closing phase of the Cassinian, but the matter is certainly far from proved and needs much further investigation. Cloud and Barnes (1946) regarded the highest beds of the El Paso, an interval of 35 feet in the type section, as containing a fauna significantly more advanced than that of the beds below, and suggested correlation with the Odenville, the Black Rock, the highest layers of the Arbuckle limestone. They cited a *Buttsoceras* from this interval from the Beach Mountain section of the Van Horn region of Texas. The specimen, which was lent to the writer with the associated gastropods, is a small fragment, but the recognition of its identification as *Buttsoceras* is almost certainly correct. The layers of the El Paso which have yielded the material used in the present study consist of the highest 3o feet of the section exposed on the east side of the Florida Mountains. This horizon at Beach Mountain and in the southern Franklin Mountains contains orange-yellow silty beds, but the southern Franklin Mountains yield a number of layers of coarse calcarenite. The Florida Mountain section exposes a somewhat different facies, in which the beds are dominantly calcarenite, occurring in layers up to 2 feet thick, but yellow, soft, silty beds are wanting; instead there are some fine-grained gray calcarenites. The brachiopod association seems similar to that reported by Cloud and Barnes at El Paso; there are also abundant if fragmentary trilobites, and a bivalved shell is locally abundant; its size suggests a pelecypod, but the possibility that it may be a bivalved crustacean has not yet been ruled out.

One would hope that the Garden City occurrence might also be very latest Canadian, and that the occurrence of the *Buttsoceras* with the trilobites, on the basis of which Ross (1951) established a zonation, would aid in correlation. Unfortunately, the two good *Buttsoceras* so far studied are both without precise stratigraphic data. The holotype of *B. williamsi* was picked up in rubble in Green Canyon, at the northern edge of Logan, Utah. It came from a spot where the layers above represent only the upper cherty member, which Ross indicates as 366 feet thick in that section. From its position, it did not come from the very base. From lithology, a dark, nearly black limestone weathering dark blue-gray and with considerable black chert, it came certainly from below the upper beds which have almost no chert, and which are the source of two remarkable endoceroid genera to be described elsewhere. These genera suggest a Whiterock rather than a Canadian age for the upper beds of the Garden City, a view consistent with the interpretation of Ross of his zone L as Chazyan in the sense of former usage, prior to the recognition of the western early post-Canadian beds as the Whiterock stage by Cooper (1956). One may note also, that the highest 12-15 feet which have yielded these cephalopods have yielded very little else; a poor sponge, a poor orbiculoid brachioid, echinoderm fragments, and some poor, small orthoid brachiopods. These layers are certainly above those which have yielded the appreciably larger fauna cited by Ross for zone L. It would appear likely the *Buttsoceras* occurs in zone K, or possibly though less probably, zone J, but it must remain to find specimens in place where the associated faunas can be noted.

The paratype, from collections made by R. W. Richards, are from beds with abundant chert and doubtless came from the same general horizon.

THE PROBLEM OF OXFORDOCERAS

Oxfordoceras Ulrich, Foerste, Miller, and Unklesbay (1944) is defined as a slender essentially straight shell, the siphuncle rather small, not marginal, composed of segments that are concave externally. The genotype, 0. *billingsi,* described in the same work, is known only from the type. It is evident that the siphuncle is rather large, the segments are short, nearly as broad as long, and the whole specimen has very much the aspect of *Buttsoceras*. *Orthoceras atticus* Billings is also tentatively placed in *Oxfordoceras*. It is known only from the ventral part of a phragmocone, preserving about 15 camerae, and ground apically to show an eccentric siphuncle, poorly preserved but seemingly with a thick wall; the thick wall may well represent a lining identical with that of *Buttsoceras*.

It is evident that neither of these species shows any features by which it can be distinguished from *Buttsoceras,* and in the absence of any evidence to the contrary, it is proper that *Oxfordoceras* should be considered a synonym of *Buttsoceras*. Is it possible that both occurrences are late Cassinian? Such a position is indicated for *Buttsoceras atticus* Billings; it is reportedly from the Corey limestone of the Phillipsburg region of Quebec. The Corey occurs above beds, the Solomons Corners formation, which have yielded an association of cephalopods clearly similar to those of the Fort Cassin and Smithville formations.

The Corey limestone is not, however, latest Canadian but is followed by the Basswood Creek limestone, concerning the fauna and correlation of which nothing is yet recorded.

Inquiry was made of Dr. Alice Wilson as to the possible stratigraphic intervals in the Canadian present at Oxford township, Ontario, reputedly the source of *Oxfordoceras billingsi.* Dr. Wilson replied that the present evidence suggests nothing higher than the Middle Canadian at that locality, but unfortunately there was some question whether the type of 0. *billingsi* came from there, as material from that locality in the collections of the Canada Geological Survey had unfortunately been mixed with material from Ste. Anne de Bellevue, Quebec. Not much is known about the occurrence at Ste. Anne de Bellevue either, but the place is 20 miles northwest of Phillipsburg and about 25 miles south of Montreal; it seems quite possible that very late Canadian may be present there, as it is at Phillipsburg.

Evidently further search is needed for the establishment of *Buttsoceras* in the late Canadian of eastern North America north of Alabama, but there is a real indication that it may be there.

Michelinoceras Foerste

Genotype: *Orthoceras michelini* Barrande

Michelinoceras Foerste, 1932, Denison Univ. Bull., Sci. Lab. Jour., vol. 27, p. 72.

As originally proposed, *Michelinoceras* was erected for smooth orthocones with central tubular siphuncles, having essentially the scope of *Orthoceras* of Hyatt 1900. The proposal of the name came after Troedsson (1931) showed that *Orthoceratites regularis,* then regarded as the proper type of *Orthoceras,* had three linear internal thickenings of the shell at midlength of the mature living chamber. Foerste's intention was merely to propose a name for generalized *"Orthoceras"* without such special features. That Teichert and Miller (1936) subsequently concluded that *Orthoceras* could not be used as a cephalopod because the first species available as a genotype was a rudistid and they proposed that *Orthoceros* Brunnich be used with *Orthoceratites regularis* as the type do not affect the scope of *Michelinoceras* materially.

Since Foerste's proposal, however, there has developed a change in concept, involving largely the realization that in the "simple" orthocones of the Michelinoceratida the shell was carried horizontally in life, as is shown by a sparse but apparently general sampling of shells with color bands; in all instances, color bands are confined to one side of the shell, the dorsum. How this mode of life could be maintained if gas were present in the camerae was long a problem; it was hard also to see how the orthocones could have prospered as they did if there were no gas, for otherwise the chambered shells would have supplied no advantage to the organism, but rather a hindrance. The answer to the dilemma was found in the deposits of camerae and siphuncle which remain apically concentrated and maintain constant adjustment of growth with growth of the shell as a whole. These deposits supplied an answer to the question of how the shell could be stabilized in a horizontal position, while gas, concentrated in adoral camerae, where deposits were wanting, so lightened the shell as to permit facile movement. Once this was realized, and evidence accumulated showing that cameral deposits are general in orthocones rather than confined to a few special groups, a change of viewpoint was required, for it then becomes evident that if there were orthocones without such deposits, we must either assume that their shells were not horizontal in life—a view for which there is no evidence—or else that they balanced by some other means, such as water in the apical camerae, for which there is also no evidence possible from the fossil shells. It follows that the existence of orthocones completely free from cameral and siphonal structures in the shell apex is suspect, and in view of the fragmentary nature of these shells (amazingly in the numerous species, no complete mature individual is known, apices are always missing), evidence of such a condition has not been demonstrated for any species.

So in defining *Michelinoceras,* we are now faced with the requirement of adding to a generalized smooth orthocone with simple suture and an essentially tubular siphuncle some knowledge of the pattern of the cameral and siphonal deposits.

Already it is evident that there is wide variation in form and distribution of the deposits. There is further wide variation in relative development of cameral and siphonal deposits spatially. In some orthocones the siphonal deposits are either suppressed or so retarded that they are confined to unknown apical shell parts. This is true, in our present state of knowledge at least, of *Orthoceros, Sinoceras, Pleurorthoceras,* and *Leurocycloceras.* In other forms, typified by *Geisonoceras, Harrisoceras,* and *Virgoceras,* both cameral and siphonal deposits are well developed. In typical *Michelinoceras,* annuli in the siphuncle are developed far in advance (in terms both of anterior extension in the phragmocone and in point of time of deposition for a given region) of the cameral deposits.

Perhaps something of a solution can be achieved by determination of the morphological pattern in *Michelinoceras michelini,* the genotype, and grouping with this obviously similar species. The results are not so satisfactory as one might hope, simply because *M. michelini* is not well enough known internally; Foerste made his selection of this species as one reasonably well known, but this was before the cameral and siphonal deposits were generally recognized as factors in cephalopod morphology. A glance at Barrande's illustrations shows that there are only two sections of phragmocones illustrated. From its size, one is plainly an anterior portion close to the living chamber. It shows a rather small tubular siphuncle but there are not, as one might expect, any cameral or siphonal deposits developed. The negative evidence is, of course, valueless. A second section, showing smaller shell width and therefore presumably a more apical part, shows very small annuli in the siphuncle, but camerae remain empty. It is desirable to know more apical sections, taken from known distances from the bases of living chambers. Such sections, far enough apicad, should show larger annuli in the siphuncle and might show cameral deposits. No material for such a study has been available.

However, there is a second-best solution, which is supplied by the material Barrande illustrated showing several species close to M. *michelini* in general proportions. They agree in showing the cameral deposits so retarded, so concentrated apically that they are unknown, and they show either only small annuli in the siphuncles or none at all if the sections are not sufficiently apicad of the living chamber.

They show that there is a group of smooth, very slender shells with deep camerae, the siphuncle of rather small diameter, its segments very faintly constricted at the septal foramina. These species further agree in that annuli develop in the siphuncle some distance from the living chamber but appear in regions in which cameral deposits are not developed at all. Such species may be summarized as follows:

M. michelini (Barrande)
M. jucundum (Barrande, pl. 389, 409)
M. currens (Barrande, pl. 407)
M. thrysus (Barrande, pl. 405)
M. *simiale* (Barrande, pl. 394)
M. migrans (Barrande, pl. 309, 348, 377)

There is another specimen of particular interest, that which Barrande figured on Plate 387 as *Orthoceras rivale*. This is a large Middle Silurian species, showing a long interval of sectioned phragmocone. It is quite like *Michelinoceras,* particularly anteriorly, in the rather deep camerae, deeply curved septa, rather small siphuncle slightly constricted at septal foramina. It is only some considerable distance from the anterior end that small annuli appear in the siphuncle; these enlarge as traced farther apicad, and where they are moderately large, one finds thin episeptal deposits in the associated camerae. This shell is certainly not true *Orthoceras rivale;* not only are gross propositions different, but in 0. *rivale,* annuli in the siphuncle appear only apicad and after development of deposits in the camerae; siphuncles are of considerably broader segments. Interestingly, this large Bohemian species is quite close to what has long been known in the Racine and Huntington beds of North America as *Orthoceras niagarense* Hall.

These species, to which could be added a fringe of a few others, departing further from the genotype in more rapid expansion and showing also some modifications of the shell surface, form a proper nucleus for the genus *Michelinoceras,* but the question remains as to how broadly *Michelinoceras* should be defined. A proper solution of this question would require a careful re-evaluation of the described species of smooth orthocones with tubular siphuncles, and no such work has been possible up to the present. Without such work, opinions on the question would certainly vary among individual students. Probably it would take a good ten years of accumulating materials and another ten in their study to achieve even reasonably stable results.

In the meantime, we must do something with the species already described. The writer would urge most strongly that inadequately known species remain in *Orthoceras*. As the genus is not properly used for cephalopods, but will not be used properly for anything else either (no student intends to use it for a rudistid); the retention of this old designation will at least indicate that the species is inadequately known. To refer species wholesale to *Michelinoceras* as was done by Kindle and Miller—in most instances without even knowledge of the outline of the siphuncle segments—is not only misleading, but unnecessarily preoccupies specific names under that generic heading, and there is danger of horrible problems of homonymy. The use of a bad generic name would seem proper for species which, in terms of present day requirements, are badly known.

If one restricts *Michelinoceras* to the above group of species, one is faced with the dilemma of proposing other names and defining other groups for reasonably well known species which lie outside the genus. While this could be done—the writer has been scrutinizing such possible groups critically for some ten years—it could not be done now with any hope of achieving stability—too many species are inadequately known internally—so one is forced to retreat to the ground of a somewhat broader if somewhat vague usage. We have, oddly, a related problem in attempting to determine the proper scope for the family Michelinoceratidae.

We can, however, reach some significant conclusions. In *Michelinoceras* there are certainly annuli in the siphuncle and our one specimen, 0. cf. *rivale* of Barrande, shows that in the extreme apex there are also episeptal deposits in the camerae. It is thus evident that *Michelinoceras* shows an internal pattern related to that of true *Geisonoceras* and *Harrisoceras,* that *Kionoceras* of the Silurian is allied, as is *Virgoceras* and probably *Dawsonoceras,* though it is specialized in recumbent necks. We know from M. *primum* that the pattern is developed in general in the first of the Michelinoceratidae known, well down in the Cassinian, and is retained in *M. buttsi* of the closing phase of Canadian sedimentation. It is a pattern which is plainly, in spite of our fragmentary evidence in terms of known or illustrated specimens, persistent from the inception of the Michelinoceratida through Ordovician, Silurian, and Devonian species, and it may well persist later, though definitive studies of interiors of Late Paleozoic and Triassic orthocones with tubular siphuncles have not yet been made.

If *Michelinoceras* is expanded to include species in which cameral deposits are not markedly retarded, approaching but not attaining the condition of *Geisonoceras,* in which cameral deposits precede annuli in development and therefore in anterior position in the shell, the genus is expanded sufficiently that one may place in it both *M.* primum and *M. buttsi,* the two oldest species which are certainly Michelinoceratidae. The alternate possibility, restricting *Michelinoceras* to the abovementioned group of Silurian species, would require the proposal of another generic name for these two Canadian species, which seems unwise, for while there are doubtless other and younger species which would fall in the genus, no listing of such species now possible would be more than a crude approximation of the true situation.

In placing *M.(?) richardsi* tentatively in *Michelinoceras,* we are necessarily using the genus with considerably more latitude. This species is distinctive in that cameral deposits are present over a rather respectable interval of phragmocone in which no siphonal deposits are developed. It may be that this species is allied to a number of Ordovician forms, not necessarily very closely related to each other, in which siphonal deposits are similarly unknown, being either greatly retarded in growth or suppressed completely. However, it is not similar to any such forms in the pattern of the cameral deposits. It may be that slightly more apical regions of the shell will show annuli; it is, of course, also possible that they might show linings as in *Buttsoceras,* but this seems unlikely inasmuch as in better known and typical members of that genus the linings are developed where cameral deposits are thinner than in this specimen.

Michelinoceras primum Flower, n. sp.
Pl. 3, fig. 22

We know this species as yet only from a small portion of a phragmocone, far enough apicad of the living chamber to show siphonal and cameral deposits. The type is a small portion of a phragmocone, now a thin section, with a maximum length of 12 mm. The basal part is blunt, rather irregular, and dark-brownish irregular material suggests that its limits result from styliolitic solution. In the adoral 1 o mm the shell expands from 1.2 mm with the siphuncle 0.4 mm across, twice as far from the dorsum as from the venter, to 2.8 mm, with the siphuncle 1 mm across, o.6 mm from the venter, 1.2 mm from the dorsum. The siphuncle is tubular, showing short necks parallel with the shell axis and thin homogeneous rings. Light fibrous calcite within is inorganic in all probability. On the venter are seen annuli, closely pressed against the siphuncle wall, thickening adapically and merging into calcite largely filling the apical portion; some of this material may be inorganic. Replacement has destroyed textures. On the ventral side of the siphuncle, cameral deposits are developed adorally where they are episeptal only; they thicken apically and seem to extend on the anterior side of the camera, as in the deposits of the Discosorida, but replacement may merely have destroyed the distinction between episeptal and hyposeptal structures. Dorsally, cameral deposits are thinner and more retarded and seem to be purely episeptal, massed against the free part of the septum, and not extended forward along the dorsal wall of the camera. Oddly, except where reinforced by deposits, the shell wall is gone, evidently from abrasion.

All indications are that this is a small slender shell of subcircular section. The surface has not been observed.

The camerae are increased from 1.0 to 1.2 mm in length in the length of the specimen; two camerae occupy a length equal to the adoral height of the shell.

Discussion.—This is a small species found in the lower part of the Cassinian portion (B213 of Cloud and Barnes) of the El Paso limestone. Identification of such small, nondescript species is difficult from fragmentary material, but apparently con-specific fragments show the phragmocone extending up to a shell diameter of 6 mm, representing portions of phragmocones. The species is nowhere abundant, and its scarcity is certainly only in part due to its small size and inconspicuous appearance. The writer has for some years delayed description of this form in the hope of more and better material; its description now is influenced by the fact that this is the earliest member of *Michelinoceras* or of the Michelinoceratida so far known.

Type.—The holotype, no. 384, is from low in the Cassinian portion of the El Paso, Mekelligon Canyon, El Paso, Texas.

Michelinoceras buttsi Flower, n. sp.
Pl. 3, fig. 3-4

This is a small slender orthocone known from fragments of the phragmocones; they are slender, with straight transverse sutures, and typical internal molds are generalized and nondescript in aspect. The holotype is a portion 22 mm long, enlarging 0.5 mm in a length of 10 mm; three and a quarter camerae occupy a length equal to the adoral shell width. Septa are shallow, their depth equal to less than half the length of a camera; the siphuncle segments are slightly fusiform, contracted at the septal foramina, outlines slightly convex, in weathered specimens exposing the siphuncle exterior; the constriction at the septal foramina is conspicuous. A segment 3 mm long may expand from 1.4 to 2.0 mm. Within the siphuncle small annuli develop at the septal foramina. In the holotype, these are clear adorally but obscured apically by vesicular material believed to be adventitious. The camerae show both episeptal and hyposeptal deposits. As shown in Plate 3, figure 3, it is clear that on the left, the assumed ventral side, episeptal deposits are developed alone and are advanced in growth, seemingly truncated anteriorly by the septum; on the opposite side, however, both episeptal and hyposeptal deposits are developed, but they appear to be continuous and not two distinct structures, a feature otherwise unobserved in the Michelinoceratida but noted previously in the deposits of the Discosorida; quite probably neither the term episeptal nor hyposeptal should be applied to such structures.

Discussion.—The material from which this species is recognized is from a topotype suite of specimens of *Buttsoceras adamsi,* and quite certainly, it is the suite of specimens studied by Ulrich and Foerste from which were selected quite probably the holotype of *Buttsoceras adamsi;* it is certainly the material from which the hypotypes of Ulrich, Foerste, Miller, and Unklesbay were selected. It was noted that in this material there were a few specimens anomalous in the small diameter of the siphuncle and the development of marked constrictions as the septal foramina. It was not, however, until a thinsection was made from one specimen that the annuli were clearly apparent, as well as a rather distinctive conformation of the cameral deposits. Clearly, the original of Ulrich, Foerste, Miller, and Unklesbay, pl. 24, fig. 5, is a representative of this species.

The suite of *Buttsoceras adamsi* specimens shows considerable variation in the size of the siphuncle and spacing of camerae, not only between this *Michelinoceras* and the *Buttsoceras* but within *Buttsoceras* itself. Either *B. adamsi* shows variation without a known parallel in proportions, or the suite of specimens contains more than one species in the genus. It must be remembered that the specimens are mere scraps of the entire shells, and that from such material concepts of species may be far too broad.

Types.—Holotype, U.S. National Museum no. 14904 paratype, no. 109484 (pars) (Ulrich, Foerste, Miller, and Unklesbay, pl. 24, fig. 5).

Occurrence.—Odenville limestone of Alabama, from between one-third and one-half mile east of Odenville, Alabama, and from near New Hope church, Alabama.

Michelinoceras vandiverense (Ulrich, Foerste, Miller, and Unklesbay)

Buttsoceras vandiverense Ulrich, Foerste, Miller, and Unklesbay, 1944, Geol. Soc. Amer., Special Papers, no. 58, p. 64; pl. 17, fig. 10, 11

This orthoconic species, known from one specimen, shows a portion of a phragmocone with unusually long camerae; the figured type shows not quite two camerae in a length equal to the adoral shell width. The anterior end of the specimen is ground to the siphuncle and shows a siphuncle nearly one third the shell diameter, tubular, the segment about twice as long as across. Annuli occur at the septal foramina and appear pressed against the siphuncle wall, elongate, and show the pattern of the Michelinoceratidae. Cameral deposits are not clearly evident from the published figure.

