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LOWER MISSISSIPPIAN CEPHALOPODS OF MICHIGAN

PART III. AMMONOIDS AND SUMMARY

BY

A. K. MILLER and H. F. GARNER

MUSEUM OF PALEONTOLOGY
UNIVERSITY OF MICHIGAN
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CONTENTS

INTRODUCTION

THIS report on the ammonoids concludes the authors' study of the Lower Mississippian cephalopods of Michigan. Part I dealt with the orthoconic nautiloids. It was published as Article 7 of Volume X of the *Contributions from the Museum of Paleontology* of the University of Michigan in April, 1953. Part II described the coiled nautiloids and appeared as Article 6 of Volume XI of the same series in November, 1953. The present

paper, Part III, in addition to a review of the ammonoids contains a summary of the authors' views in regard to the entire cephalopod fauna and a comprehensive index to the three parts.

The Michigan cephalopod collections that are now available were assembled during most of the past century and all are housed in the Museum of Paleontology at the University of Michigan. From 1861 to 1870 Winchell published several accounts of the stratigraphy of the Lower Peninsula and the fossils known at that time. His descriptions of the species, unfortunately, were not accompanied by illustrations, which makes their identification difficult, and his work on the stratigraphy has to a considerable extent been superceded, especially by that of Monnett in 1948. Both Michigan Lower Mississippian formations that carry cephalopods, the Coldwater shale and the Marshall sandstone, are extremely fossiliferous, and particularly is this true of the Marshall. The fauna, though predominantly molluscan, is quite varied and other fossil groups, besides cephalopods, merit the careful attention of future workers.

Acknowledgments are due to Dr. G. M. Ehlers and Dr. E. C. Stumm, of the University of Michigan, and to Dr. W. A. Kelly, of Michigan State College, for facilitating our study in many ways. The photographs for the accompanying plates were retouched by Messrs. Howard E. Webster and Frederick D. Leach. The completion of the report was made financially possible by the Graduate College of the State University of Iowa.

Unless otherwise indicated, all specimens described are deposited in the Museum of Paleontology, University of Michigan, and the catalogue numbers refer to the collections in that institution. Localities given without a state designation are to be understood to be in Michigan.

THE CEPHALOPOD FAUNA AND ITS SIGNIFICANCE

We believe that the cephalopods of the Coldwater shale and the Marshall sandstone constitute a single fauna. Although the Coldwater shale is stratigraphically older than the Marshall sandstone, the two formations are locally gradational both lithologically and paleontologically. Fossils are not nearly as abundant in the Coldwater as in the Marshall, but in the younger formation they tend to be more fragmentary and less well preserved. The differences between the assemblages from the two formations are largely, if not wholly, due to ecology (as reflected by the lithology) rather than to age, for the Coldwater consists for the most part of well-indurated gray shale, whereas the Marshall is predominantly of sandstone which is ferruginous and locally conglomeratic or calcareous. The stratigraphic and geographic distribution of the cephalopods in the Lower

Mississippian of Michigan is given in Table I. For the convenience of the reader, the species and the localities are arranged alphabetically.

As may be seen from this table, a few species of cephalopods, representing at least four genera, are common to the Coldwater and the Marshall formations. Certain of these, for example the orthoconic nautiloids, are perhaps not stratigraphically very significant. But the presence of such distinctive species as the ammonoid *Beyrichoceras allei* and the coiled nautiloid *Vestinautilus altidorsalis* in both formations indicates that the two formations are of similar age. With the possible exception of *Cycloceras,* every cephalopod genus known from the Coldwater occurs in the Marshall. The fact that the younger Marshall has yielded representatives of seven, possibly eight, genera not known from the Coldwater can hardly be explained as entirely due to the relative dearth of specimens from the older formation. There was presumably early in Marshall time an incursion of new faunal elements into the Michigan Basin. It should be emphasized that all of the many cephalopods known from Marshall, Michigan, came from a thickness of only 4½ feet of strata. Indeed, every species listed from there is represented in a single 6-inch bed of extremely fossiliferous limonitic sandstone in the very small quarry that is the type locality of the Marshall sandstone.

The Michigan depositional basin existed before and after the Mississippian period. The Coldwater shale is of much greater areal extent than the Marshall sandstone, which suggests that the sea in the basin was becoming progressively smaller and shallower. In post-Marshall Mississippian times the sea was at least temporarily isolated and more or less locally desiccated, as the presence of evaporites in the later Mississippian strata indicates. Even so, some sea must have remained, for at Grand Rapids, on the western edge of the basin, the Point au Gres limestone of Meramec or possibly Chester age, has yielded a small marine fauna which includes two species of coiled nautiloids.

Some discussion of the paleoecology is given in Part I (which see). It should be added to the observations there that spiriferoid brachipods are abundant in the Coldwater but rare in the Marshall, whereas pelecypods, bellerophontid gastropods, and ostracodes exhibit a reverse of this relative distribution for the two formations. Nautiloids and ammonoids are also more abundant and much more varied in the Marshall, though locally one or two species are not rare in the Coldwater. Probably these faunal differences resulted from a clearing and shallowing of the sea, after the deposition of the Coldwater shale, that was followed or accompanied by an influx of forms adapted to the changed ecological conditions, in which sand replaced mud as the chief bottom cover.

The preservation of the Michigan ammonoids is such that their early

TABLE I

DISTRIBUTION OF CEPHALOPODS IN THE LOWER MISSISSIPPIAN OF MICHIGAN

Species	Coldwater Formation			Marshall Formation																
	Locality			Locality																
	Coldwater	Holland	Union City	Alan's Quarry	Battle Creek	Burnt Cabin Point	Columbia	Flat Rock Point	Grindstone City	Hardwood Point	Hillsdale	Holland	Jackson	Marshall	Moscow	Napoleon Cut	Osseo	Pointe Aux Barques	Stony Point Quarry	Waterloo
Beyrichoceras allei	x	?	x	..	x	..	..	..	..	..	x	?	..	x	..	..	..	..	..	..
Chouteauoceras? ingenitor	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
C.? sp. aff. *C.? tessellatum**	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
C.? spp.	x	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
Cycloceras ehlersi	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
C.? michiganense	..	?	..	..	..	..	..	..	..	..	..	?	..	x	..	..	..	..	..	..
Gattendorfia? shumardiana	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..
G. stummi	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
G.? sp.	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Imitoceras romingeri	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
I. rotatorium	..	?	..	..	..	x	..	..	x	..	..	?	..	..	..	..	..	x	..	..
Kazakhstania americana	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
Kionoceras bellilineatum	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
Maccoyoceras discoidale	..	..	..	..	?	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..

Merocanites houghtoni	..	..	..	..	..	x	..	..	..	..	..	..	x	x	..	..	..	..	..	x
M. marshallensis	..	..	..	..	?	..	x	x	x	..	..	..	..	x	?	x	..	..	x	..
Mooreoceras barquianum	x	..	..	..	..	..	..	..	..	x	x	..	..	..	..	..	..	x	..	..
M. sp. aff. *M. cliftonense*	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
M. clinocameratum	..	..	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..
M.? gracilium	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
M. sp. cf. *M. indianense*	..	?	..	..	..	x	..	..	..	..	..	?	x	x	..	x	x	..	..	..
M. kellyi	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
M. marshallense	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
M. vinchellanum	..	..	..	..	..	..	..	..	..	..	..	..	..	x	x	..	..	..	..	..
M.? sp.	..	?	..	..	?	..	..	..	..	..	..	?	..	x	..	..	..	..	..	..
Münsteroceras oweni	..	..	..	..	..	x	..	..	..	..	..	..	..	x	..	..	..	x	..	..
M. pergibbosum	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
M.? pygmaeum	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Poterioceras? robustum	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	x	..
P.? sp.	..	..	..	x	..	..	..	..	..	..	..	..	x	x	x	..	x	..	x	..
Rineceras meekianum	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
R. strigatum	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
R.? striatulum	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
Spyroceras sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
S.? sp.	..	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..
Stroboceras intermedium	..	..	..	..	..	x	..	..	..	..	..	..	..	..	..	..	..	..	..	..
S. planidorsale	..	..	..	..	x	x	..	..	..	..	..	..	..	x	..	..	..	..	..	..
Vestinautilus altidorsalis	x	..	..	..	..	..	..	..	..	..	..	..	..	x	..	..	..	..	..	..

* Marshall sandstone at some unspecified locality in Michigan.

ontogenetic development can be readily studied. We have prepared several series of drawings (Figs. 1–16) to show the progressive changes in the sutures during early growth stages as well as their shape at maturity. These are treated in detail in the systematic portion below. Here it is sufficient to state that their ontogeny makes clear that the various elements of the Michigan fauna continued or were developed from forms represented in slightly older strata, like the Rockford limestone of Indiana and the Chouteau and related formations of Missouri. For example, such ammonoid genera as *Gattendorfia, Imitoceras,* and *Münsteroceras* persisted; *Beyrichoceras,* however, appears to have evolved from *Münsteroceras* and *Merocanites* from *Protocanites.*