Discussion.—Apparently little but the association with the other species assigned to *Buttsoceras* in the Odenville limestone of Alabama dictated the previous generic assignment of this species. Previous recorded facts are adequate to show the necessity of placing this species in the Michelinoceratidae and not with *Buttsoceras* in the Troedssonellidae.

Holotype.—U.S. National Museum no. 109492.

Occurrence.—From the Odenville limestone of Alabama, the type is from about 6 miles west of Vandiver, Alabama.

Michelinoceras (?) richardsi Flower, n. sp.
Pl. 3, fig. 18-20

The type is a fragment 110 mm long. At the base it is subcircular in section, scarcely depressed, 13 X 13.5 mm, the siphuncle 3 mm across, 4 mm from the venter, 7 mm from the dorsum, which is incomplete. In the basal 75 mm the shell expands in width to x 8 mm, orad of which the plane of the section passes eccentrically so that maximum width and normal expansion are not shown, but it extends 35 mm farther orad. Camerae are spaced three and a half in length equal to the shell width; two occupy 8 mm apically, 1 o mm adorally, except for the last few camerae which are shortened and probably mark the adoral end of a mature or nearly mature phragmocone. The siphuncle is tubular and void of any internal structures throughout the length of the specimen. The camerae show well developed deposits apically, where hyposeptal deposits are thicker along the free part than along the mural part of the septum, and smaller episeptal deposits are developed. Adorally the episeptal deposits thin and are wanting in the adoral camerae, but those camerae still retain thin hypospetal deposits which thicken gently from the margin to about two thirds the distance to the siphuncle, and then decrease in thickness over a distance of less than half the remaining length.

Septa are deeply curved, three-fourths the length of a camera apically, where they appear deeper owing to the episeptal deposits, and nearly the length of a camera adorally.

The last two camerae are shorter than the others, together occupying 9 mm, and orad of them the shell wall continues for an additional 25 mm on one side. This is possibly the base of a living chamber, as it is aseptate, but if so, the species is unusual in the development of hyposeptal deposits so far orad in the phragmocone.

With no deposits whatsoever in the siphuncle the assignment of this species is uncertain. However, the writer has had other *Buttsoceras* in which cameral deposits are developed adorally where there is no lining in the siphuncle, though not so strongly as in this species. From *B. williamsi* this form is distinct in the closer septa, deeper camerae, and the development of cameral deposits well orad in the phragmocone, where no lining or other deposits exist. Assignment to *Michelinoceras* is possible, and indeed seems more probable on the basis that annular deposits in that genus may be so retarded that they appear only well apicad of the anterior limit of the cameral deposits. However, we have a fragment of an evident *Buttsoceras* from the El Paso succession with thin cameral deposits in camerae surrounding a portion of siphuncle which is completely empty, and this form is quite consistent with associated *Buttsoceras* of more orthodox structure. Our material consists only of this one specimen. A section at the apical end shows the ventrolateral thickening of the episeptal deposits. The shell lay in the matrix with the venter up, and weathering is from the ventral side.

The type USNM no. 14903 is from four-fifths mile west of Fishaven, Montpelier quadrangle, Idaho, T. 16 S., R. 42 E., USGS no. 1507.

The specimen is from the upper cherty beds of the Garden City limestone.

Family Troedssonellidae Kobayashi 1935

This family is defined as Michelinoceratida, with essentially tubular siphuncle segments, short straight septal necks, thin homogeneous rings, the siphuncle containing a lining, thickening apicad as in very slender endocones.

It is clear that *Buttsoceras,* now demonstrated to possess siphuncle segments of the type of the Michelinoceratida rather than of the Ellesmeroceratida and possessing such a lining, belongs in this family.

Troedsson (1932) described as *Polygrammoceras endoceroides* a small slender orthocone from the Orthoceras limestone, which showed such a siphuncle. The shell exterior shows fine longitudinal markings; hence, his original generic assignment to *Polygrammoceras,* originally defined on the basis of surface features alone. He regarded the deposits in the siphuncle as endocones, and they are like very slender endocones with the one reservation that they show growth lamellae finer and much more closely spaced than anything found in the Endoceratida. Kobayashi (1935) saw in this form a stage of evolution leading from the supposedly holochoanitic endoceroids to the "Orthoceratidae," in which short necks had developed but endoceroid endocones were retained and made for this species the genus *Troedssonella* and the family Troedssonellidae.

In the light of fuller knowledge obtained by subsequent study, it is evident that the supposedly generally holochoanitic condition in the Endoceratida is untrue. Primitive Endoceratida, included in the probably still too-broad Proterocameroceratidae, have dominantly short necks. Endoceroids show also thick rings of some complexity, and origin of the Troedssonellidae or any Michelinoceratida in that stock now seems a most dubious hypothesis. Instead, it is apparent that it is in the higher Baltoceratidae, in which siphuncles become smaller, more central, and in which there is a tendency toward thinning and simplification of the connecting ring and the beginning of cameral deposits, that there is a very close approach to the pattern of the Michelinoceratida, and probably the real beginning of the group.

The linings, though similar to endoceroid endocones (a similarity which now seems greater in view of the demonstration of diaphragms crossing the small tubular cavity remaining where the lining is most completely developed), show some differences, notably the fine, closely spaced lamellae of growth, the tendency of such lamellae to curve, the convexity directed orad, around the anterior ends of the septal foramina, suggesting a relationship with annuli of the Michelinoceratida. This similarity, of course, does not eliminate the possibility that the linings may be archaic and the annuli may be derived from them. Our present stratigraphic evidence suggests the Michelinoceratidae with annuli to be the older stock, but the later Canadian is yielding such surprises in terms of morphology and range of types that we are probably not at the end of making such finds; thus, future discoveries may alter or even reverse the picture of stratigraphic succession as it now appears. However, the lamellae are so different in character from those of the Endoceratida as to suggest a structure similar in form but of completely independent derivation, and it seems from the study of large suites of endoceroids in comparison with the Troedssonellidae that the two structures are probably as independent, one from the other, as are the endocones developed in the Discosorida from either (see Flower and Teichert, 1957).

Recognition of the Troedssonellidae as Michelinoceratida with tubular siphuncles containing nonsegmental linings raises the question as to whether there are previously described forms which may be related. The Troedssonellidae as now known are seemingly confined to the latest Canadian and very early Ordovician. Some forms deserving of consideration seem to have similar nonsegmental linings in siphuncles, though in siphuncles in which the segments are considerably expanded.

Kobayashi (1936) has figured and described an apparently continuous lining in *Stereoplasmocerina tofangoensis,* an orthoconic shell with a siphuncle of fusiform segments. The lining is seemingly separated somewhat from the siphuncle wall, but an alternate explanation of an outer dark layer, possibly with carbonaceous material, and an inner, lighter, more purely calcareous layer seems possible. Sweet (1958) has shown by line drawings similar apparently continuous linings but without differentiation of material and lying directly against the siphuncle wall, in *Stereoplasmocerina lineata,* in S. *approximata,* and in an unnamed species of *Ctenoceras.* In the last form, siphuncle segments are slightly fusiform, and the continuity of the lining is somewhat imperfect.

In the later Ordovician, *Striatoceras,* known only from the Cape Calhoun formation of northern Greenland, seemingly combines spherical siphuncle segments with somewhat similar linings. Only two species are known. Troedsson (1926) described them as *Sactoceras lineatum* and *S. striatum, Teichert* (1934) restudied S. *striatum,* presented a drawing of the siphuncle showing layering in the lining, and referred the species to *Troedssonoceras.* On the basis of the structure shown there, Kobayashi (1935) erected the family Troedssonoceratidae. Kobayashi's point that a family was needed for orthocones with spherical siphuncle segments containing nonsegmental linings is valid. However, reference of these species to *Troedssonoceras* proved incorrect. Flower (1939b) found that the genotype of *Troedssonoceras* was a true actinoceroid, internally identical with *Deiroceras;* the two genera were for some time accepted as distinguishable by the smooth shell of *Deiroceras* and the kionoceroid exterior of *Troedssonoceras,* but subsequent investigation (Flower, 1957) showed that (a) there was considerable intergradation between smooth and fluted shells and (b) it was not demonstrable that *Deiroceras python* (Billings) actually has a smooth shell; its shell surface is unknown, and the species is known from portions of siphuncles with bits of attached septa. It therefore is best to consider *Troedssonoceras* as a synonym of *Deiroceras.* Wilson (1961) has retained the two genera as distinct but has failed to give any good reason for assuming the shell of *Deiroceras python,* which still remains unknown, to be smooth. D. *python* comes from Cobourg faunas, in which the fluted shells of *Troedssonoceras* are developed. Troedsson's two species are not actinoceroids, and thus are apart from the problem of true *Troedssonoceras.* Another generic name is needed for them. Shimizu and Obata, in their indiscriminate proposal of new genera and families, made a new genus for each of the species and assigned them to separate families. *Sactoceras striatum* was made the type of *Striatoceras* and assigned to the Ohioceratidae *(Ohioceras,* based upon *Kionoceras myrice* Hall and Whitfield, is a kionoceroid shell known only from dolomitized specimens. Though our knowledge of the siphuncle is insufficient, it appears that the expansion of its siphuncle segments is comparable to that shown in true *Kionoceras* in the Bohemian Silurian, and the family probably has no real validity), while *S. lineatum* was made the type of the genus *Greenlandoceras,* and that genus is the only one in their family Greenlandoceratidae. As pointed out earlier (Flower, 1939b, p. 482), the differences in siphuncle outlines are insufficient to distinguish two genera here, to say nothing of two families, and, other conditions being equal, page priority was used, the genus *Striatoceras* was recognized, and *Greenlandoceras* was made its synonym. This was fortunate, inasmuch as *S. striatum* was somewhat better known morphologically than *S. lineatum.* The need for a family with the scope of Kobayashi's Troedssonoceratidae resulted in the proposal of the family Striatoceratidae.

What is the phyletic relationship of *Striatoceras* and the Striatoceratidae? Present evidence is insufficient to select among several possibilities. The hypothesis is reasonable that the Troedssonellidae initiate a stock within the Michelinceratidae in which continuous linings develop in the siphuncles, and it is possible that in this lineage there developed first slightly expanded siphuncle segments such as those of *Stereoplasmocerina* and *Ctenoceras,* noted above, continuing into the later Ordovician into the more broadly expanded segments of *Striatoceras.* However, investigation of this possibility encounters some uncertainties. The greatest one surrounds the nature of the Ordovician Stereoplasmoceratidae. Kobayashi (1936) revised this family, recognizing it as a group of Ordovician orthocones with expanded siphuncles and with well developed cameral deposits. Flower (in Flower and Kummel, 195o) used this family name, perhaps inadvisedly and too broadly, for Ordovician forms of this aspect but included in it genera with linings in the siphuncles made of fused segmental elements. It is now evident that such a stock exists and is significant in the Ordovician. It is not evident, however, that *Stereoplasmoceras* has such structure, and thus the family name Stereoplasmoceratidae cannot be used for it; the family Proteoceratidae is proposed below. Certainly, unless alteration and loss of textures has produced deceptive effects, the apparently continuous linings of *Stereoplasmocerina* and of *Ctenoceras* are quite apart from the Proteoceratidae. However, what is known of the structure of *Striatoceras* shows a layering so reminiscent of that of the endocones of the Discosoridae, that one wonders whether, as in the Discosorida, such "endocones" may not be modified by alteration in growth habit of originally annular deposits which at first merely fuse to form linings made up of individual segmental units. Thus, the origin of the Striatoceratidae in older Ordovician forms such as *Stereoplasmocerina* and *Ctenoceras,* which might form something of a transition from the true Troedssonellidae, seems questionable, as an alternate segmental origin of the deposits is equally possible.

One must note another anomalous form possibly allied to *Striatoceras;* this is the species which Teichert (1934) described as *Stokesoceras balticum* from the glacial drift of Denmark. Though similar to *Stokesoceras* in the expanded siphuncle containing a lining, thickening apically, and thus suggesting endocones of the Discosorida, this form is anomalous in several respects both in relation to *Stokesoceras* and to the Discosorida as a whole. The shell is slender and the siphuncle is more gently expanded than in typical *Stokesoceras;* also, the siphuncle segments are less closely appressed and probably the recurved necks are less abruptly bent. The apical thickening of the lining in the known series of segments is anomalously gentle for any known *Stokesoceras.* It appears quite probable that this is no discosorid but a relative of *Striatoceras.* The shell surface is not known, and indeed, the orientation of the figured section and the position of siphuncle in relation to dorsum and venter are not known. It would appear probable, however, that the siphuncle here is essentially central; in *Stokesoceras it* is properly ventral.

Teichert saw in this form a possible connection between *Stokesoceras* and some orthocones which Barrande figured, showing subspherical subcentral siphuncle segments containing apparent linings. Re-examination of Barrande's figures suggests that these affinities are most doubtful. Barrande's *Orthoceras visitatum* (shown on his pl. 225, fig. 19) shows a rather long series of subspherical siphuncle segments. In the apical part there are small annular deposits, and over these annuli there is an apparently nonsegmental layer which is quite clearly inorganic calcite, developed as geoidal filling of the siphuncle cavity. Barrande's *Orthoceras dominus* (shown on his pl. 318, fig. 2), is more ambiguous, lacking annuli and showing a lining in well-rounded segments, surrounding more irregular calcite in the centers of the segments, but while in general the pattern is vaguely reminiscent of the fused annuli of the Proteoceratidae, the apparent lining extends through one broken siphuncle segment into the camerae, a clear indication that the whole of this lining is inorganic and completely adventitious. We are, then, without demonstrable Silurian orthocones with spherical segments containing continuous linings, the age of *Stokesoceras balticum* being uncertain. The orthocones with expanded siphuncle segments and apparently nonsegmental linings are apparently Ordovician and fail to connect in any way with the Discosorida.

Ordovician forms here placed in the Proteoceratidae include most of those which have recently been placed mistakenly in the Devonian and younger family Pseudorthoceratidae. Miller and Youngquist (1949) assigned Hall's Ortho*ceras sociale* to *Dolorthoceras,* and Teichert and Gleinster (1953) demonstrated similar structure in *Ephippiorthoceras* and also in their new genera *Stromatoceras* and *Gordonoceras.* With these genera in the Gordon River limestone, they found another, *Mysterioceras,* which seems possibly allied to the Troedssonellidae. This is a smooth orthocone with a subcentral siphuncle, its segments most faintly convex in outline, rather like those seen in typical *Buttsoceras.* Septal necks are short, essentially parallel with the shell axis. The peculiarity of the genus lies in the deposits of the siphuncle which appears first at the anterior end of a segment, and grows apicad, not orad; this is the reverse of the growth pattern found in the Pseudorthoceratidae, and what these authors could have been thinking of in assigning the genus to that family, the writer cannot imagine. Further, if the interpretation shown in their text figure is correct (the photographs of the thinsection are not quite adequate to remove all possible doubt), the deposit is unique in that it develops first not at the apical end but at the adoral end of a ring, growing uniformly apicad until the new deposit meets that of the preceding segment. Here the illustrations leave one crucial matter uncertain. The illustrations are not completely adequate to show whether, when two segments join, further longitudinal growth ceases and the deposits merely thicken with further growth, or whether, as in *Striatoceras,* the younger deposit continues, growing apicad over the preceding deposit.

In either event, it seems that *Mysterioceras* is the only genus which is possibly at all closely allied to *Troedssonella* and *Buttsoceras* of the Troedssonellidae. Until the above questions concerning *Mysterioceras* can be answered, it is futile to attempt to decide between two alternate taxonomic disposals of this genus, but clearly, it should either be included in the Troedssonellidae with a slight extension of the present definition of the family, or it should be placed in a separate but related and quite probably derived family.

The stratigraphic position of *Mysterioceras is* not certain, but quite clearly, the evidence supporting the supposed Middle Silurian age of the Gordon River limestone is highly suspect. In Tasmania it is possible to recognize (I) a late Canadian assemblage, (z) a Whiterock assemblage, (3) an assemblage of late Middle or early Upper Ordovician age, and (4) the Gordon River assemblage, which may not be very much younger. The first is marked by the association of *Piloceras, Manchuroceras, Allocotoceras, ?Utoceras,* and *"Suecoceras."* The beds at Railton, containing Wutinoceratidae are clearly to be interpreted as representing a Whiterock assemblage. The Ida Bay beds contain *Trocholites* (originally placed in *Trocholitoceras)* and *Hecatoceras. Hecatoceras* is a type of discosorid not known in North America prior to the development of endocones modified from annular deposits, first found in *Faberoceras* in beds of Maysville age, and later found by Sweet in *Cyrtogomphoceras,* of Red River age, which is probably slightly older. *Trocholitoceras* is properly a late Canadian genus, but this species is not typical, and lies within the wide variation in terms of cross section and whorl enlargement found in *Trocholites. Mysterioceras* is from the Ida Bay beds. Interestingly, it is beds at Smelter's quarry, at Zeehan, which again yield *Hecatoceras,* which have yielded also the unique endoceroid *Tasmanoceras.* The overlying Gordon River beds have yielded *Ephippiorthoceras,* otherwise Ordovician,* the new genera *Stromatoceras* and *Gordonoceras,* and the supposedly Silurian *Gasconsoceras.* Silurian age was concluded by placing the greater weight on the occurrence of the *Gasconsoceras,* but the writer is inclined to place the greater weight on the *Ephippiorthoceras,* largely because so many surprises have turned up in relation to coiled cephalopods in the Early Paleozoic, as the *Bickmorites* in the Cincinnatian (Flower, 1946).

From the above discussion it is evident that orthocones with continuous linings in expanded siphuncles are possible descendants of the Troedssonellidae, but the relationship cannot be postulated with certainty until alternate possiblities have been more thoroughly examined. At the present time the Troedssonellidae contains certainly only two genera, *Buttsoceras* and *Troedssonella,* while *Mysterioceras* deserves consideration as a genus certainly related, but more information is needed before one can say whether it is best included in the family or placed in an allied family; if the latter course is adopted, there is at present no other genus which could be placed with it.

* The genus appears in North America in Cobourg, Collingwood, English Head, and Vaureal faunas in eastern North America; again in the Maquoketa shale of the upper Mississippi valley, in a scattering of Red River beds in western North America, and in a number of Arctic occurrences, some definitely Red River, some possibly involving some Richmond with Red River below.

In the writer's previous treatment of *Troedssonella* (Flower, in Flower and Kummel, 195o), the genus was left in the Michelinoceratidae, largely because though the "endocones" were unique, they seemed an isolated specialization without significance. It is now clear that such a development characterized a small group, but one significantly distinct from the Michelinoceratidae early in the history of the order.

While it is necessary to note that this step restricts the Michelinoceratidae on the basis of the character of the siphonal deposits, it would be absurd to say that the procedure creates a precedent, namely, the recognition of lineages as families on the basis of siphonal deposits alone. Such a statement would place emphasis where it does not belong, on the subjective elements of classification, and surely the assumption that one can invoke such principles in classification is most unsafe, evolution being the wayward process that it is.

The present material has raised the question as to whether the Troedssonellidae could be modified Endoceratida. The slender Endoceratida so far known in the Canadian show in general short septal necks, but the connecting rings are thick, either with layered structure or with the eyelet type of structure, with the dense amorphous material concentrated at the tip of the ring. No trace of such rings is known in the Troedssonellidae. Oddly, typical, slender Endoceratida of the Canadian show in general shorter, more rapidly expanding endosiphocones; also, with a very few dubious exceptions, septation is remarkably close; we know of no slender Canadian endoceroids in which the segments of the siphuncle are not materially shorter than they are wide. The first such siphuncles known in the endoceroids are found in *Dideroceras* of the Orthoceras limestone faunas, of probable Whiterock equivalence. Further, our Canadian Endoceratida have as yet yielded no good examples in which the siphuncle is materially removed from the ventral wall of the shell,* and there are none whatsoever known in which cameral deposits are developed. Both of these features are anticipated, however, in the Baltoceratidae of the Ellesmeroceratida, where there is also a tendency toward thinning and simplification of the connecting ring. In view of these facts, the similarity of the linings of the Troedssonellidae with endoceroid endocones seems suspect as a guide to relationship, and one is inclined to re-emphasize the contrast between the closely spaced growth lamellae of both *Buttsoceras* and *Troedssonella* and the much wider spacing of the endosiphosheaths general throughout the Endoceratida wherever such structures are observed. The writer has raised the question as to whether endoceroids which lack all traces of such growth lamellae did not have endosiphuncles which grew by such gradual accretion of materials that no such lamellae were ever developed. In calcitic preservation, traces of lamellae normal to the growing surface are commonly seen, which have no apparent counterpart in the Troedssonellidae. Indeed, the differences suggest that endoceroid endocones and the linings of the Troedssonellidae were possibly quite different in original texture and composition and may have been very different in their mode of secretion.