Just what the age of the Coldwater and the Marshall formations is has long been a moot question. At one time or another they have been stated to be Chemung, Catskill, Kinderhook, and/or Osage. In his later papers Winchell called them Kinderhook. On the basis of the contained goniatites Smith (1903, p. 13) also placed them in that series. Williams (1932) came to the conclusion that the Coldwater is Kinderhook and Osage in age and that the Marshall is uppermost Osage. In a more recent decision, the Coldwater and the lower Marshall were placed in the upper Kinderhook and the upper Marshall ("Napoleon sandstone") in the lower Osage by the Mississippian Subcommittee of the Committee on Stratigraphy of the National Research Council (Weller and others, 1948, chart opposite p. 188). Later in that same year, Monnett (1948, pp. 630, 677–79) assigned both formations to the Kinderhook, in part at least, because of a preliminary examination of certain of the goniatites by Miller. In 1951 Cohee, Macha, and Holk correlated part of the Coldwater and all of the Marshall with Osage strata; but they had, like Weller (1948, p. 157), apparently misinterpreted a statement by Cox (1875, p. 45) and taken it to mean that the goniatites from the type section of the Rockford limestone of Indiana "were collected loose in the bed of White River."

From our study of all the cephalopods known from these Michigan Lower Mississippian strata, we have reached certain conclusions in regard to their age. Some of the goniatites, for example *Imitoceras rotatorium* and *Münsteroceras oweni,* are conspecific with forms from such undoubted Kinderhook strata as the Rockford limestone of Indiana; and the cephalopods of both the Coldwater and the Marshall are in general reminiscent of those of the Rockford and such equivalent strata as the Chouteau limestone of Missouri. The two species just cited, however, are representatives of rather long-ranging types; consequently, we do not believe them to be as reliable for detailed correlations as members of such genera as *Merocanites* and probably *Beyrichoceras.* In America *Merocanites* is known from outside

the confines of Michigan only from the Reeds Spring limestone of southwestern Missouri and the New Providence shale of Kentucky; and *Beyrichoceras* has not been found elsewhere in the western hemisphere except in the New Providence shale and the lower part of the Boone formation in southwestern Missouri. All three of these formations are undoubtedly Osage. It is evident, therefore, that the Marshall and at least the upper Coldwater contain some cephalopods with Kinderhook affinities and some with Osage. Furthermore, both Kinderhook and Osage types occur in direct association in a 6-inch bed of sandstone in the lower Marshall. We are inclined to believe that the heralders of a new time are more significant than the holdovers from the past. Accordingly, we conclude that the occurrence of these particular cephalopods is proof that the Michigan strata which yielded them are younger than typical Kinderhook and older than typical Osage. They are most probably of about the same age as the Reeds Spring formation of southwestern Missouri and the New Providence shale of Kentucky, both of which are now generally regarded as early Osage. The New Providence shale contains certain types of goniatites that are absent from the Coldwater and the Marshall, which suggests that the Kentucky formation is not of precisely the same age as the Michigan. At least the lower part of the Coldwater shale, however, which has yielded no cephalopods, may well be Kinderhook.

Many localities in western Europe have yielded cephalopod assemblages that remind one of the Michigan fauna, but none that is particularly similar to it. The upper Tournaisian of Belgium carries *Imitoceras rotatorium,* several species of *Münsteroceras,* and *Protocanites lyoni,* just as does the upper Kinderhook Rockford limestone of Indiana. It seems logical to correlate these strata from opposite sides of the Atlantic, even though the European beds have not yielded *Prodromites,* which is a characteristic and striking form in the Rockford and in the stratigraphically equivalent strata in Missouri, Iowa, and Illinois. Acceptance of such a correlation leads to the conclusion that in the European section the approximate correlative of the Mississippian goniatite-bearing beds of Michigan is the lower Viséan. (*Imitoceras, Münsteroceras, Beyrichoceras,* and *Merocanites* all occur in the lower Viséan, together with *Pericyclus,* which, as we interpret that genus, is not present in Michigan.) If this conclusion is correct, the American Osage strata are the approximate stratigraphic equivalent of the European lower Viséan, rather than of the upper Tournaisian, as commonly stated. We are, of course, not the first to advocate this view.

In northern Africa (western Algeria) there are forms that are closely similar to, possibly identical with, *Imitoceras rotatorium* and *Münsteroceras oweni.* The African beds which yielded them are perhaps equivalent to

either the upper Kinderhook or the lower Osage of America, in which both of these species occur. No prolecanitids, good index fossils, were associated with the western Algerian specimens; but it may well be significant that Follot (1952, p. 38) lists from southern Algeria *"Munsteroceras parallelum, . . . Prolecanites* aff. *Lyoni,* [and] *Imitoceras rotatorium,"* an assemblage which is certainly suggestive of the American upper Kinderhook. From a little higher in the same section Follot lists *Beyrichoceras.*