An allied but completely different question is whether iso-

* Neither *Cyptendoceras* nor *Cyptendocerina* are endoceroids, as shown in a work now awaiting publication.

lated portions of siphuncles of the Troedssonellidae containing well-developed deposits could be certainly distinguished from endosiphuncles of true Endoceratida.

Oddly, in the latest Canadian where *Buttsoceras* is known, the question has not arisen. The Odenville has yielded a few isolated siphuncles, but most of the material has septa and shell walls attached. Even isolated siphuncles are distinguishable from those of endoceroids, which have not been found in the Odenville, by their essentially tubular form and the wide spacing of septal ridges. The highest El Paso materials do not show silicification, and thus isolated siphuncles with organic filling either of the Endoceratida or the *Buttsoceras* are not conspicuous; it is, however, worth noting that no such specimens have been found in rather exhaustive collecting, and oddly, we know of no true endoceroids in the association of the Florida Mountains which yielded our material of *Buttsoceras*. The cherty beds of the Garden City have likewise yielded no evident endoceroid siphuncles in the general interval from which *Buttsoceras* must have been derived, and our one siphuncle from a somewhat mutilated specimen (pl. **2,** fig. 10-12) shows septa retained because they are reinforced by cameral deposits. The whole aspect of the specimen is completely different from that of any known Canadian endoceroid.

While the late Cassinian has not yielded any specimens which involve any perplexity in assigning them to the Troedssonellidae or to *Baltoceras* rather than to the Endoceratida, nor have any such been found in the lower Cassinian, the basal division of the Jeffersonian of the El Paso succession has yielded some very small slender siphuncles, silicified and removed by etching, showing faintly nummuloidal outlines suggestive of long, slender siphuncle segments; their anterior ends show very deep slender endosiphocones. This material, on which we have been delaying description in the ever present hope of obtaining more complete material, is not at present certainly assignable either to the Endoceratida or to the Troedssonellidae of the Michelinoceratida.

PART II

NOTES ON THE MICHELINOCERATIDA

Abstract

The order Michelinoceratida is discussed, tracing the main evolution as previously known, making some new contributions, and pointing out problems which still remain. Previously proposed family names (exclusive of the Michelinoceratidae and Troedssonellidae discussed in the preceding work) are summarized, with some indication of their value and scope. A following section describes the families Proteoceratidae, describing the genera briefly and including some new ones; the new families Sphooceratidae, Engorthoceratidae, Offleyoceratidae are proposed, with new genera in some instances. A final section deals with contributions to the morphology of *Orthoceros regularis, Pleurorthoceras clarkesvillense,* and *P. selkirkense,* and *Dawsonoceras.*

Introduction

The previous paper, in dealing with the revision of *Buttsoceras,* and necessarily extended to include some *Michelinoceras* associated with and in part formerly confused with that genus, led to the recognition and revision of the Troedssonellidae and consequent restriction of the Michelinoceratidae.

This associated work continues further the stirring of the troubled waters of the Michelinoceratida, one of the largest and at the same time certainly the most poorly known of the orders of the Nautiloidea. Even though the results may be best summarized by the line from a Pick and Hammer Club song, "I've organized my ignorance," it may be that the present imperfect results will serve toward clarification of the problem of understanding the morphology, evolution, and classification of this great group. Some years back the writer had been undertaking investigations of this group; a part of this work, an analysis of the forms of the Bohemian Basin, was necessarily interrupted because of a move to an institution where Barrande's work was not available. This matter has been corrected recently, but completion of the investigation has not yet been possible. However, it has seemed relevant to add to the preceding work such observations as were ready for publication. They include (1) a discussion of the order Michelinoceratida and the family Michelinoceratidae, (2) a summary of families previously proposed now known to belong to the Michelinoceratida, (3) proposal of some new families and genera, already long delayed, and (4) description and illustration of some crucial forms of unusual morphological interest, a disparate lot to be sure, but including further investigation of the morphology of *Orthoceros regularis* (Schlotheim), investigation of the remarkable *Cycloceras selkirkense,* which proves to show a *Cycloceras-like* surface only when cameral deposits are exfoliated from the internal mold. This with the allied *Orthoceras clarkesvillense* combine to form a distinctive new genus, *Pleurorthoceras.* Illustration and brief description of the familiar *Dawsonoceras* follow, which shows rather similar cameral deposits, but exhibits annuli of the aspect of the Michelinoceratidae in a siphuncle which has recumbent septal necks restricting otherwise tubular siphuncle segments at the septal foramina, a feature previously unreported.

Acknowledgment

Troedsson's figured material of *Orthoceratites regularis* Schlotheim was loaned for study through the kindness of the Sveriges Naturhistorische Museum of Stockholm, and Mr. Harry Mutvei, curator of paleontology of that institution, for which this opportunity is taken to express thanks.

Order Michelinoceratida

The Michelinoceratida is the great order of "generalized" orthocones, forms with primitively tubular siphuncles with short necks and thin homogeneous rings, though it is recognized that several families developed expanded siphuncles and there are also some departures from the orthoconic form. The order contains the bulk of the species which were placed, a generation ago, in *Orthoceras,* though of course the same generic designation was given to some actinoceroids, endoceroids, a few straight oncoceroids, and even a few Discosorida, but the bulk of the old *"Orthoceras"* certainly belongs in the Michelinoceratida.

Bases of classification have varied. To Hyatt (1900) the forms with tubular siphundes seemed divisible on the basis of surface markings, though he recognized the Loxoceratidae as containing smooth orthocones with expanded siphuncles; this family he placed at the beginning of his Cyrtochoanites, and though he did not say so specifically, the arrangement suggests that this family, developed from his Orthoceratidae, was the point of origin of more specialized cyrtochoanitic cephalopods. With further work it became evident that the situation was not that simple, and that among shells which, in terms of Hyatt's classification seemed to be assignable generically on the basis of the ornament alone, there were forms, with both tubular and expanded siphuncles, those with expanded siphuncles showing considerable difference in the shape of the segments.

It became further evident that though genera had been distinguished among orthocones on the surface markings, such generic groups contained forms so different internally that they evidently contained convergent homeomorphs. It was the realization of this situation, which stemmed largely from the careful work of Foerste, that led to the abundant proposal of new families and genera in the 1930's. The largest group of such proposals was that of Shimizu and Obata (1935, 1936). Unfortunately, further study has shown that the definitions which these authors supplied are sometimes contrary to the features found in their designated genotypes, and the work is highly unreliable in this respect. Also, they separated genera on the basis of differences in form of siphuncle segments now known, and pretty well evident even then, to be the sort of differences which may be found between different growth stages in a single species.

The discovery that such characteristic ornament patterns as those characterizing *Spyroceras, Cycloceras,* and *Kionoceras* were found in both orthochoanitic and cyrtochoanitic shells led to the recognition that ornament types may contain unrelated homeomorphs, but the distinctness is not necessarily so great as it at first seemed in the light of Hyatt's division of Orthochoanites and Cyrtochoanites as orders. It has since been necessary to abandon this classification and to recognize that the Cyrtochoanites contained several groups in which expanded siphuncle segments were achieved independently. It remains true that, in general, form of siphuncle segments is less subject to rapid evolutionary change than are surface patterns, but we have a few lineages in which general surface patterns remain constant, though internal features change. The Protocycloceratidae of the Ellesmeroceratida have tubular siphuncles, but the derived Apocrinoceratidae contains three obviously related genera showing progressive expansion of the siphuncle segments. One could argue that the recognition of the Apocrinoceratidae as a distinct family is subjective and that these forms should be returned to the Protocycloceratidae with which they clearly intergrade. In the primitive Paraphragmitidae siphuncles are primitively tubular, and they become expanded only in *Paraphragmites* itself, the most specialized genus of the lineage.

It was in the middle 1930's that attention began to be given for the first time to the value in classification of the cameral and siphonal deposits. Hyatt (1900) had used annulosiphonate versus actinosiphonate deposits to characterize two major divisions of his Cyrtochoanites and had, of course, recognized the endocones in the Endoceratida, but he gave no attention to the deposits in more generalized orthocones which had been amply illustrated by Barrande (1865-1877). Teichert (1933) recognized characteristic features by which the actinoceroids were distinguished, such as the general form of the annular deposits, the vascular system of the siphuncle, the perispatium, and was the first to assert the use of patterns supplied by more than the outline of the siphuncle segments. Had he applied his own principle consistently, he would not have fallen into the error of including the Westenoceratidae in the Actinoceroidea. He also (Teichert, 1931) concluded that the Discosoridae could not be related to the true actinoceroids, and brought (Teichert, 1933, 1934, 1934a) attention to some varied structures in siphuncles, not then fully understood.

Flower (1939) applied the pattern of cameral and siphonal deposits, particularly the latter, to the classification of the Pseudorthoceratidae, recognizing this family as derived from the "Orthoceratidae" with tubular siphuncles in the Silurian, and presented further suggestions as to the origin, nature, and function of these deposits, emphasizing their general retardation of development beyond that of camerae and siphuncle wall and the consequent confinement of the "deposits" to apical parts of phragmocones. Likewise, some orthochoanitic genera were recognized on the basis of patterns of deposits; *Virgoceras* Flower 1939 was thus defined as was *Harrisoceras* Flower 1939A, and *Leurocycloceras* (Flower, 1941) was revised on the basis of these internal structures.

The treatment of the Michelinoceratida in Flower and Kummel (195o) was admittedly generalized. The family Michelinoceratidae was employed for forms with tubular siphuncles ranging from Ordovician to Triassic. The derived families then recognized were those established on the basis of expanded siphuncle segments and some deviations in shell form. Derived stocks recognized as appearing in the Ordovician are as follows: (1) the Stereoplasmoceratidae, orthocones with expanded siphuncle segments and deposits in siphuncle and camerae, (2) the fusiform shells of the small family Clinoceratidae, and (3) the Allumettoceratidae, orthocones with the venter strongly flattened and ventral expanded siphuncles. This family was regarded as derived either from the Michelinoceratida or from the Oncoceratida. Only the small family Paraphragmitidae was regarded as differentiated in Silurian time and only the Pseudorthoceratidae as differentiated in the Devonian.

The tracing of lineages in the Michelinoceratida and their taxonomic recognition is a task which has only been begun. The families recognized in Flower and Kummel (195o) are probably only a beginning. One might hope that those lineages characterized by expanded siphuncle segments and deviations in form have already been recognized, but even here there remain serious questions, such as the true morphology of the Stereoplasmoceratidae and the possible origin of *Striatoceras.*

Serious problems are encountered in attempting a taxonomic revision of the Michelinoceratida, stemming in part from questions of morphology and relationship and in part from questions of nomenclature and priority. The group is a large one. Barrande recognized over *700* species of *"Orthoceras"* in the Bohemian basin, largely from the Silurian and Devonian. Probably not more than twenty of these are actinoceroids, and perhaps thirty are straight shells belonging to Oncoceratida. Bassler (1915) listed 277 species of *"Orthoceras"* described from the American Ordovician and Silurian; Foerste has described additional Michelinoceratida, but even yet there are many species in this category which have so far escaped description. Kindle and Miller (1939) listed 161 species in the North American Devonian, of which 78 were placed with question in *Michelinoceras;* siphuncles were not known for the majority of these species.

Though the spate of descriptions of *"Orthoceras"* species has descended to a trickle since the turn of the century and descriptions of species of Michelinoceratida in terms of more restricted genera have not been numerous, it is clear that the order is a large one, and one in which much descriptive work remains to be done. There are, however, several very real difficulties. First, for comparison one is forced to deal with a large number of named species, many of which are most inadequately known. The possibility is ever present that if one describes a new species, assigning it to a modern genus, that some inadequately known species of *"Orthoceras"* might prove to belong to the same genus, and the older name, if identical, would of course have priority. Common descriptive names are largely exhausted in *"Orthoceras."*

Second, for purposes of priority one must consider a considerable number of proposed names at the genus and family level, most of which cannot be used until the critical species have been carefully restudied. The Pseudorthoceratide is now a fairly well known family. It was proposed by Flower and Caster in 1935. It was only a little later in the same year that Shimizu and Obata named the Spyroceratidae as annular shells with longitudinal markings and orthochoantic siphuncles. That the siphuncle of *Spyroceras* is not orthochoanitic is beside the point, or that it has the siphuncle segments and siphonal deposits of the Pseudorthoceratidae. Only an accident of dates of publication relieves us of the necessity of using Spyroceratidae for this family, if priority is to be observed.

Two late Paleozoic genera, *Loxoceras* and *Cycloceras,* are at present so inadequately known that species other than the types cannot be referred to them with certainty. There is, however, a serious possibility that should their genotypes be found represented by material good enough for proper morphological study they would be found to be Pseudorthoceratidae. *Loxoceras* is a late Paleozoic smooth shell with a supposedly small siphuncle of expanded segments. As no other stock than the Pseudorthoceratidae is known to have these features in that range, it seems probable that with proper material one would find *Loxoceras* belonging to the family; if so, one could defend the supplanting of the Pseudorthoceratidae by the older Loxoceratidae. Turner *(fide Litt.)* has noted that while the genotype of *Cycloceras is* so preserved that probably one will never know its interior, the only late Paleozoic species of similar aspect have expanded siphuncles and are probably Pseudorthoceratidae. Should this be provable for *Cycloceras annulare* Fleming, the family name Cycloceratidae would have priority over the Pseudorthoceratidae.

Third, orthocones are commonly fragmentary, and it is commonly necessary, to obtain a proper concept of the species, to examine a considerable suite of specimens; it is desirable to have both mature and immature individuals, it is desirable to know the condition of mature living chambers, proportions of anterior mature camerae, and also the deposits of siphuncle and camerae, which may be confined to relatively apical portions of phragmocones. Sections are commonly necessary to establish siphuncle form and structure, and exceptional preservation is required if one is to ascertain the pattern of cameral deposits accurately.

A great many described and named species are not adequately known in terms of present day taxonomic requirements. Some, as for example orthocones known only from specimens flattened in shales, should perhaps never have been described, but on the other hand, without the knowledge provided by such descriptions our concept of the faunas would have been even more incomplete. Many better preserved specimens and species remain most inadequately known internally; their redefinition must, in many instances, be preceded by the collecting of suitable material. Orthocones are not uncommonly large, and they occur in hard limestones. Their size and the effort needed to obtain good and relatively complete specimens largely precludes the obtaining of adequate material by casual collecting.

A last but very serious consideration contributing to inadequate records of the Michelinoceratida particularly is the expense of adequate illustrations. It is safe to say that no adequate descriptions or illustrations of Michelinoceratida have appeared in any number except Barrande's monumental *Systeme Silurien du Centre de la Boheme.* Even in Foerste's valuable work, commonly the condition and perhaps the ownership of the material precluded the adequate making of sections.

The net result is that the Michelinoceratida is perhaps the greatest remaining unexplored wilderness in the Cephalopoda; it is also the most difficult, requiring abundant and well-preserved material. It follows that the classification is still far from what it should be, but at least it is possible to summarize past results and make some additional contributions.

Oddly, *Orthoceratites regularis* Schlotheim was designated as the type of *Orthoceros* (it may become the type of *Orthoceras* by plenary powers of the International Commission of Zoological Nomenclature) and *Orthoceras Michelini* Barrande was made the type of *Michelinoceras,* two generic names which have assumed importance among the more generalized of these cephalopods, and in each instance the author selected what he considered an adequately known species. This was true enough in relation to the standards of the early 1930's, but it is since that time that the role of siphonal and cameral deposits has come to be realized, and published information on these structures is inadequate for the types of both of these genera. For *Orthoceros regularis,* Troedsson

(1931) made the mature living chamber well known and studied layers of the shell wall, but only one section was figured, from an anterior part of a phragmocone, adequate to show the form of the siphuncle segments but failing to supply any information on cameral and siphonal deposits, as they are typically wanting in such regions of the shell. Are such deposits present though confined to more apical regions of the shell? Happily it was possible to borrow Troedsson's material, with permission to section a relatively apical portion. This portion shows only incipient cameral deposits 35 to 4o camerae from the living chamber and a siphuncle which is still empty. Would still more apical sections show siphonal deposits? For *Michelinoceras michelini,* Barrande figured only two sections; one, plainly anterior from its size, shows only empty camerae and siphuncle. Another, from a portion of smaller diameter, shows only incipient annuli in the siphuncle and the camerae are still vacant. In itself, this species is inadequate to show the form of more advanced annuli and whether any cameral deposits occur farther apicad. Barrande's illustrations do, however, show that this is one of a small group of species showing in general deep camerae, a rather small siphuncle, the camerae always free from deposits, and the siphuncle with only very small annuli or none. One very large species of this aspect is known from an exceptionally long series of sectioned camerae; it shows annuli developed and also small, evidently incipient, episeptal deposits present only in extreme apical camerae.

Attempts to trace lineages have been partially successful but have remained largely unpublished, mostly because at almost every phase the investigation encounters some problems such as those noted in connection with the above two species and genera, and in most instances, as with these, material adequate for the solution is not available.

In 195o the Michelinoceratidae was recognized as the primitive stock from which were derived several specialized groups recognized as families, already reviewed. A few families are added in the present work, the secondarily cyrtochoanitic Proteoceratidae appearing in the Ordovician, and without making any serious contribution to the morphology, it is evident that families are needed for the truncated *Sphooceras,* the secondary holochoanitic *Offleyoceras,* and the Devonian *Engorthoceras.*

The real vexation of the order is the overly large Michelinoceratidae of previous usages. In the present work it is restricted by recognition of the Troedssonellidae used for some forms with linings, the Orthocerotidae and Sinoceratidae, which may eventually be put together into one family, the Sphooceratidae, Offleyoceratidae, and Engorthoceratidae. Probably other families could be proposed at the present time, but the group has already suffered so severely, and so many vexations attend any taxonomic revision, from the precipitant proposal of family names which must be considered if only from the viewpoint of priority, that further work should precede with caution.

It is evident that the Michelinoceratidae have, from their inception, annuli in the siphuncle. It is highly probable that future work will show the desirability of excluding from the family those genera in which annuli are either suppressed or so retarded that they are not commonly demonstrable; but as yet no nomenclatorial provision is made for such orthocones, except for those few which, as the Orthocerotidae, Sinoceratidae, and Offleyoceratidae, are specialized more conspicuously by other and quite different features.

Discussions centered around the *Treatise of Paleontology* initiated by Teichert showed concern not with lineages but with the proper scope of proposed genera and family names. This proved, as one might suspect, an odd sort of backstairs approach to the problem, but re-emphasized that previous proposals in this group were largely colored by views which are now abandoned, as the inalienable distinction between the Orthochoanites and Cyrtochoanites, the necessary uniformity of size and shape of siphuncle segments throughout most of the shell length, and other concepts of morphology which are now suspect. One would expect that there should be a simple orthocone without cameral or siphonal deposits, but this belief is suspect. It is now realized that these deposits serve to so weight the shell apex as to permit a horizontal mode of life combined with a free-swimming habit ranging possibly all the way from vagile benthos to dominantly nektonic and evidently even planctonic species. Though some have deposits confined to extreme shell apices, and such deposits may be relatively thin and, presumably, light, even there, it is doubtful whether any of the Michelinoceratida were completely free from such structures. If there are such shells, one must approach the question of their mode of life anew and ask whether they lived with the shell in a vertical position or whether perhaps some other mechanism permitted a horizontal shell position in life. Color bands are not known from many orthoconic cephalopods, it is true, but those known show a fair sampling of the various stocks now recognized; all are unanimous in indicating a shell held horizontally in life, by color bands confined to one side, the dorsum. The writer has often wondered whether this applied to the small slender shells, *Plagiostomoceras, Protobactrites, Arkonoceras,* such forms as *Bactrites,* and *Orthoceratites gracilis* of the Budenbach slates. In many instances, examination of such shells has shown very thin cameral deposits in relatively apical shell parts; the presence of cameral and siphonal deposits in varying combinations is certainly general throughout the Michelinoceratida, and exceptionally good evidence to the contrary is needed for the recognition of exceptions to this generalization.

Proper revision of the Michelinoceratida is not now possible. It is, however, possible to make a slight contribution toward that end, in a summary of the family names which have been proposed, a brief statement as to the problems surrounding the scope and recognition of each of them, the description of the Proteoceratidae, and a few other needed family names, mostly for odd specialized genera, and some notes on the morphology of a few interesting forms, among them *Orthoceros regularis,* two Ordovician species of a new genus, *Pleurorthoceras,* and observations on the siphuncle of *Dawsonoceras.*

Family Michelinoceratidae Flower 1945

This family was proposed to include orthocones with subcentral tubular siphuncles. It had been found that *Orthoceras* could not be used properly for cephalopods (Teichert and Miller, 1936) and though Foerste, for slightly different reasons, had proposed *Michelinoceras* for generalized orthocones of this nature, Teichert and Miller suggested tentatively the revival of *Orthoceros* Brunnich with *Orthoceratites regularis* Schlotheim the designated genotype, and the possible use of the family Orthocerotidae.

Though *Orthoceros* Brunnich actually predates *Orthoceras* Brugiere, as shown by Teichert and Miller, they have overlooked the fact that we are obliged to deal with accidents of sequence of publication of a generic name which quite certainly had a rather extensive pre-Linnaean usage. It is not evident that Brunnich had any intention in his work of proposing a new name, and it is doubtful whether his *Orthoceros* was other than a *lapsus calami* for *Orthoceras.* There is no Greek nor Latin word or suffix *-ceros.* Acceptance of *Orthoceros*, indeed, raises the embarrassing question as to what gender should be given the name. It would appear that if Brunnich was deliberately coining a name here, it must be taken as a second declension Greek noun and therefore masculine.

While proof of this matter is, of course, impossible, the writer's own experience offers an interesting commentary. I have previously attempted to discuss the genus *Orthoceros* and the family name Orthocerotidae. Upon at least three such occasions, my editors have considered this an error with such conviction that they changed the text without my knowledge after I had returned proofs. Thus, I find that in 1945, where I was largely successful, I appear as stating that *Orthoceras* (instead of *Orthoceros)* is a *lapsus calami*, and in 1946 on page 73, I have mentioned the Orthoceratidae instead of the Orthocerotidae.

The first use of Orthocerotidae without a definite statement of tentative intention seems to be that of Ulrich, Foerste, Miller, and Unklesbay (1944). There is no definition, but apparently they were using it for orthocones with simple tubular siphuncles and relatively smooth surfaces. The genera they placed in it include *Ellesmeroceras*, *Albertoceras* and *Copiceras*, today assigned to the Ellesmeroceratida, *Proterocameroceras*, long known to be a true endoceroid, the genera *Buttsoceras* and its probable synonym *Oxfordoceras*, and the little known *Ogygoceras*, which is still of uncertain position. Neither scope nor implied definition can be accepted.

Flower proposed the Michelinoceratidae in 1945 defining it only in terms of the tubular siphuncle. It was felt that delimiting of families on the basis of surface markings which Hyatt had attempted in recognizing his Orthoceratidae, Kionoceratidae, and Cycloceratidae, was unwise, as surface markings by themselves had proved an unsafe criterion for recognition at the generic level.

Flower in Flower and Kummel (195o), used the Michelinoceratidae again with this same broad scope. It was recognized that other family names had been proposed which were involved, being based on some of the genera then listed in the family, but space forbade proper discussion of these names, most of which were dubious and involved rather intricate questions.

It is recognized that the previous scope of the Michelinoceratidae is far too broad to be particularly meaningful, but it is a useful generalization in our present state of ignorance of this vast group of orthocones. Further restriction is desirable. The recognition of the Troedssonellidae is one step in restricting the family, eliminating those forms with nonsegmental linings in the siphuncles. It is possible at the present time to set aside some other distinctive genera in families, the Sphooceratidae, the Engorthoceratidae, and the Offleyoceratidae, but the attrition on the vast mass of Michelinoceratidae is very small in terms of known species and genera thus removed. Happily, among the previously proposed family names, one can find some that may be recognized to good purpose; *Orthoceros* may be set off in the Orthocerotidae, characterized by the internal thickenings at midlength of the mature living chamber; *Sinoceras* and the Sinoceratidae may be set apart by the rather long septal necks. Both of these further agree in a marked retardation of cameral deposits, while siphonal deposits are so retarded that they are as yet unknown.

Even this reduction by attrition is minor, involving the removal of only a very few genera. Probably the Michelinoceratidae will ultimately be restricted to orthocones containing annuli in the tubular siphuncles, but as yet such a separation is not possible. All genera with annuli nearly or completely suppressed cannot now be removed to other families that can be defined clearly, and it is evident that while *Sinoceras* and *Orthoceros* may be related that there are other groups with annuli suppressed which do not seem to be closely related to those genera, and which should probably not be included in the same family. This applies to *Leurocycloceras* of the Silurian (see Flower, 1941) and to *Pleurorthoceras*, described in the present work; it is not even evident that these genera are closely related. There is also a group of small very slender orthocones including the genera *Protobactrites*, *Plagiostomoceras*, and *Arkonoceras*, in which siphonal deposits are unknown and cameral deposits are greatly retarded in development, which again cannot be separated clearly from the Michelinoceratidae at present.

Much of the present difficulty stems from the fact that it is only recently, in the middle 1930's, that the taxonomic value of cameral and siphonal deposits in the Michelinoceratida came to be even suspected, and earlier descriptions of species, as well as proposals of genera and families, naturally gave these matters no attention. Today it is evident that such deposits are general features of the Michelinoceratida, rather than structures found in a few exceptional types, and persist in varying combinations throughout the order, playing as they do a significant role in the ecology of the group.*

We are then forced, in dealing with the Michelinoceratidae, to use the family in a rather broad and vague scope, pending needed study of the interiors of more of the orthocones with tubular siphuncles. It is, however, evident that such orthocones lacking cameral and siphonal deposits completely are, if not completely mythical, at least small groups specialized necessarily both in structure and ecology.

* Color bands, known in a sparse but unsorted series of samples in the Michelinoceratida, indicate that the animal lived with the shell horizontal and the dorsum up. How shells could have been held this way in life with gas in the camerae was long a problem; if there were no gas, it was hard to see how the orthocones could have been as successful a group as they obviously were in the Paleozoic. When it was found that the cameral and siphonal deposits show such growth relationships as to weigh down the shell apex, making possible balance with the shell horizontal but still with buoyant gas, greatest of course in the anterior camerae, a simple solution to the dilemma was presented. The question then arose as to whether there could be Michelinoceratida or other orthocones lacking all such deposits. Though some shells show only cameral deposits greatly concentrated apically, and quite thin even there, the complete absence of these structures has not been demonstrated; thin vestiges of such deposits are found even in the Bactritidae and in the older of the Coleoidea.

Summary of Previously Proposed Families of the Michelinoceratida

Under this heading are summarized the families previously proposed which pertain to the Michelinoceratida. As seen already in the discussion of the order, the valid families have been outlined; others range from family groups, the recognition of which may one day be quite possible but which involve problems of scope and definition unsolved up to the present, to those proposals which cannot be considered at all seriously either because of ignorance of morphology or for reasons of nomenclature. The arrangement of the families is alphabetical.

FAMILY ALLUMETTOCERATIDAE Flower, 1946

The family Allumettoceratidae was erected for straight shells, rather slender, with a depressed cross section, the venter being strongly flattened, and a siphuncle of expanded segments quite close to the venter. It was indicated in 195c as doubtfully assigned to the Michelinoceratida or to the Oncoceratida. A later diagram (Flower, 1954) indicated only the oncoceroid origin. The question is still not perfectly resolved, but it seems more probable that *Allumettoceras* developed from the Stereoplasmoceratidae or Proteoceratidae, orthocones with expanded siphuncles developed in the earlier Ordovician, though there are some difficulties, in particular the absence of known cameral and siphonal deposits in the Allumettoceratidae. The family contains *Allumettoceras,* ranging from Chazy to Trenton, *Tripteroceras* ranging from Black River to possibly Richmond, *Tripterocerina* and *Rasmussenoceras;* in the last genus the siphuncle is reduced in size greatly and returns to an essentially tubular condition, but there can be little question of its relationship inasmuch as, even in the absence of much material showing good interiors, there is some gradation between *Tripteroceras* and *Rasmussenoceras.* The Devonian genus *Eudoceras,* known only from E. *pandum* of the Schoharie Grit, is similar in aspect to *Rasmussenoceras* and was tentatively placed in the family more because it fitted by definition and there was no other suitable resting place than from any great conviction. The isolated stratigraphic position of this genus in the lower Middle Devonian suggests the possibility of homeomorphy, but as yet, no other possible origin of this genus has been suggested.

FAMILY BACTRITIDAE Hyatt, 1883

The bactritids are slender smooth or costate shells, with deep chambers, a small marginal siphuncle, a swollen protoconch at the base. The group has been given various ranks, and families have been recognized on details of both curvature and ornament. The writer would consider a family sufficient for the several genera and would assign it as a family to the Michelinoceratida, quite apart from the historical importance of the group, largely because of the discussions which have surrounded its role in ammonoid evolution, which in the opinion of the writer is nonexistent.

FAMILY CHOANOCERATIDAE Miller, 1932

Miller (1932) and Flower (1941) regarded *Choanoceras* as a member of the present Ascoceratida. However, it is now evident that the apparent connection supplied by *Ecdyceras* is false. *Choanoceras* is a slender shell, very gently curved, in which there is natural truncation of the shell and gradual adoral inflation of siphuncle segments, and fusion of anterior septa. Such a development parallels that of the true Ascoceratida, but it is now clearly not possible to trace *Choanoceras* to that lineage. The alternate explanation of the genus is that it parallels the development of the Ascocertida but is derived from some part of the Michelinoceratida, as yet unrecognized. The genus *Choanoceras* is the only known member of the family; it is from the Middle Silurian of Gotland. Anomalously, a second species is from the Platteville of Illinois.

FAMILY CLINOCERATIDAE Flower, 1946

Here are placed conical, more or less fusiform, shells, straight, with an eccentric siphuncle which is planoconvex in *Clinoceras* and biconvex in *Whit fieldoceras;* shells are largely straight but show very faint exogastric curvature. Aside from these two genera, *Whiteavesites is* tentatively placed with the family, but the internal structure of this genus is not really adequately known.

The family, though small, is significant as containing the ancestral radicle of the Ascocertida.

FAMILY CYCLOCERATIDAE Hyatt, 1893

This family was made for orthocones with annuli, transverse markings, and tubular siphuncles. Miller, Dunbar, and Condra (1933) have noted that the interior of the genotype of *Cycloceras is* not known, a condition which will probably never be remedied, the species being known from scraps of shells in sandstones. Consequently, one cannot use the genus for species with such surfaces with either tubular or with expanded siphuncle segments with certainty. It seems now probable that the genotype, *Orthocera annularis* Fleming of the British Mississippian might prove to belong to the Pseudorthoceratidae, but this guess is based upon similar species close stratigraphically but not identical and is not proof. Consequently, it is best to remove the genus and the family derived from its name from serious classification.

ESKIMOCERATIDAE Shimizu and Obata, 1936

Shimizu and Obata (1936, p. 22) made this genus for annulated orthocones with expanded siphuncle segments but without longitudinal markings. *Eskimoceras* is a shell with annuli and subspherical siphuncle elements. Only the anterior part of the phragmocone is known; it shows no deposits of siphuncle or camerae. It is, of course, not evident from the known material whether the siphuncle was really empty or whether it had structure like that of the Proteoceratidae, or *Striatoceras,* or simple annuli like *Michelinoceras.* The family is merely another name to be reckoned with. Shimizu and Obata included in the family two new genera, *Pseudoskimoceras,* based on *Cyloceras? manchuriense* Endo, and *Kogenoceras,* based on *Tofangoceras huroniforme* Kobayashi. There is no good reason to consider this last species as other than a *Tofangoceras,* as Kobayashi (1936a) has also concluded.

GEISONOCERATIDAE Zhuravleva, 1959

Zhuravleva has proposed this family to include the genera *Geisonoceras, Geisonocerina, Harrisoceras, Sactorthoceras, Sigmorthoceras, Hedstroemoceras* and *Tretoceras* Salter. The writer can see no good justification for grouping these genera together and would regard Barrande's *Orthoceras rivale* of his pl. 387 as a good *Michelinoceras.* With such confusion surrounding the boundary of *Geisonoceras* and *Michelonoceras,* the separation of families based on these genera is scarcely feasible. The only possible justification for separating two such families would occur should future work show complete suppression of cameral deposits in *Michelinoceras;* at present, there is evidence against the existence of such a condition in the genus. In any event, there is no good evidence suggesting the grouping of the little known genera *Sactorthoceras, Sigmorthoceras,* and *Tretoceras* with *Geisonoceras.*

GREENLANDOCERATIDAE Shimizu and Obata, 1935

Greenlandoceras was based by Shimizu and Obata upon *Sactoceras? lineatum* Troedsson 1926. As pointed out by Flower (1939, Jour. Paleontology, vol. 13, p. 482), there is no good basis for distinguishing between *Greenlandoceras* and *Striatoceras,* based upon *Sactoceras? striatum;* as the latter name has page priority, Flower made *Greenlandoceras* a synonym of *Striatoceras.* Under the circumstances, using Greenlandoceratidae becomes absurd. Flower proposed the family Striatoceratidae.

HAMMELLOCERATIDAE Shimizu and Obata, [1]935

Shimizu and Obata defined this family as combining shells of the external aspect of *Spyroceras* with more than usually prominent longitudinal ridges with cyrtochoanitic siphuncles. There is no good reason yet apparent for distinguishing *Hammelloceras.* Flower (1943, p. 118) made *Hammelloceras* a synonym of *Gorbyoceras.* The same disposal was made of *Porteroceras,* based on *Spyroceras porteri* Schuchert. *Dawsonoceras hammelli* Foerste, the genotype of *Hammelloceras,* was redescribed by Flower (1946).

FAMILY KIONOCERATIDAE Hyatt, 1900

Hyatt conceived this as a family of orthochoanitic orthocones with shell surfaces with prominent longitudinal markings; he recognized only two genera, *Kionoceras* and *Spyroceras.* Though true Devonian *Spyroceras* does show an ontogeny in which longitudinal markings precede annuli in appearance, and there is gradual development of annuli in Silurian species figured by Barrande, also strongly suggesting such a relationship, it is now evident that *Spyroceras* as conceived by Hyatt was too broadly drawn, that it is properly confined to Devonian species which have internal structure very similar to that of *Dolorthoceras* of the Pseudorthoceratidae, to which both genera belong. The difficulty lies in the fact that shell surfaces typical of *Spyroceras* were attained at least four times in the evolution of the Michelinoceratida, in *Anaspyroceras* of the Ordovician, which has the tubular siphuncle of the Michelinoceratidae, in *Stereospyroceras* of the Ordovican Proteoceratidae, with possibly the Cincinnatian *Gorbyoceras* as a modified descendant, in Silurian species allied to *Kionoceras,* and again in *Spyroceras* of the Devonian Pseudorthoceratidae. Barrande's figures show species which are quite uniform internally, showing stages from the simply fluted *Kionoceras* through some forms with incipient annuli to others with quite pronounced annuli; perhaps such species deserve another genus, but in practice it is not possible to draw a clear line between these forms and true *Kionoceras.*

Other generic groups were proposed, split off from *Kionoceras,* as *Polygrammoceras* for shells with fine, low, close longitudinal markings, and *Parakionoceras,* for a shell with distant deep striae instead of ridges. These ornament types as represented by Barrande in the Middle Silurian of Bohemia show a general internal similarity suggesting a close relationship. Anterior siphuncle segments become fusiform, some showing constrictions at the septal foramina faintly reminiscent of *Sactorthoceras gonioseptum* Kobayashi; cameral and siphonal deposits are considerably retarded and are extremely confined apically, but where observed, siphonal deposits are simple annuli. With this group of genera the faintly curved *Lyecoceras* is apparently allied in ornament and also in internal structures. The family Kionoceratidae could be employed for this group of genera, but there are some additional difficulties. It is not certain that *Polygrammoceras twenhofeli* of the Ellis Bay formation of Anticosti is really a member of this grow. It is certain that its proportions are somewhat anomalous, and it is therefore suspect. It is quite evident that the Ordovician *Polygrammoceras endoceroides* Troedsson, the type of *Troedssonella* and the family Troedssonellidae, is only homeomorphic with the group of Silurian species. Likewise, as pointed out (Flower, 1952), the group of small slender shells of the surface pattern of *Kionoceras* which range through much of the Ordovician is not certainly true *Kionoceras,* from which they differ in the tubular siphuncle; one such specimen has yielded odd oval bodies, as yet not understood, within the siphuncle.

While in one sense it is embarrassing to place the Silurian *Kionoceras* and its obvious relatives of equivalent age in the already overcrowded Michelinoceratidae, it is equally vexing to recognize a family based upon a genus the scope of which seems doubtful and the present definition of which seems questionable.

FAMILY LOXOCERATIDAE Hyatt, 1900

To Hyatt, this was a family of smooth orthocones with expanded siphuncle segments. He placed it at the beginning of his Cyrtochoanites, and though he did not say so, quite clearly he thought it might be the archaic member of the stock and derived from the Orthoceratidae of the Orthochoanites. The confusion surrounding *Loxoceras* has been discussed by Miller, Dunbar, and Condra (1933). Bassler has been the first to designate a type; this is *Orthoceras breynii* Martin, from the Carboniferous of Yorkshire. We do not know enough about the morphology of the species to be certain of its position. From its late Paleozoic occurrence, one can guess that it belongs to the Pseudorthoceratidae.

MOOREOCERATIDAE Shimansky, 1954

Shimansky has proposed the family Mooreoceratidae. The genera *Pseudorthoceras* and *Mooreoceras* agree in the general form of the siphuncle segments and in the development of a siphonal deposit in which adjacent segmental units fuse ventrally and then grow laterally, but may never fuse completely on the dorsum. Such a feature was made the basis of the subfamily Pseuodorthoceratinae, to which *Pseudorthoceras* and *Mooreoceras* were asigned (Flower, 1939). Review of the question in the light of Shimansky's proposal fails to show a good basis for separating *Mooreoceras* from the Pseudorthoceratidae. Indeed, the genus is close to *Pseudorthoceras,* differing primarily in the larger size of the shell, the depressed section, slightly sinuate suture, and the more ventral position of the siphuncle.

OHIOCERATIDAE Shimizu and Obata, 1935

This family was defined as containing orthocones with longitudinal markings and a "sactoceroid or ormoceratoid" siphuncle. To Shimizu and Obata small siphuncles of rounded segments were apparently "sactoceratoid"; medium-sized ones, "ormoceratoid"; and large ones, "actinoceroid." Oddly, Foerste says of the type that the segments of the siphuncle are cylindrical or nearly so. The siphuncle remains unfigured. There can be no real basis for the recognition of *Ohioceras* or of the Ohioceratidae from the evidence now available.

FAMILY ORTHOCERATIDAE McCoy, 1884

Early definitions of this family are hardly significant. Hyatt (190o) used it for essentially smooth orthocones with tubular siphuncles. Teichert and Miller (1936) showed that the first post-Linnaean species assigned to the genus was a rudistid, not a cephalopod, and properly only this species is available as a type. They tentatively proposed using *Orthoceros,* designating *Orthoceratites regularis* as the type and using the family Orthocerotidae, which is discussed below.

A current petition before the International Commission of Zoological Nomenclature requests the validation of *Orthoceras,* with *Orthoceratites regularis* Schlotheim designated as the genotype. The writer feels that this is unfortunate; *Orthoceras* has had such a long history as a repository for inadequately known species that it seems clarity will be best achieved by leaving it as a wastebasket for such species. The selection of *Orthoceratites regularis* as a type seems unfortunate, as previous work has failed to supply any information as to the nature of cameral or siphonal deposits, and even the investigation in the present paper is considered not completely adequate.

It would appear wise, should *Orthoceras* be validated and based on *Orthoceratites regularis,* that the Orthoceratidae be considered as restricted, possibly on the basis of the three longitudinal internal thickenings at midlength of the living chamber, though possibly the family might be expanded slightly to include other forms, such as *Sinoceras,* in which cameral deposits are retarded in development and siphonal deposits are either so retarded that they are unknown or are completely suppressed. However, until a more comprehensive and detailed restudy of the entire Michelinoceratida can be accomplished, one can hope for little permanence of scope of major categories and little agreement among various students of the Cephalopoda. It would appear, however, eminently desirable to consider the Orthoceratidae, if it must be considered at all, as so restricted as to leave the Michelinoceratidae as a repository for forms with annuli in the siphuncles.

FAMILY ORTHOCEROTIDAE Teichert and Miller, 1936

The original proposal of this family name was tentative, suggesting the advantages of using such a name and involving the further tentative proposal of *Orthoceratites regularis* as the genotype of *Orthoceros.* Oddly, subsequent authors overlooked this distinction, and technically the first one to cite the genus with this genotype with qualification is, in a nomenclatorial sense, the author of the proposal. Surely, this is strictly true, but it is nonsense.

Ulrich, Foerste, Miller, and Unklesbay (1944) use Orthocerotidae referring to it *Ellesmeroceras, Albertoceras,* and *Copiceras,* referable to the Ellesmeroceratidae, *Buttsoceras,* and *Oxfordoceras,* here regarded as probably the same and referred to the Troedssonellidae, the little known *Ogygoceras,* which may possibly be a synonym of *Suecoceras,* and *Proterocameroceras,* now assigned to the Proterocameroceratidae of the Endoceratida.

Properly, the family may remain restricted on the basis of the peculiar internal thickenings at midlength of the mature living chamber. It will then contain only *Orthoceros.* Similar features reported in *Ctenoceras* are probably adventitious and the result of crushing.

FAMILY PSEUDORTHOCERATIDAE Flower and Caster, 1935

This is a family, dominantly of orthocones, with the siphuncles first developing annuli which grow forward and fuse to form a continuous lining in the siphuncle, and develop also expanded siphonal segments. The family has been monographed (Flower, 1939) with the recognition of three subfamilies, and later (Flower, 1957) the subfamily Macroloxoceratinae was added. The family is known to range from early Devonian through the Permian. Some late Paleozoic genera have been added by recent workers, but it is not necessary now to cite or evaluate these genera. It should be noted that supposed Ordovician and Silurian Pseudortheratidae are here assigned to the family Proteoceratidae.

FAMILY SACTORTHOCERATIDAE Flower, 1946

This family cannot be used in accord with its original definition; namely, for orthocones with suborthochoanitic necks and segments which show only the faintest expansion. In designating the family, an important fact was overlooked: that three very distinct species groups were included in *Sactorthoceras*, (I) forms with short camerae and rather short tubular segments, (2) forms with longer camerae, segments faintly expanded, and (3) forms with septal necks geniculate, the siphuncle tubular over most of its length but abruptly contracted at the septal foramina by these peculiar necks. Group 2 was considered in defining the Sactorthoceratidae, but unfortunately the genotype belongs in group 3. Therefore, if the family is to be used at all, it must be used with a completely new definition.

S. gonioseptum Kobayashi 1934, the genotype, is known from only three specimens of which one, the original of Kobayashi's pl. 20, fig. 9, seems doubtful as to assignment.

As yet, no other Ordovician cephalopods are known which show similar geniculate necks. In the Silurian there are some species figured by Barrande among orthocones of generalized aspect, but these species are as yet of even uncertain generic assignment, and we have no assurance that they represent a lineage with true *Sactorthoceras* as its beginning. Oddly, the fact has been long overlooked that *Dawsonoceras* has a somewhat similar siphuncle, though it is one in which the septal necks are short, actually recumbent, and such necks form narrow projections within an otherwise tubular siphuncle. Again, it is not certain that *Dawsonoceras* developed from *Sactorthoceras;* indeed, the writer would suspect that the internal specialization is peculiar to the genus and that it developed not from shells of the aspect of *Cycloceras*, but possibly from *Kionoceras* of the Silurian, in which segments commonly show faint expansion.

There seems at the present time no good basis for recognizing a family Sactorthoceratidae as necessarily revised in the light of the genotype of *Sactorthoceras*. Neither is it evident that there is a real need for a family with the definition given to the Sactorthoceratidae by the writer in 1946. At that time it appeared that such a family was the potential source of not only advanced Michelinoceratidae with expanded siphuncles such as the Stereoplasmoceratidae and Proteoceratidae of the present work, but also of forms with ventral expanded siphuncles, the Allumettoceratidae and the beginning of the lineage of dominantly exogastric shells with ventral expanded siphuncles, the Oncoceratidae and their allies. It seems necessary to abandon this concept of relationship in the light of newer information and to regard the Oncoceratida as stemming through the Graciloceratidae, now considered the archaic and atypical family of the order, through the Bassleroceratidae of the Tarphyceratida.

The error stemmed from an attempt to recognize the Eurysiphonata and Stenosiphonata of Teichert, though with the necessary revisions apparent even at that time, using the first group not only for forms with large siphuncles (Eurysiphonata) of commonly though not universally expanded segments, but also including in it the archaic cephalopods in which the ring was of considerable thickness and commonly rather complex. It now appears that the thin homogeneous rings developed independently (r) from Baltoceratidae to Michelinoceratida, (2) within the Actinoceratida, (3) from the Bassleroceratidae to the Graciloceratidae, and (4) from the Tarphyceratida to the Barrandeoceratida. It is now evident that the older cephalopods cannot be divided into two groups to which the terms Eurysiphonata and Stenosiphonata can be applied, even with considerable emendation of definitions of these groups.

FAMILY SINOCERATIDAE Shimizu and Obata, 1935

Shimizu and Obata used *Orthoceras chinensis* Foord as the basis of the new genus *Sinoceras* and the new family Sinoceratidae, both the family and the genus being based on the long septal necks, one fourth to nearly half the length of a segment. There can be little point in putting this genus and its one species in a family by itself. Retardation of cameral deposits and apparent absence of siphonal deposits suggest a relationship with *Orthoceros*, and the two genera might be put in the same family. The name Sinoceratidae has priority. Oddly, internal molds of living chambers have not been figured; we do not know that *Sinoceras* has similar internal thickenings at midlength of the living chamber, but neither do we know that it does not.

SPYROCERATIDAE Shimizu and Obata, 1935

Shimizu and Obata defined this family as containing annulated shells with longitudinal markings and an orthochoanitic siphuncle. They had not troubled to investigate the genus on which the family is based, which has an expanded siphuncle; segments in form and deposits are similar to those of *Dolorthoceras*, and *Spyroceras* is referred to the Pseudorthoceratidae.

FAMILY STEREOPLASMOCERATIDAE Kobayashi, 1934

Kobayashi (1934) proposed this family without definition other than its use for the genera *Stereoplasmoceras* and *Tofangoceras*. Kobayashi revised the family later (1936a) adding *Stereoplasmocerina* and *Tofangocerina*. Flower (1939) discussed these forms as possible relatives of the Pseudorthoceratidae, but concluded that there was no evidence of real affinities. Flower in Flower and Kummel (195o) employed the family for a group of Ordovician orthocones with expanded siphuncles, defining it as containing forms with expanded siphuncles and nonsegmental deposits. Later (Flower, 1955) forms with segmental deposits were included under the family name. As noted in the discussion of the Troedssonellidae, some questions of interpretation are involved as to whether some linings are segmental or non-segmental, and further conclusions as to relationships involve additional inferences. It is clear, however, that since *Stereoplasmoceras* is so restricted as to contain orthocones with expanded siphuncle segments without demonstrable siphonal deposits, the family name cannot be used without considerable embarrassment for forms with either segmental or apparently continuous linings. Actually, there is some embarrassment inasmuch as *Stereoplasmoceras* rests upon S. *pseudoseptatum* Grabau, and Kobayashi (1936a) has eliminated the original of Grabau's pl. 9, fig. 11 as an actinoceroid, and the original of pl. 6, fig. 7 as of uncertain affinities; the originals of pl. 6, fig. 5 and 6 are all that remain. Siphuncles are not exposed in longitudinal section in these specimens, and only the heavy cameral deposits remain as diagnostic. Form of siphuncle segments, and any possible siphonal deposits, are thus unknown, but the size of the siphuncle as seen in cross section leaves one with the uncomfortable impression that it is too large for what Kobayashi later called *Stereoplasmoceras,* and the things are more probable actinoceroids. Cross sections show calcite in the siphuncle, suggesting annuli of actinoceroids, and seem at variance with the empty siphundes figured in later works by Kobayashi. From Kobayashi (1936), only species with fairly well-rounded segments are put in the genus; none is known to show any deposits at all in the siphuncle. It seems best to avoid these perplexities in the only way possible, by admitting that doubt surrounds the nature of *Stereoplasmoceras pseudoseptatum* and using other family names than Stereoplasmoceratidae.

FAMILY STRIATOCERATIDAE Flower, 1939(a)

This family is based on *Striatoceras,* the genotype of which, *Sactoceras? striatum* Troedsson, 1926, is an orthoconic shell with fine longitudinal markings, a subcentral siphuncle of subspherical segments within which there is a lining which Teichert (1934a) represented as composed of several lamellae growing one over the other rather irregularly. As noted in the discussion of the Troedssonellidae, where this form is considered as a possible relative of that family, such a development could have sprung either from modification of segmental deposits, as in the Proteoceratidae, or possibly it could be a continuation of the lining of the Troedssonellidae. There are a number of orthoconic forms known which show somewhat similar linings, but almost none has had the structure studied in sufficient detail. Teichert's *Stokesoceras balticum (1934)* is such an orthocone, but we do not know enough about it; conceivably, it could have lost a longitudinally marked surface by abrasion. Possibly *Stereoplasmocerina* could be placed here, but we know too little of the morphology of the genotype.

It should be noted that *Stereoplasmocerina* as made known by Kobayashi (1936) and that genus and *Ctenoceras* as interpreted by Sweet (1958) are similar to *Striatoceras* in the apparently nonsegmental linings, but they have shown no such layering as suggested by Teichert's (1934) interpretation of *Striatoceras.* If one is seeing the most logical assignment, these genera might be added to the Striatoceratidae, but, as noted in the discussion of the Troedssonellidae, it is not certain that this interpretation is correct.

FAMILY TROEDSSONOCERATIDAE Kobayashi, 1935

As noted in the discussion of the Troedssonellidae, Kobayashi was correct in proposing a family for orthocones with spheroidal segments containing nonsegmental linings, but the name Troedssonoceratidae which he proposed has to be dropped, because the species showing this structure, *Sactoceras striatum* Troedsson, is not a true *Troedssonoceras; Troedssonoceras is* an actinoceroid and is here considered a synonym of *Deiroceras.* The family Striatoceratidae Flower, 1939, replaces the Troedssonoceratidae of Kobayashi, and is, indeed, little more than a new name required for reasons of nomenclature.

New Family Proposals

FAMILY PROTEOCERATIDAE Flower, new family

Here are placed slender shells, dominantly straight, some slightly exogastric, of the Michelinoceratida in which siphuncle segments are expanded and develop annular deposits like those of the Pseudorthoceratidae. They differ from the Pseudorthoceratidae, although homeomorphic with them to a degree, in that ( ) except in unknown earliest stages, the siphuncle segments progress gradually in ontogeny from broadly expanded to tubular segments and (2) form of the siphonal deposits is different. Annuli grow in some species apicad as well as orad from their point of inception at the septal foramina in some forms, but only orad in others. In either instance, deposits thicken where the segment curves orad from the septal foramen, and commonly the deposits leave a cavity in the siphuncle which widens in the anterior third or quarter of the segment.

It is this group of genera that the writer had previously placed in the Stereoplasmoceratidae (Flower in Flower and Kummel, 195o; Flower, 1955). However, in doing this some questions were by-passed, largely involving the fact that our present information on the structure of *Stereoplasmoceras* is not adequate to demonstrate similar features in that genus. Indeed, if *Stereoplasmocerina* is allied and correctly interpreted, the siphuncle contains probably nonsegmental deposits and is thus quite alien to the present family Proteoceratidae. Actually, no specimens retained in *Stereoplasmoceras* after the separation of *Stereoplasmocerina* by Kobayashi (1936) are known to show any deposits in the siphuncle whatsoever. Unfortunately, the question cannot be resolved easily, as material from North China and Manchuria would be required for investigation as to possible siphonal deposits in more apical parts of the siphuncle of *Stereoplasmoceras.* As far as can be determined, available collections lack the requisite specimens. Quite aside from the difficulties of time and expense in attempting to collect more material, the present international situation makes this impossible, and there is little reason to hope for improvement of these matters in the near future. In the meantime, a name is needed for the present Proteoceratidae based upon cephalopods more certainly known morphologically; if subsequent work should show the Stereoplasmoceratidae identical, adjustment of terminology may reasonably follow.

The genera now known may be summarized as follows:

Proteoceras Flower 1955.—Smooth slender shells, straight adorally, early part gently exogastric or straight; siphuncle segments broadly expanded in the young, subtubular in the adult; late stages alone would be considered Michelinoceratidae by the incautious. Siphuncle ventrad of center, with annular deposits, greatly delayed and present only apically, growing both orad and apicad of the septal foramen; when advanced, deposits leave a cavity wide in the anterior third of the segment, narrow and tubular in the apical part.

Stereospyroceras Flower 1955.—Shells with the annuli and longitudinal markings of *Spyroceras,* but with siphuncles and siphonal deposits very similar to the above. Species show considerable variation in the adoral simplification of the siphuncle, but the trend is general and some forms at least attain anterior segments which are perfectly tubular. Very abundant in the Chazyan of eastern North America.

Mesnaquaceras Flower 1955A slender shell with low annuli and fine transverse markings; siphuncle segments barrel-shaped in the only observed portion (early maturity) with siphonal deposits growing orad from their inception, rather irregular. Slope of annuli, concentration of cameral and siphonal deposits suggest the siphuncle to be dorsad rather than ventrad of the center.

Tofangoceras.—This genus possibly belongs in this group, but the Asiatic material and genotype fail to show the deposits of the siphuncle. American species of the aspect of *To*

do, but for some years the writer was reluctant to propose a new genus for them. Wilson (1961) has proposed such a genus, *Monomuchites,* based on a new species *M. costalis,* and while we cannot learn much more of the morphology from this species than from *Tofangoceras,* from the type illustrations we at least are reasonably certain that material from the Black River of New York, Ontario, and from Lake St. John, Quebec, belongs certainly to the genus and shows segmental deposits of the Proteoceratidae. As it is, it is doubtful whether Dr. Wilson has solved the always difficult matter of specific relationships in orthocones known from fragmentary materials, but it seems most doubtful whether this species is common to the "Leray" beds and Sherman Fall beds. Fortunately, the Leray material includes the types.

Monomuchites.—This genus may be defined as shells of the aspect of *Cycloceras* (certainly relative spacing of septa and annuli fails to differentiate obviously valid species groups or genera), the siphuncle subcentral, segments expanded broadly in the young, slender in the adult, annuli similar to those of the above genera, greatly concentrated apically.

Gorbyoceras Shimizu and Obata, emend Flower.—This is a genus of shells with longitudinal markings and generally low rounded annuli, a subcentral siphuncle of expanded segments, deposits not definitely known. This is one of the numerous indiscriminately proposed and poorly defined genera of Shimizu and Obata that are rescued as valid by subsequent work. The known species are Cincinnatian, and have been described and illustrated by Flower (1946). In the absence of definite knowledge of deposits in the siphuncle, assignment to the Proteoceratidae is necessarily tentative, but on the other hand, it is quite possibly a late Ordovician expression of *Stereospyroceras,* which differs primarily in the more sharply defined annuli and the rather larger siphuncle segments which undergo a more marked adoral simplification. If *Gorbyoceras* is not a member of the Proteoceratidae, and evidence is meager, for specimens showing interiors are few, fragmentary, and not particularly well preserved, it belongs to some cyrtochoanitic stock of the Michelinoceratida as yet inadequately known or unrecognized.

Isorthoceras Flower, new genus.—Genotype: *Orthoceras sociale* Hall, of the Maquoketa shale. Smooth, subcircular, siphuncle subcentral, early siphuncle segments barrel-shaped, slender, expansion concentrated at the septal foramina; later segments become subtubular. Annuli grow both apicad and orad from inception, apically; in adoral segments growth is mainly forward; the resultant lining is more uniform in thickness with less constriction of the cavity in the apical parts of segments than in related genera. Deposits are greatly concentrated apically. In addition to the Maquoketa genotype, representatives of this genus occur in the Cynthiana and Cathys, and probably in the middle Trenton, though future work may show the desirability of making yet another genus for these allied species.

Orthonybyoceras Shimizu and Obata, based upon *Ormoceras covingtonese* Foerste and Teichert.—This genus preoccupies *Treptoceras* Flower. The shells show rather small siphuncle segments, with recurved brims as in *Armenoceras* in the young, passing through stages like those of *Ormoceras* and later *Dieroceras.* Though long regarded as an actinoceroid, the genus is peculiar in the minute early stages, the persistence of the septal furrow. Though annular deposits are regular, suggesting actinoceroids, thinsections show an absence of a perispatium and of radial canals, and early stages of 0. *duseri* Hall and Whitfield show patterns of those of *Proteoceras* in the development of annuli.

Euorthoceras Foerste.—This genus, proposed in connection with a group of species from the Brassfield limestone, contains shells with a similar ontogenetic succession in terms of siphuncle outline, but segments are in general more slender and essentially tubular segments are found in the later growth stages. Deposits in the siphuncle are not certainly known, but it is worth noting that these Brassfield species are quite possibly the lineal decendants of *Orthonybyoceras* of the Cincinnatian; it is possible that future work may show that the genera are not distinguishable. If so, *Euorthoceras* must be retained on the basis of priority.

Ephippiorthoceras Foerste.—This genus was first recognized as an orthocone, slightly compressed in section, sutures with slight lateral lobes, a siphuncle between center and venter with expanded segments. Teichert and Glenister (1953) have assigned to the genus a species which for the first time shows the internal structure clearly. The siphuncle segments contain annuli which grow forward; cameral deposits are advanced where siphonal deposits are developed; other material indicates adoral slendering of the segments of the siphuncle. The genus, developed in the Red River faunas in North America, extends into the Cobourg but is not definitely known in beds of certain Richmond age. The Tasmanian species is from the Gordon River limestone, the Silurian age of which seems questionable from the presence of this genus.

Stromatoceras Teichert and Glenister.—This genus is based upon a slender, longitudinally marked shell from the Gordon River limestone of Tasmania, gently but rather irregularly curved; one may question to what extent curvature may be the result of distortion. The siphuncle, ventrad of the center, shows apically an appearance very similar to that of *Proteoceras.*

Oddly, the light calcareous deposit in this genus seems comparable to that found in *Proteoceras.* In *Proteoceras* this material was at first thought to be organic, but more study based upon more specimens led to the conclusion that it was calcite complementing the incomplete penetration of matrix in the siphuncle. This does not appear to be true of *Stromatoceras*, for such material lies on both the dorsal and ventral sides of the central matrix in a vertical section. Cameral deposits are somewhat doubtful, and are possibly greatly retarded in development.

Gordonoceras Teichert and Glenister, 1953.—Gently exogastric, slender, circular in cross section; sutures straight and transverse, siphuncle between center and venter, segments fusiform, more abruptly contracted adorally than adapically, deposits annular, grow orad from septal foramen, thick, constricting the apical part of the siphuncle cavity markedly. Thick complex episeptal deposits.

Cyrtactinoceras Hyatt.—Genotype: *Cyrtoceras rebele* Barrande. This genus, to which only the genotype can be assigned with certainty, is composed of small, very gently exogastric, slender shells of subcircular section. The mature living chamber contracts gently toward the aperture and is, in form, rather reminiscent of the Ordovician *Beloitoceras.* The siphuncle shows a transition from early segments subspherical and close to the venter to anterior segments more nearly central and essentially tubular. Annular deposits in the siphuncle are slightly concentrated ventrally, grow slightly more orad than apicad of the septal foramen, tending to be large and massive in the expanded parts of the siphuncles; anterior surfaces of the deposits are strongly oblique and flattened, as in many Proteoceratidae. This genus, previously assigned to the Actinoceratida, fails to show perispatium or radial canals, but conceivably its features could be a specialized condition in the Actinoceratida. However, it is now evident that the form of the annuli and the general ontogeny of the form of the siphuncle segments are, together, typical of the Proteoceratidae.

FAMILY OFFLEYOCERATIDAE Flower, new family

This family is proposed for Michelinoceratida which, in late Middle Silurian and Devonian times, developed rather large siphuncles in which the necks were extended to a truly holochoanitic condition. *Offleyoceras arcticum is* from possibly Lower Devonian strata of the arctic, as is the allied *Orthoceras scheii* Foerste. The writer has related forms from the late Middle Silurian, not yet described. The range of this group of forms, in which the writer at present recognizes only one genus, though a need for others is suggested by the present material, is such as to make it most unlikely that the lengthening of the necks had anything to do with the development of the early Ordovician *Sinoceras.* Cameral and siphonal deposits in the Offleyoceratidae remain unknown.

FAMILY SPHOOCERATIDAE Flower, new family

This family is erected for Michelinoceratida with subcentral tubular siphuncles, rather deep septa, natural truncation of the shell. It contains only the type genus:

Genus SPHOOCERAS Flower, n. gen.

Genotype: Orthoceras *truncatum* Barrande

The genus has the characters of the family. Only the genotype is recognized, from the Middle Silurian of Bohemia. The distinctive growth habit of this species is such that the need for its segregation in a genus and a family by itself has long been apparent. The species was extensively discussed and amply and faithfully illustrated by Barrande. Such observations as the writer has been able to make have supported his conclusions most completely.

FAMILY ENGORTHOCERATIDAE
Flower, new family

This family is erected for the single genus *Engorthoceras,* conical straight shells with marginal siphuncles. The conical rather than tubular shells distinguish this family from the Bactritidae. Protoconchs are not known, but the negative evidence is not of great value in view of the limited material known and its fragmentary nature.

Genus ENGORTHOCERAS Flower n. gen.

Genotype: *Orthoceras wortheni* Meek and Worthen

This is a conically expanding shell of subcircular cross section and a completely marginal small siphuncle, which has as yet not been fully observed but is apparently tubular or nearly so. The conical shell is suggestive of the phragmocone of a belemnite, but the genotype has a rather thick shell with coarse transverse markings outlining a transverse aperture with only a faint ventral hyponomic sinus.

I shall illustrate this genus upon another occasion. 0. wortheni is common to the Middle Devonian of Ohio and Indiana. Its type material is in the Worthen collection of the University of California. The genus is of interest in that its shape suggests that it is possibly the ancestor of *Eobelemnites,* while more slender Mississippian belemnites suggest instead a possible origin in the Bactritidae.

Contributions to the Morphology of Some Michelinoceratida

Under this heading are grouped some heterogenous observations, with illustrations, largely contributing further to the morphology of some Michelinoceratida. They include, first, further investigation of the morphology of *Orthoceros regularis* (Schlotheim); second, some new material of an Ordovician genus, previously unrecognized, characterized by oddly mural deposits of the camerae. Oddly, when such deposits are exfoliated with the shell, the resulting internal mold has the aspect of "*Cycloceras*" and one such species was referred to that genus. Third, brief description and illustration of the interior of *Dawsonoceras* are presented, a genus unique in showing deposits of generalized Michelinoceratida in a siphuncle with recumbent septal necks.

ORTHOCEROS Brunnich

Orthoceros regularis (Schlotheim)

Pl. 4, fig. 1-7

Teichert and Miller (1936) suggested that this species would be an appropriate one to designate as a genotype of *Orthoceros* Brunnich, which name might well replace "Or-*thoceras*" in scope for smooth generalized orthoconic cephalopods with subcentral tublar siphuncles.

Troedsson (1931) made this species quite adequately known, but his description left unanswered some question as to whether the siphuncle and camerae were void of deposits, or whether the apparent absence of these structures was due to the sectioning and examination only of portions of the phragmocone too close to the living chamber. Troedsson's material was kindly lent and permission was granted to make an additional section. The results are shown on Plate 4, figures 1-7. The anterior end consists of a reasonably long but not quite complete living chamber, 19 mm across at the suture at the base, 155 mm long, 27 mm wide near the adoral end. The internal thickenings occur 72-80 mm from the base. Attached to the base are three camerae, together measuring 20 mm long. Fitting on the base of this portion are six camerae broken and exposing the siphuncle, followed by an interval ground to the siphuncle of six more camerae, the two together 6o mm long. (pl. 4, fig. 2, 3). An enlargement of the ground portion is presented; neither siphuncle nor camerae show any organic deposits.

There follows a portion i 52 mm long, expanding from 9 to 16.5 mm and containing 27 camerae. The apical portion alone was sectioned, being ground in the vertical plane, shown X 2 in plate 4, figure 6, and the apical part in greater enlargement in figure 7. Here the siphuncle is free of any organic deposit; the lining developed is apparently inorganic. The section is vertical, with the dorsum on the left as shown on our plates. On the dorsal side, cameral deposits are extremely thin, the surface straight, and largely confined to the mural part of the septum. On the venter, deposits are similarly thin, but extend along the anterior surface of the septum about half way to the siphuncle. Their course against the mural part of the septum is obscured here, there is some loss by exfoliation. It is clear that the deposits are present here but extremely thin and show only incipient stages of development.

Discussion.—It is evident that 42 camerae from the base of the living chamber there are no organic deposits in the siphuncle, and vestigial cameral deposits are apparent only in camerae 36-42. Whether more apical portions would show siphon-al deposits as well as thicker cameral deposits, it is impossible to say. It seems likely. However, in this specimen, which is far more complete than are most specimens which have been figured and described, it is apparent that 35 camerae and roughly 200 mm from the base of the living chamber, there are only vestigial cameral deposits, and 42 camerae and 25 mm farther, there are still no evident siphonal deposits. It is of interest to note that in this species the shell shows the weighting of the apex which is commonly involved in orthocones and makes possible an active mode of life with the shell held horizontally, confined to such a small apical extremity as to be puzzling in relation to any attempts to reconstruct the hydrostatic relationships of the living animal.

It is not possible to give more than a rough estimate of the apical missing part of the shell in this specimen, but it seems likely from associated fragments that apical portions are slender, and the missing portion may be as long as 100 mm and certainly no shorter than 8o mm.

The specimen here figured is No. Mo 3032, a-d. Some earlier fragments which do not fit are included, but their identity with this specimen seems doubtful as they do not fit it. The material is from the upper Orthoceras limestone of Reval, Esthonia.

PLEURORTHOCERAS Flower, n. gen.

Genotype: *Orthoceras clarkesvillense* Foerste

This genus is erected for slender orthocones, smooth externally, with rather deep camerae in the known species, a siphuncle slightly ventrad of the shell center, composed of essentially tubular segments faintly constricted at the septal foramina. Siphonal deposits are unknown; if not completely absent, they are so delayed in development that they are confined to extremely apical shell parts. Cameral deposits are distinctive in that they are strictly mural and are not extended at all along the free parts of the septa. Such deposits are thickened ventrally, as is usual, show a midventral boss, and are faintly thickened and longitudinally striated in zones at the apical ends of the camerae; these zones are wide ventrolaterally, thinning toward the dorsum. Shells are subcircular in section, very slightly depressed, with straight transverse sutures.

Oddly, Foerste, in proposing *Michelinoceras,* noted that 0. *clarkesvillense* was the only American species then known which was really typical. This conclusion rested upon the slender shell form and the rather long camerae. The pattern of siphonal and cameral deposits was then not considered significant. From the present study, it is apparent that 0. *clarkesvillense* and 0. *selkirkense* are peculiar in the strongly developed, strictly mural deposits, a feature shared actually with very few other species, and found again, surprisingly, in the genus *Dawsonoceras.*

Whiteaves (1892) described *Orthoceras selkirkense,* a straight shell with apparent distant annuli. Foerste (5929, p. 161, pl. 37, fig. 4A-B) redescribed the species and assigned it to *Cycloceras.* Miller, Dunbar, and Condra (1933) pointed out that the genotype of *Cycloceras* was so poorly known that there was uncertainty as to the exact features of the genus. Shimizu and Obata (1936, p. 2 I) proposed the genus *Foersteoceras* for shells with annuli and an essentially tubular siphuncle. They assumed the presence of fine transverse markings, not demonstrated in 0. *selkirkense.* While a genus is needed for shells of the aspect of *Cycloceras* in the early Paleozoic with tubular siphuncles, two objections exist in relation to the present proposal. First, the generic name chosen was preoccupied by *Foersteoceras* Ruedemann, based upon *Trochoceras turbinatum* Hall of the Cobleskill limestone of New York. Second, it was felt that before a new name was proposed, *Orthoceras selkirkense* should be made better known. New material now shows that the apparent annuli of this species result from exfoliation of cameral deposits with the shell wall from the internal mold; the species has a smooth shell externally. The material figured and described here shows the species in section, and also shows an internal mold from which cameral deposits were exfoliated, showing surface details not apparent in the material available to Whiteaves or to Foerste.

It has seemed best to make *Orthoceras clarkesvillense* the type of this genus, largely because the sectioned specimen shows the structures with little ambiguity, while dolomitization has altered shell parts in our material of 0. *selkirkense.* The latter species, however, has shown surface impressions of cameral deposits more clearly and is apparently relatively common, while 0. *clarkesvillense* is rather rare. The combined collections of the University of Cincinnati and of Miami University contain not more than a dozen good specimens of 0. *clarkesvillense,* while less than an hour's collecting resulted in the four specimens of 0. *selkirkense* here described.

Pleurorthoceras clarkesvillense (Foerste)

Pl. 6, fig. 1-4

Orthoceras clarksvillense Foerste, 1924, Denison Univ. Bull., Sci. Lab., Jour., vol. 20, p. 220, **pl. 42, fig. 1 A-B.**

This is a slender shell with rather deeper camerae than most of those found in the Cincinnatian, with a subcentral, subtubular siphuncle. The species is not common, and it appears to be confined to the Blanchester member of the Waynesville and the Liberty intervals of the Cincinnati section.

The specimen here figured is of unusual interest in that it retained, when found, two rather widely separated parts of the phragmocone. The arrangement of the two parts on our plate shows the approximate length of the missing intervening portion. The anterior portion shows eight camerae in a length of 75 mm, siphuncle segments are slightly expanded, more so in the adoral half than in the apical half of each camera; here are about two and a half camerae in a length equal to the adoral shell diameter. This portion shows no deposits in siphuncle or camerae and increases in width from 24 to 28 mm.

The apical portion, 96 mm long expanding from 15 to 23 mm, was separated from the anterior portion by a length of between 4o and 75 mm. This portion is sectioned. On the left one can see calcite-replaced cameral deposits in most of which the calcite is widened adapically, representing the striated zone seen in *Pleurorthoceras selkirkense.* On the right side, the deposits are apparently augmented by and confused by inorganic calcite, and the pattern is not at all clear in the adoral portion. However, in the second and third camerae from the apical end, calcite apparently represents only the organic cameral deposits.

The siphuncle segments are faintly expanded, attaining their greatest width orad of the middle, and expanding more rapidly apicad than orad from the septal foramina. The siphuncle is completely void of siphonal deposits, though at the apex we see a camera that is at least the twenty-fifth and quite possibly as much as the thirty-fifth from the base of the living chamber.

An additional specimen is figured showing an internal mold of a few camerae in which the apical striated zone is seen enlarging from the lateral to the midventral region. Deposits are young here, and that there is no midventral boss as in *P. selkirkense is* possibly of no real significance.

Figured specimens.—Collection of the late Dr. W. H. Shideler, Miami Univ., Oxford, Ohio.

The figured specimens are from the Liberty beds of Adison's Creek, near Blanchester, Ohio.

Pleurorthoceras selkirkense (Whiteaves)

Pl. 4, fig. 8; **Pl.** 5, fig. 1-8, 11-13, **16,** *17*

Orthoceras Selkirkense Whiteaves, 1892, Royal Soc. Canada, Trans., vol. **9,** sec. **4, p. 8z, pl.** 8, fig. **2,** za, 2b.

Cycloceras selkirkense Foerste, 5929, Denison Univ. Bull., Sci. Lab., Jour., vol. **24,** p. 161, pl. 37, fig. 4A-B.

Foersteoceras selkirkense Shimizu and Obata, 1936, Shanghai Sci. Inst. Jour., sec. **2, vol. 2, p. 2**1.

Whiteaves described this species in terms of the genus *Orthoceras,* basing his description upon two specimens. Foerste redescribed it and assigned it to *Cycloceras;* he had only one of Whiteaves' original specimens but mentioned one additional specimen. The shell is slender, with apparent annuli agreeing with septa in spacing, rather deep camerae and a subtubular subcentral siphuncle. The genotype of *Cycloceras* is so little known that no other species can be placed in the genus with certainty. Shimizu and Obata erected the genus *Foersteoceras,* based upon *Cycloceras selkirkense,* for shells of the aspect of *Cycloceras* with subtubular orthochoanitic siphuncles. Flower (1943) pointed out that while such a genus was needed, *Foersteoceras* was preoccupied, having been used by Ruedemann (1925) for a trochoceroid genus based upon *Trochoceras turbinatum* Hall of the Cobleskill limestone of New York. It was suggested, however, that before a new name be proposed for a generic group with the scope of *Foersteoceras* Shimizu and Obata, this species should be studied more closely.

New material now makes such a study possible, and the results have been most surprising. The specimens show that this species has actually a smooth shell. Cameral deposits are strictly mural, unusual in form, and when such deposits are exfoliated with the conch and mural parts of septa, the resulting internal mold has much the aspect of a shell with external annuli. Actually, the species shows structure similar to that of *Orthoceras clarkesvillense*, but the similarity with shells of the aspect of *Cycloceras* is superficial and misleading. The several specimens here illustrated and discussed individually below will suffice to demonstrate these matters.

Our best preserved specimen (pl. 4, fig. 8, pl. 5, fig. 1-8, 11, 12, 16, 17) is a portion of 12 camerae of a phragmocone, evidently considerably removed from the living chamber, judging from the development of cameral deposits throughout the length of the specimen. Though portions of the shell are retained largely dorsally and laterally, for the most part cameral deposits have been exfoliated from the internal mold, which retains an impression of their surface features with unusual fidelity and detail. The specimen is 137 mm long, expanding from 17 mm at the base to a slightly depressed condition adorally, where the height is 22 and the width 24 mm. Cameral deposits, thin adorally, thicken gradually apicad, and apical proportions are necessarily approximate, as exfoliation is general in that region. Camerae are spaced one and a half in a length equal to the adoral shell height adorally, and 1.3 camerae occupy a similar length apically, though they remain 1.5 in a length equal to the adoral shell width. Sutures are very slightly oblique, sloping faintly forward from venter to dorsum. Adorally, the siphuncle is 4 mm across, 5 mm from the venter, and 14 mm from the dorsum. It seems more eccentric apically, but in part this appearance is due to exfoliation of the cameral deposits, which are markedly thicker ventrally than dorsally. The pattern of the cameral deposits is of unusual interest and is shown in detail in the illustrations. In general, deposits thicken from dorsum to venter. On the apical end of each camera there is a zone, slightly thicker than the remainder and thus incised into the internal mold, in which the deposits bear longitudinal striations. This zone, wanting middorsally, thickens from the dorsolateral to the ventral region; laterally, its margins are prominent, but midventrally it loses its identity. Orad of this region, the surface of the internal mold is covered with round, pitted areas, the pits larger and more prominent in adoral than in adapical camerae, as shown particularly in Plate 5, figures 12, 16, and 17. In figures 16 and 17, the pits are larger over the adoral two camerae, finer and less distinct on the apical three camerae. On the midventral region the deposit is thickened into a median boss, slightly elongate, and with poorly defined margins. Dorsally, the surface of the internal mold shows a faint median groove over most of its length, reminiscent of the septal furrow, but it terminates in a marked tubercle at the anterior end of the camerae, well shown in the anterior camera shown in Plate 5, figure II, and again apically in Plate 4, figure 8. A section was made of the apical part of this specimen, which is not illustrated, as preservation of the siphuncle is not particularly clear; it is, however, sufficient to show that in this region, where cameral deposits are well advanced in growth, there are no deposits whatsoever in the siphuncle.

The latest growth stage observed is shown by a specimen rather poorly preserved externally, which is not figured. It shows a living chamber, the surface rather roughly preserved but obviously smooth, expanding from 28 and 35 mm at the base to 35 and 37 mm at the adoral end, in a length of 90 mm. It probably represents the complete length of the living chamber, but only parts of the apparent aperture are preserved; no hyponomic sinus is evident. At the base of the living chamber a piece 17 mm long preserved three camerae and part of a fourth; camerae are spaced two and a half in a length equal to the adoral shell width. At the base of the living chamber the siphuncle is 6 mm across, 6 mm from the venter, and 16 mm from the dorsum. It should be noted that while this specimen establishes the maximum observed shell diameters for the species, it lacks evidence of a preoral constriction of the interior of the living chamber or shortening of the adoral camerae, and so is not mature; the species probably attained a slightly larger maximum size. However, it should be noted that the anterior end of our first specimen showing the cameral deposits would lie between 110 and 16o mm from the base of the living chamber of this specimen and would be separated from such a living chamber by between 8 and I2 camerae.

A third specimen (pl. 5, fig. 9 and 1 o) retains ten camerae in a length of 135 mm; it was originally 14 mm high and 18 mm wide at the base, enlarging to 18 and 22 mm adorally. Siphuncle segments are retained throughout most of the length, showing the usual faint expansion, largest in the adoral half of the segment. No deposits are present in the siphuncle and are only faintly and poorly suggested in the apical camerae, and there only on the ventral side. It would thus appear that this phragmocone was from an immature shell.

A fourth specimen, Plate 5, figures 14 and 15, is a portion of phragmocone 16 and 18 mm across apically, 6o mm long, and 18 and 23 mm across adorally. Considerable portions of the smooth shell are preserved throughout. In the apical three camerae the siphuncle segments are preserved in outline, but septa are most faintly indicated, and there is no differentiation between matrix in the camerae and cameral deposits or shell wall, though much of the shell surface is preserved over this interval. The adoral four camerae show a filling of inorganic calcite, the outer margins of which are faintly concave, being thus shaped in accordance with the mural deposits of the camerae. The deposits, mural parts of septa and shell wall are represented by dark granular dolomite, quite like the material filling the camerae of the apical portion, though again the specimen separated readily over the smooth shell surface. The siphuncle segments show the usual faintly fusiform outline, and fail to show any organic siphonal deposits.

A rather long, poorly preserved interval of phragmocone is shown in Plate 5, figure 13. This specimen, viewed from the dorsum, shows parts of eight camerae (the entire length is not illustrated) viewed from the dorsal side. In the center, shell wall and cameral deposits have been exfoliated, showing an internal mold with narrow sharp annuli developed at the regions of the septa, but laterally one can see readily the combined thickness of shell wall and cameral deposits, the two together being considerably darker than the surrounding matrix. The specimen shows a width of 24 mm at the base, increasing in 130 mm to 27 mm; the camerae average 14 mm in length.

Hypotypes.—The specimens on which the present description is based, which are hypotypes, are nos. 385-389 in the collection of the writer; they are from the Selkirk limestone, from a small abandoned quarry slightly east of the main quarries at Tyndall, Manitoba. The four specimens and a poorer fifth specimen were collected in a visit of a half hour, and the species is fairly common there; however, in the main quarries, farther east, which are slightly higher in the Selkirk limestone, no specimens were encountered.

Family Dawsonoceratidae

Michelinoceratida with small annuli in the siphuncle and cameral deposits, strictly mural in the one genus known. The internal pattern is that of the Michelinoceratidae with one important exception; namely, that the siphuncle has segments largely tubular but constricted at the septal foramina by recumbent necks. Only one genus, *Dawsonoceras,* is certainly known to belong in this group. Internal patterns suggest derivation from generalized Michelinoceratidae with annuli in the siphuncles. As yet, the connection has not been established, but it seems probable that it may be found in Silurian *Kionoceras,* in which incipient constriction of siphuncles at the septal foramina has been observed.

DAWSONOCERAS Hyatt, 1883

Genotype: *Orthoceras annulatum* Sowerby

Shell straight, with annuli, fine transverse markings which are festooned, acute adorally, curved adapically, the adoral extensions of the ornament may be joined by longitudinal ridges. Shells are subcircular in section, with simple transverse sutures, the siphuncle slightly ventrad of the center is composed of segments tubular for most of their length, but abruptly constricted at the septal foramina by short recumbent septal necks which cause narrow but marked constrictions of the cavity of the siphuncle. Annuli are developed in the siphuncle, but only adapically, and cameral deposits are strictly mural in distribution.

The recognized species are largely Middle Silurian in range, and common to Europe and to North America. The several species recognized in North America have been differentiated primarily upon details of surface markings. Shells are commonly large, and most specimens known are fragments; further, many of them are somewhat distorted fragments, more or less flattened, and such material serves as a poor criterion for comparison on any basis other than ornament, for relative spacing of sutures and position and relative size of siphuncle are thus altered.

The described species may be summarized as follows:

D. annulatum Sowerby.—Recognized as common to the Middle Silurian of England, Bohemia, and Gotland. A form with festooning scarcely developed.

D. *americanum* Foord.—Festooning more pronounced. Typical forms are regarded as those of the Rochester and Osgood formations.

D. *tenuilineatum* Savage.—Not adequately known, but of interest as the only Lower Silurian species known.

D. nodocostatum McChesney.—Prominent distant longitudinal lirae form faint nodes where they cross the annuli. Laurel, Liston Creek, Racine formations.

D. granti Foerste.—Prominent longitudinal ridges, rather distant festoons transverse lines. Barton beds of Ontario.

D. hyatti Foerste.—Rather broad annuli, low close festooned transverse markings, but no prominent longitudinal lirae. Joliet to Guelph, Illinois, Indiana, Ohio.

D. *bridgeportense* Foerste.—Sharply raised, slightly oblique annuli, festooned markings and longitudinal lirae. Racine of Illinois.

D. multiliratum Foerste.—A Racine form with prominent rather close longitudinal markings.

D. graftonense Foerste.—A rather small species with rather low annuli, not sharply limited, crenulate, rather distant, transverse markings.

In addition it should be noted that the Waldron shale of Indiana and Tennessee has yielded a rather varied lot of forms, all abnormally small species, in which festooning and annuli are lost in mature portions.

Hyatt (1900), in placing *Dawsonoceras* with *Cycloceras,* implied that the genus is a specialization from *Cycloceras* by the festooning of the ornament. Oddly, we know of no shells of the aspect of *Cycloceras* with tubular siphuncles which are likely ancestors of the genus. The other origin in Ordovician genera is equally difficult to establish. Silurian *Kionoceras* species show small annuli in the siphuncle and segments that are slightly contracted at the septal foramina, but while this seems the most likely origin from the present evidence, it is far from demonstrated.

Oddly, until now the recumbent necks of *Dawsonoceras* have not been recorded, though they are clearly shown in a specimen, a fine, long sectioned shell from the Laurel limestone, which was on exhibit in the New York State Museum from about 1912 to 1952.

Dawsonoceras cf. nodocostatum (McChesney)

Pl. 4, fig. 9, 10; pl. 6, fig. 5-7

The forms here figured represent this or an allied species; they are all from the Laurel limestone, and specimens do not separate readily from the matrix in such a way as to show clear surface details. It is evident, however, that longitudinal lirae are developed and they are somewhat nodose as they cross the annuli.

The earliest stage, shown in Plate 4, figures 9 and 10, is a small portion from a somewhat distorted shell; the piece is 32 mm long and shows a distorted cross section at the base 8 by II mm across. It shows six and part of a seventh siphuncle segments, averaging in range from 4.2 to 5.o mm long. Cameral deposits are evident on the left side as shown in Plate 4, figure 9. At the septal foramina, the recumbent necks constrict the siphuncle cavity to about half its diameter in other portions, and small annuli constrict the cavity still further.

A second specimen is a fragment 125 mm long containing parts of 16 camerae, enlarging from 20 mm near the base to 32 mm in 100 mm. Camerae increase in length from 7 to 9 mm. The plane of the section is horizontal; the siphuncle thus appears central and cameral deposits are about equally developed on the two sides. The deposits are strictly mural, are wanting in the anterior two camerae, increase in thickness markedly when traced apicad through the next five camerae, are nearly uniform in thickness in the next six camerae, and are obscured farther apicad by weathering. It is evident that this portion represents a rather rapidly expanding early stage of a large shell, the missing adoral part of which is slender, nearly tubular, and the missing anterior part of the phragmocone is probably about twice as long as the preserved portion. The siphuncle segments are parallel-sided throughout most of their length, but are abruptly contracted at the septal foramina. Recumbent necks constrict the siphuncle cavity to about half its normal diameter and are further covered by small annuli in the lower two thirds of the specimen.

A third specimen, not figured, is a small portion from a later growth stage showing five siphuncle segments in a length of 45 mm, 32 mm across at midlength, preserving four annuli. Here the cameral and siphonal deposits are wanting, but the short recumbent necks appear much as before.

The material here figured is from the Laurel limestone from about two miles south of Westport, Indiana. The specimens are in the collection of the writer, nos. 390-392.

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PLATES 1-6

WITH EXPLANATIONS

PLATE 1

Buttsoceras novemexicanum Flower, n. sp.
P. 5

1-3. Holotype, ×1; fig. 1, anterior view showing incomplete cross section; fig. 2, cross section taken at break near anterior end; fig. 3, longitudinal view showing position of break shown in fig. 2, slender form, and simple sutures. No. 380.

4-5. Opposing surfaces of cut taken through the anterior part of fig. 3. ×2.

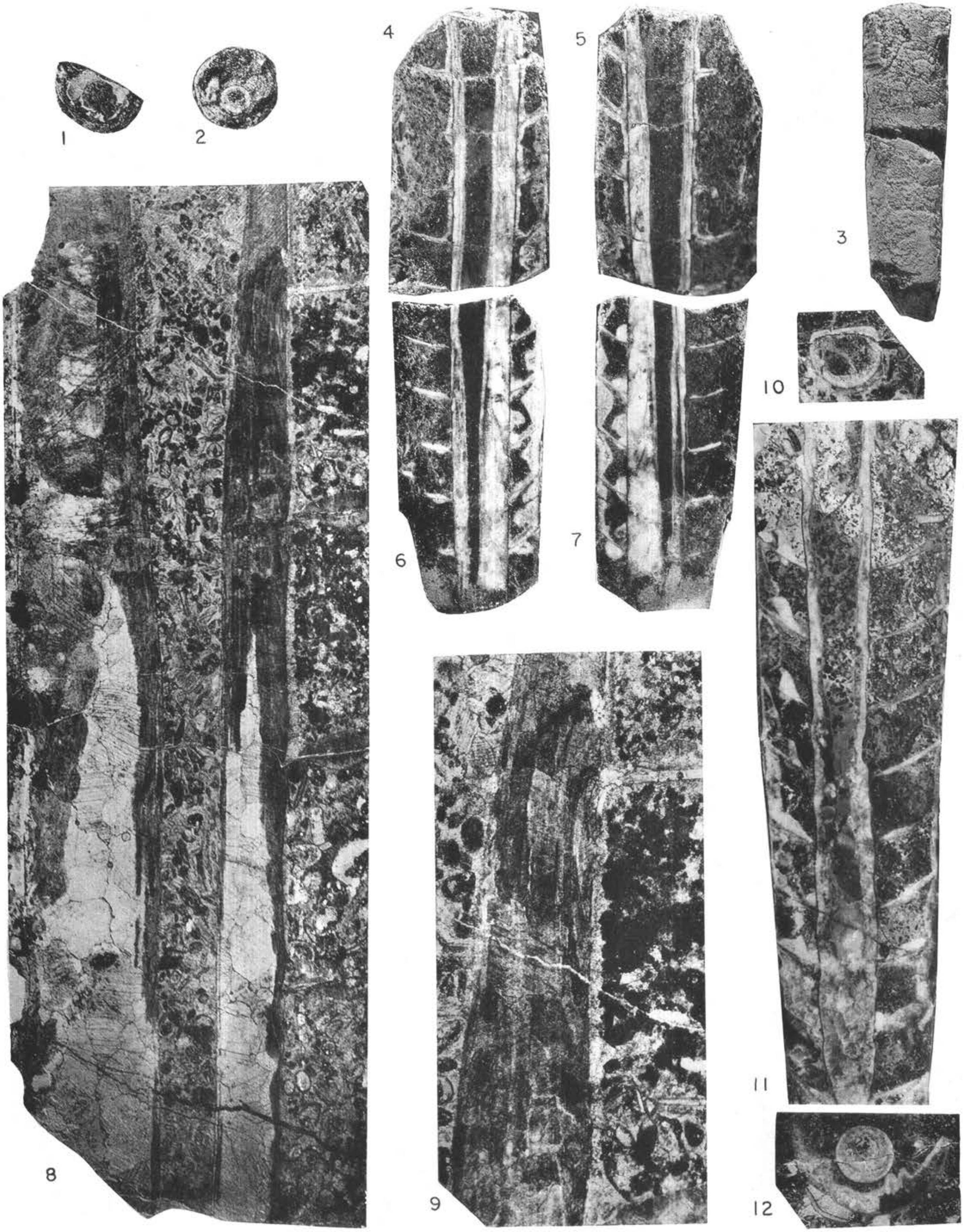
6-7. Opposing surfaces of cut taken through the apical part of fig. 2. The planes of 4-5 and 6-7 are not quite parallel.

8. Thinsection from fig. 6, the ventral camerae lost in preparation, venter on left, ×10, showing lamellae preserved in anterior part of the siphonal lining short necks, and thin homogeneous rings.

9. Further enlargement of part of the same section, ×22, showing lamellae in greater detail, with a suggestion of their outward curvature orad of the septal foramen.

10-12. A paratype, No. 382, showing a later growth stage. Fig. 10 is a section across the anterior end showing the siphuncle; the flattening above is dorsolateral, not in the plane of symmetry, and apparently adventitious. Fig. 11 shows a section ground along the plane of a break, the position of which can be seen in figs. 10 and 12. In the lower third, the plane of the break, and also of the siphuncle, lies a little below the surface ground, but at the very base the siphuncle curves upward, and the section lies below the point of its greatest width. Fig. 12 is a section at the apical end, prior to grinding the section shown in fig. 11. No. 382. All ×2.

All specimens from the highest 30 feet of the El Paso limestone, from the east side of the Florida Mountains, New Mexico.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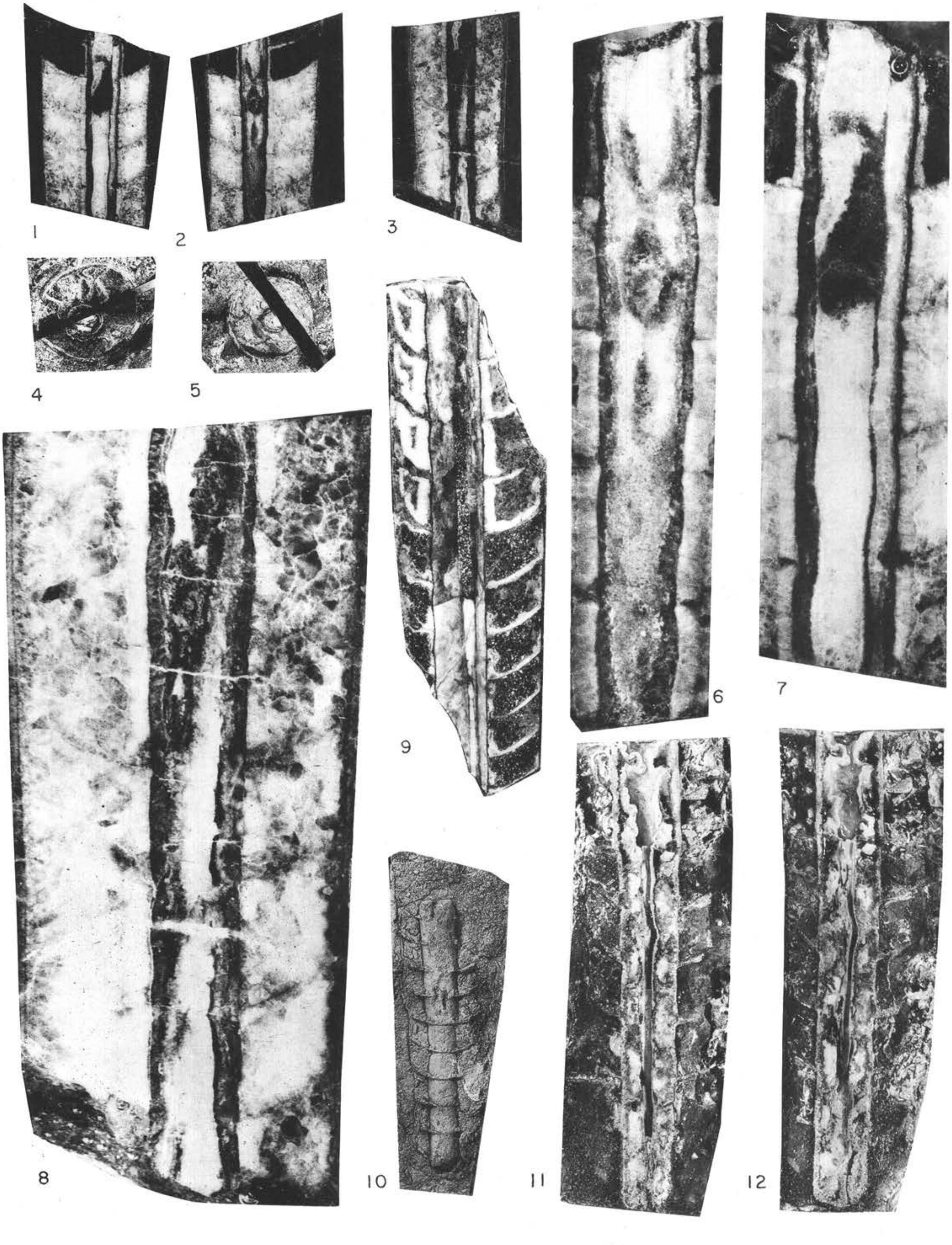
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PLATE 2

Buttsoceras williamsi Flower, n. sp.
P. 4

1-2. Opposite sides of a longitudinal cut made in the anterior part of the holotype, $\times 1$.

3. Longitudinal section of the apical part of the holotype, $\times 1$.

4-5. Apical and anterior ends; fig. 4, the anterior end, shows the position of the longitudinal sections shown in figs. 1 and 2; fig. 5, the apical end, shows the position of the section shown in fig. 3.

6. Enlargement of siphuncle from fig. 2, showing suggestion of segmental structures, in part at least probably adventitious. $\times 3.5$.

7. Enlargement of siphuncle of section shown in fig. 1; $\times 3.5$, showing short necks, apparently thin homogeneous ring, lining, and inorganic calcite partly filling the cavity of the siphuncle.

8. Enlargement of siphuncle $\times 3.5$, from fig. 3. The section is central adorally, slightly eccentric apically. The lining and inorganic calcite are distinct adorally, but merged by alteration apically. From the upper cherty beds of the Garden City formation, Green Canyon, north of Logan, Utah.

Collection of the writer, No. 295.

Buttsoceras novemexicanum Flower, n. sp.
P. 5

9. Vertical section of the paratype, $\times 2$, a portion of phragmocone showing an apical portion of the deposit, here so thick that apically the remaining cavity is a small tube; the apical part of the tube is set off by diaphragms, two of which are visible here; venter on left.

Collection of the writer, no. 381, from the highest El Paso of the east side of Florida Mountains.

Buttsoceras williamsi Flower
P. 4

10. Paratype, $\times 1$, weathered portion of phragmocone showing septa and siphuncle.

11. Portion of the same specimen, $\times 2$, showing the anterior end of the siphuncle etched, the remainder ground down to the tube within the lining. Note suggestion of annular structure in the lining, absence of diaphragms in the tube.

12. The same specimen, the surface ground to a slightly lower level, and passing apically below the tube.

U.S. National Museum, No. 14902, from the upper cherty beds of the Garden City limestone, from Mill Creek, T. 12 S., R. 42 E., northwest of Liberty, Idaho.

PLATE 3

Buttsoceras adamsi (Butts)
P. 7

1. Longitudinal thinsection, ×5, well-developed cameral deposits largely obscure the septa. The deposit in the siphuncle is dark; within it is seen a rather irregular tublar cavity. Occurrence as in Figs. 5-17.
2. Further enlargement of the siphuncle of the same section, × 11. U.S. National Museum No. 14905.

Michelinoceras buttsi Flower, n. sp.
P. 12

3. Thinsection, the holotype, ×5, showing different proportions of septa, episeptal and hyposeptal deposits continuous on the right, only episeptal deposits on the left, siphuncle of fusiform segments, small annuli in anterior part of siphuncle, apical part filled with adventitious vesicular material. Occurrence as in Figs. 5-17.
4. Enlargement, × 10, of siphuncle from the same section. U.S. National Museum, No. 14904.

Buttsoceras adamsi Butts
P.7

5-17. Specimens attributed to *Buttsoceras adamsi,* all ×2, showing wide variation in proportions; figs. 5-6, anterior and longitudinal views of one specimen, No. 14906; figs. 7-8, the latter showing cameral deposits and part of the siphuncle, No. 14907, are similar in proportions though representing slightly different growth stages. Figs. 9-10 show a proportionately smaller siphuncle, septa closer and more deeply curved, No. 14908; figs. 11-12 are a unique, very slender form with extremely long camerae, No. 14909. Figs. 13 and 14 are from the opposite sides of a single specimen, the adoral view shown in fig. 15; fig. 13 is on the left side of fig. 15; fig. 14 on the right. Fig. 13 represents a dorsal view, fig. 14 a ventral view; silica retains the shape of septa and cameral deposits, the latter thickened on the venter, but thinned in the extreme midventral region, No. 14910; figs. 16-17 show another fragment, viewed in fig. 17 from the dorsum and showing the symmetry of the cameral deposits. No. 14911. All the above are from the Odenville limestone near Odenville, Alabama, and in the U.S. National Museum, from USNM No. 109489, plesiotypes of *Buttsoceras adamsi.*

Michelinoceras (?) richardsi Flower, n. sp.
P. 12

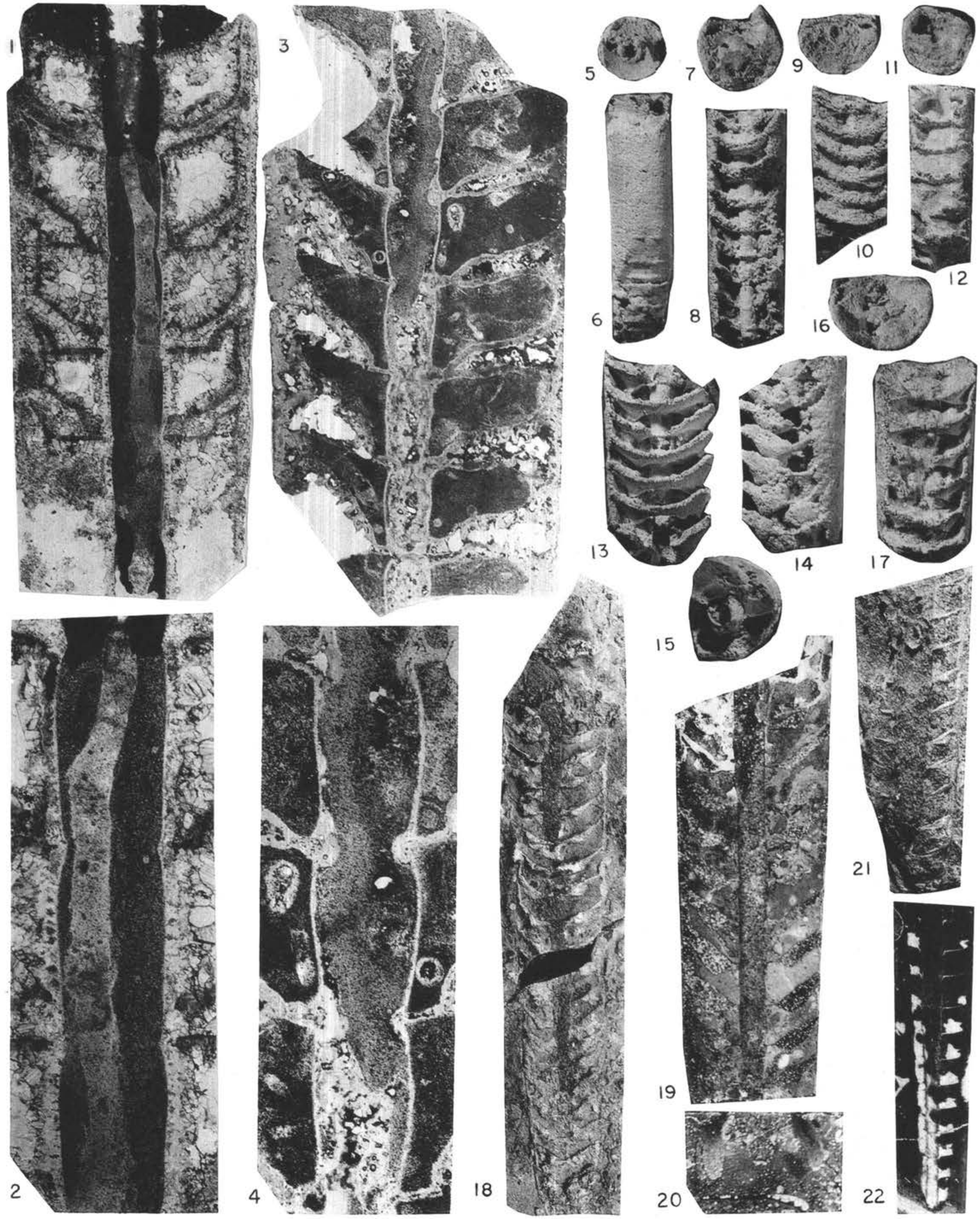
18. Holotype, × 1, a specimen showing the phragmocone weathered from the ventral side, exposing much of the siphuncle in the anterior two-thirds; the incomplete anterior portion is aseptate, regarded as the base of the living chamber of a nearly mature individual, as indicated by slight shortening of the anterior few camerae. Note presence of hyposeptal deposits close to the living chamber.
19. Apical portion of the same specimen, ×2, ground down to the level of the siphuncle, concealed in this part in the lower part of fig. 18.
20. Cross section at the base of the specimen prior to grinding the surface shown in fig. 19; the venter is above; note ventrolateral thickening of cameral deposits. The dorsum is wanting.
Holotype, USNM No. 14903 from the cherty beds of the Garden City limestone, from three quarters of a mile west of Fishaven, Montepelier quadrangle, Idaho.

Buttsoceras cf. *novemexicanum* Flower
P. 7

21. A side view of a weathered portion of phragmocone, × 1, remarkable in that cameral deposits are developed, though the siphuncle lacks any trace of a lining. Collection of the writer, no. 383.
From the highest El Paso limestone, east side of the Florida Mountains, New Mexico.

Michelinoceras primum Flower, n. sp.
P.11

22. Thinsection, the holotype, showing an essentially vertical section. Annular deposits in the siphuncle, on the ventral side only, and confused with additional calcite apically; cameral deposits thick ventrally, thinner dorsally. The apex is styliolitic, and not the true apex of the shell, though close to it from the small size. Holotype, collection of the writer, No. 384, from B2b (Cloud and Barnes, 1946) Cassinian, of the El Paso limestone, from the southern Franklin Mountains at El Paso, Texas, ×3.5.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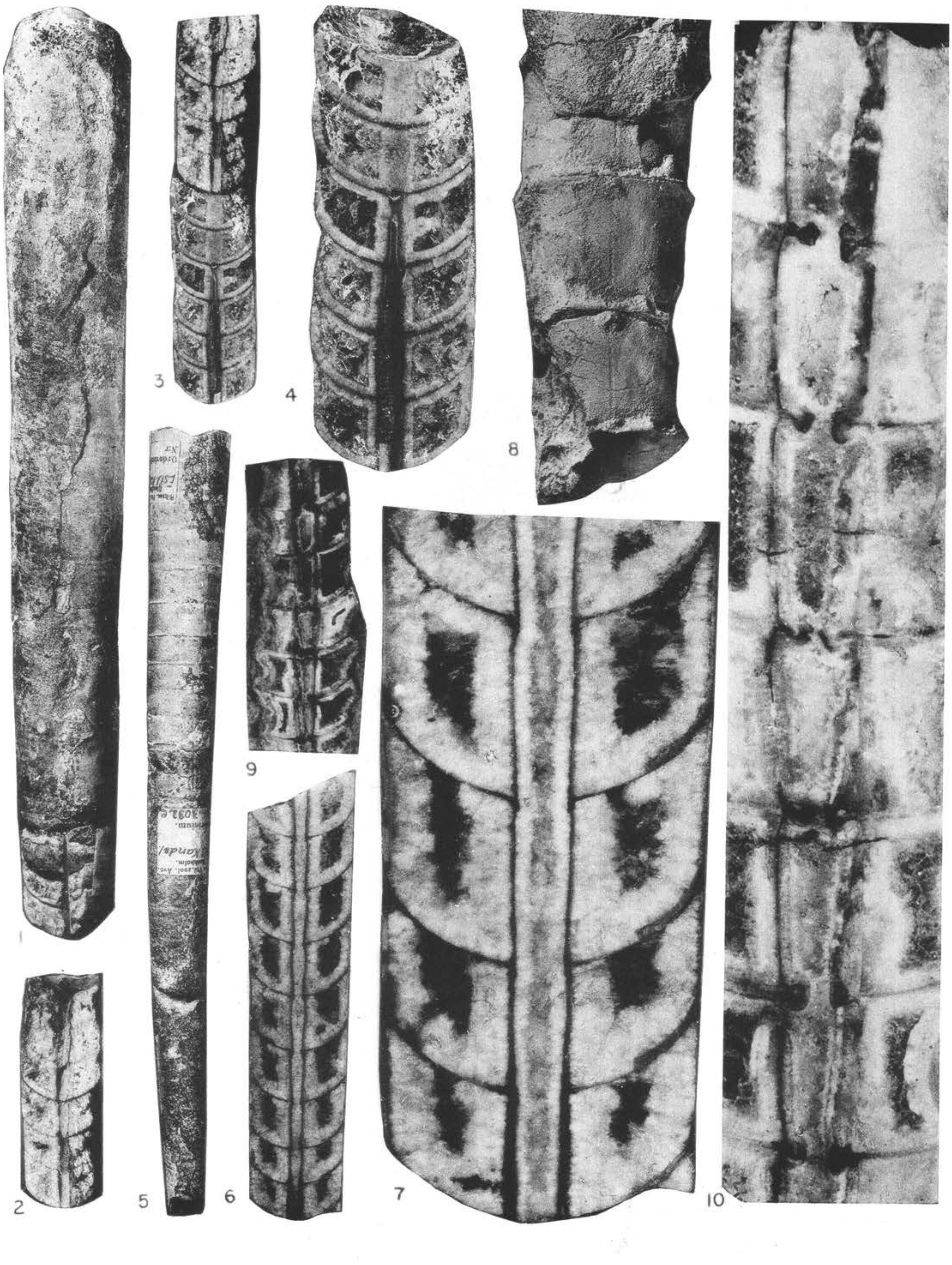
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PLATE 4

Orthoceros regularis (Schlotheim)
P. 35

1. Anterior portion, ×1, a living chamber, showing internal thickenings a little before midlength, and with three attached camerae.

2. Portion fitting on the apical end of fig. 1, a portion of phragmocone broken to a little below the level of the maximum width of the siphuncle.

3. Basal portion of fig. 2 with a more apical ground portion of phragmocone attached, ×1.

4. Ground portion of fig. 3, ×2, showing absence of cameral or siphonal deposits.

5. Portion fitting on apical end of fig. 3, ×1.

6. Apical part of fig. 5, ground vertically, dorsum on left, × 2.

7. Enlargement of apical part of fig. 6, ×7, showing vestigial cameral deposits and absence of siphonal deposits.
From the Orthoceras limestone, Kandel, Esthonia, Naturhistorische Riksmuseum, Paleozoological Avd., Stockholm, Mo. 3032. One of the specimens studied and figured by Troedsson, 1931.

Pleurorthoceras selkirkense (Whiteaves)
P. 36

8. Apical portion of same specimen shown in Pl. 5, fig. 1-8, dorsal side of apical part, ×2, showing small tubercle at anterior end of camerae and faint longitudinal groove on the internal mold, both reflections of features of the cameral deposits. See Pl. 5, fig. 1-8, 11, 12, 16, 17.

Dawsonoceras cf. *nodocostatum* (McChesney)
P. 39

9. A small portion of a sectional phragmocone, ×1.

10. Siphuncle from the same specimen, ×8, showing short recumbent necks and annuli. On the right, chalcedony presents adventitious outlines, and the connecting ring there is obscured in the lower part of the figure.
Laurel limestone, from about two miles south of Westport, Indiana.

PLATE 5

Pleurorthoceras selkirkense (Whiteaves)
P. 36

1-8. Portions of an exfoliated internal mold, in which cameral deposits have been removed, and surface impressions of the deposits are shown in exceptional detail. No. 385. The two parts, shown detached, fit imperfectly.

1-2. Two portions, $\times 1$, viewed from the venter, showing midventral boss of deposits and an apically striated region which thickens ventrally. An anterior camera is not shown.

3-4. Same portions, viewed ventrolaterally, showing ventral boss near the left, and portions of the retained shell on the dorsal side, to the right.

5-6. Same portions, with anterior camera added, $\times 1$, viewed from the dorsum; portions of the shell wall are retained.

7. Septal view of the anterior camera, showing cross section and position of siphuncle.

8. Lateral view of apical portion, venter on right, $\times 1$, showing more clearly than fig. 4 the ventral widening of the apical striated zones of the cameral deposits.

11. Dorsal view of anterior camera, $\times 2$, showing a smooth surface, a dorsal furrow simulating the septal furrow, and an anterior boss.

12. Enlargment $\times 2$ of fig. 1, showing fine surface detail.

16. Lateral view, $\times 2$, of apical portion, venter on right, showing variation in surface texture and ventral widening of the apical striated zone.

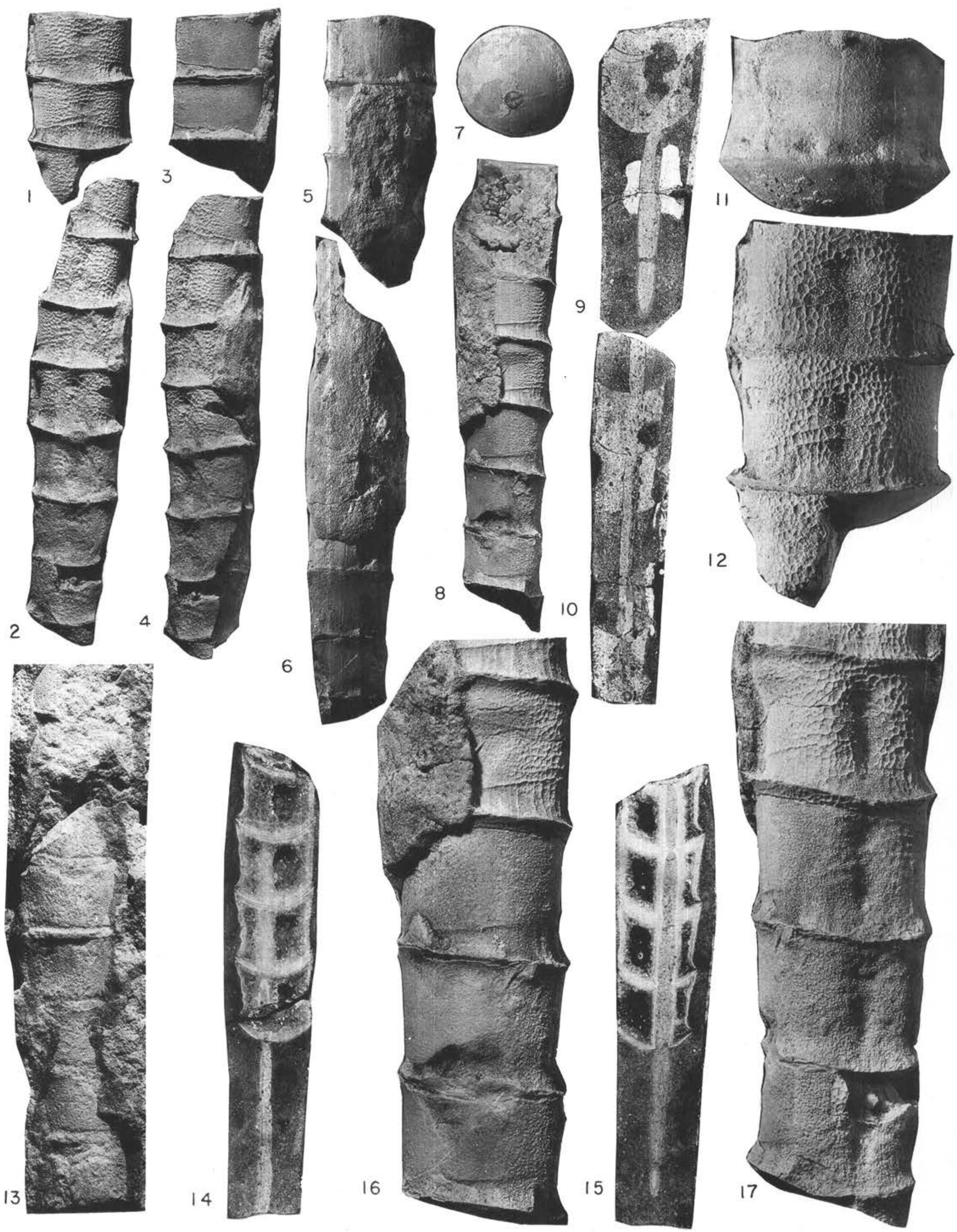
17. Slightly oblique ventral view, $\times 2$, showing finer pitting, almost granular texture of surface where deposits are well advanced, in contrast to coarser pitting shown in the anterior camera and in fig. 12, of less advanced deposits.

9-10. Adjacent portions of an apparently immature specimen, sectioned vertically, showing form of siphuncle segments, but lacking clear evidence of cameral deposits. No. 387.

13. Dorsal view of a portion of phragmocone, exfoliated in the central portion, showing annuli which are molds of cameral deposits, and some indication of the dark material representing cameral deposits and shell wall, in the lighter matrix. Not quite the entire length of the specimen is shown. No. 388.

14-15. Opposite sides of a vertical section of another individual, showing the matrix-filled siphuncle surrounded by inorganic calcite filling the adoral four camerae, outside of which dark dolomite represents the combined shell wall, mural parts of septa and cameral deposits. Oddly, this material cannot be distinguished from matrix surrounding the siphuncle in the apical three camerae, though externally considerable portions of the smooth shell surface are apparent. No. 386.

All material in the collection of the writer, from quarries at Tyndall, Manitoba; somewhat east of the main quarries and the small hotel, and thus presumably relatively low in the Selkirk limestone.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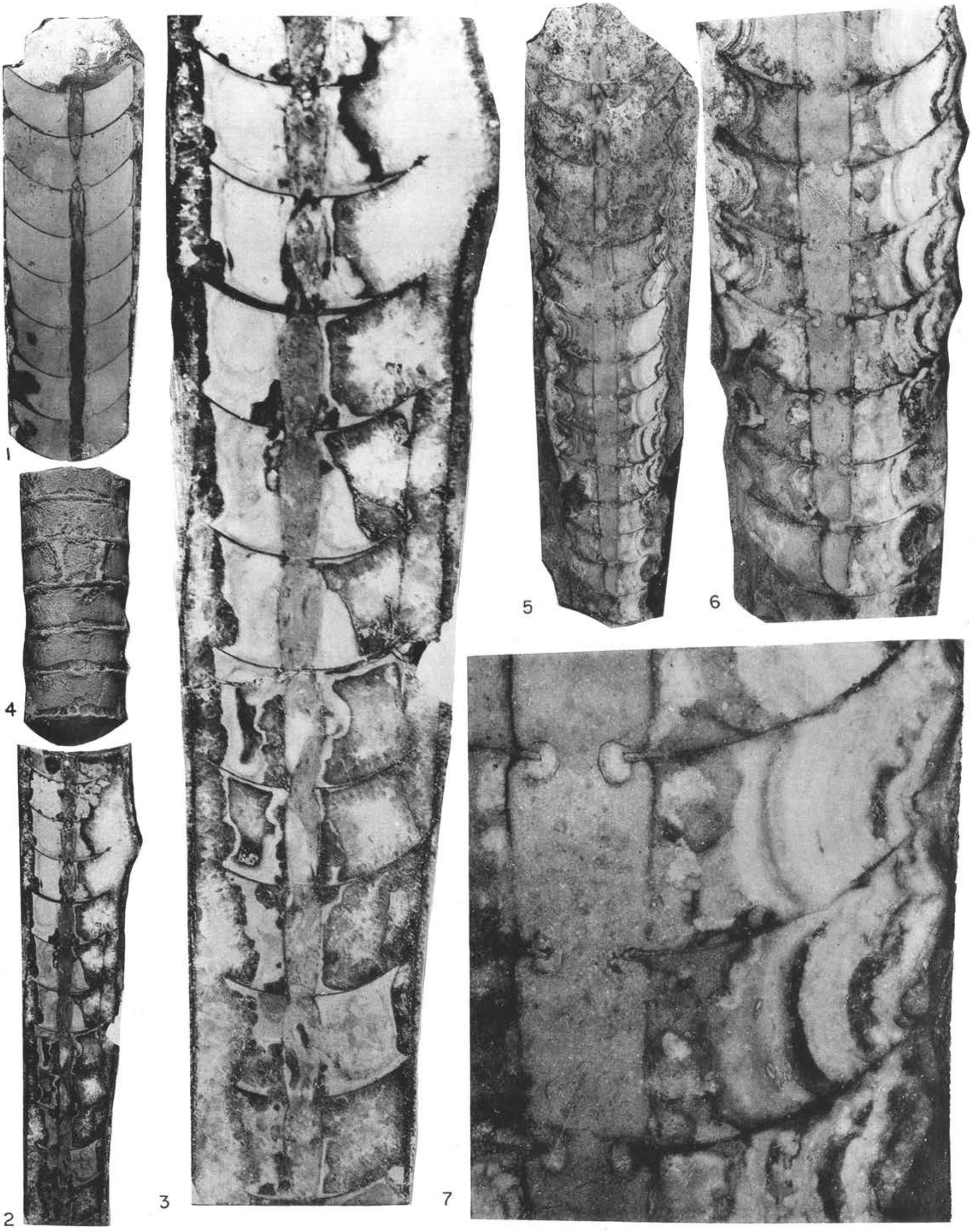
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PLATE 6

Pleurorthoceras clarkesvillense (Foerste)
P. 36

1. Anterior portion of a phragmocone, showing interval void of cameral deposits, ×1.
2. Apical portion from the same specimen, ×1, spaced at approximately the interval in which this portion lay in relation to fig. 1.
3. Enlargement of the section shown in fig. 2. The section is not quite vertical, with the left side relatively ventral, showing cameral deposits thickened apically in what evidently is the striated zone. On the dorsal side, to the right, inorganic calcite obscures the original structure for the most part, but calcite occupies cameral deposits only in the apical two camerae on this side. The siphuncle is shown, preserving the outline of the segments clearly, but showing no trace of siphonal deposits.
4. A portion of another specimen, viewed from the venter, showing incipient cameral deposits, and the ventral widening of the striated zone. The ventral boss is not developed.

All are from the collection of Dr. W. H. Shideler, at Miami University, Oxford, Ohio.

Dawsonoceras cf. *nodocostatum* McChesney
P. 39

5. A portion of a phragmocone, representing a relatively early growth stage, ground horizontally exposing siphuncle and showing strictly mural cameral deposits. Deposits are not apparent in the adoral camerae, thicken progressively over five camerae, are of nearly uniform thickness and presumably mature over the next five camerae, obscured by weathering in the remaining apical camerae.
6. Enlargement, ×2, of the apical part of fig. 5, showing further detail of cameral deposits, short recurved septal necks projecting into the cavity of the otherwise tubular siphuncle, and development of small annuli on the necks.
7. Further enlargement, about ×5.5, of the upper left of fig. 6, showing siphuncle and cameral deposits of one side in greater detail.

From the Laurel limestone, about two miles south of Westport, Indiana, collection of the writer, No. 371.

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Numbers in **boldface** indicate main references.