In Middle Asia (north Kazakhstan) Librovitch (1940) recognized several Carboniferous "cephalopod complexes." One, the oldest of these "complexes", contains representatives of *Gattendorfia, Kazakhstania, Imitoceras, Karagandoceras,* and the species *Protocanites lyoni;* and it is to be correlated in a general way with the fauna of the American upper Kinderhook. The second of Librovitch's Kazakhstanian "complexes" consists of species belonging in *Münsteroceras, Pericyclus,* and probably *Merocanites;* it presumably does not differ greatly in age from the Lower Mississippian Michigan fauna we are studying. To the east, in the Tien Shan, there occurs a prolific goniatite fauna that contains a variety of representatives of *Pericyclus* in association with *Münsteroceras* and *Merocanites;* it also seems to be of about the same general age as the Michigan assemblage. Librovitch, however, was inclined to place the Kazakhstanian "complex" containing *Merocanites?* in the upper Tournaisian and the Tien Shan fauna in the lower Viséan. It should perhaps be mentioned that through the work of Delépine (1941) we know a goniatite fauna from New South Wales in Australia with representatives of *"Imitoceras* aff. *rotatorium," Münsteroceras, Protocanites lyoni,* etc.; this assemblage is believed to be upper Kinderhook in age.

SYSTEMATIC DESCRIPTIONS

Genus *Gattendorfia* Schindewolf

When Schindewolf (1920, pp. 116, 123–24) established this genus, he designated as its type species *Goniatites subinvolutus* Münster of the basal Lower Carboniferous (the so-called Gattendorfia-Stufe) of east-central Germany. In that species the conch is subglobular and widely umbilicate, the growth lines are essentially straight and directly transverse, and each mature suture has eight undivided lobes, five of which lie outside the umbilical seams.

Gattendorfia resembles *Imitoceras,* of the same author. Both Schindewolf (1920, pp. 123–24; 1952, p. 302) and Librovitch (1940, p. 226), if we interpret their position correctly, believed that the chief difference between the two genera lay in the position of the umbilical lobes of the sutures, which in *Gattendorfia* are outside the umbilical seams, but in *Imitoceras*

more or less center on the seams. Miller and Collinson (1951, pp. 467–68), however, have recently proposed to separate the two on the basis of the character of the umbilicus: open in typical *Gattendorfia* and closed in *Imitoceras*. This distinction was, of course, noted by Schindewolf and Librovitch.

The relative importance of the different criteria is, to be sure, a matter of opinion and both features are gradational. For example, in modern *Nautilus* the umbilicus is closed in some species and open in others, and the position of the umbilical lobe varies within such ammonoid genera as *Pseudoparalegoceras* of the Pennsylvanian. All of the specimens described in the present report and definitely referred to *Gattendorfia* have open umbilici and sutures in which the umbilical lobes are well outside the umbilical seams. Furthermore, those that we are placing in *Imitoceras* have closed umbilici and sutures in which the umbilical lobes center on or near those seams. Such is, however, not the case with specimens described from elsewhere and we prefer to limit *Gattendorfia* to forms which, like its type species, have open umbilici. Species with similar sutures, but with discoidal conchs, very large umbilici, and whorls that are only slightly impressed dorsally belong, in our opinion, to *Kazakhstania* Librovitch.

As we interpret *Gattendorfia,* it is confined to the Upper Devonian and early Lower Carboniferous. It is of rather widespread occurrence at least in the northern hemisphere, for it is known from Europe, Asia, and North America. In North America it has been found in Missouri, Indiana (*Goniatites brownensis* Miller), Ohio, Michigan, and New Mexico, and it is invariably Lower Mississippian in age.

Gattendorfia andrewsi (Winchell)
(Pl. I, Figs. 4–6)

Goniatites Andrewsi Winchell, 1870*a*, Amer. Philos. Soc., Proc., Vol. 11, p. 259.
Prionoceras? andrewsi Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 29, 59.

Three of the syntypes of *Gattendorfia andrewsi* are available for study. We have illustrated the largest of the three (Pl. I, Figs. 4, 5) and the better of the other two (Pl. I, Fig. 6). All three are completely septate internal molds preserved in ferruginous sandstone.

The largest specimen has a maximum overall measurement of about 20 mm., and near its adoral end the height and width of conch are approximately 10 mm. and 12 mm. The conch is subglobular, as the whorls are rounded ventrally, very broadly rounded laterally, and considerably impressed dorsally. Where the conch of the other figured specimen is about 8½ mm. high and 10 mm. wide, its dorsal impressed zone is 4 mm. deep. The maximum width of the conch is at the umbilical shoulders.

The umbilicus is open and in both figured specimens it has a maximum diameter of about 5 mm. The umbilical shoulders are subangular and the umbilical walls, though slightly convex externally, are essentially normal to the plane of bilateral symmetry of the conch.

On the internal mold there are rounded transverse constrictions that are very slightly sinuous, which form rather indistinct ventral and lateral sinuses. These sinuses are more easily discerned on the smaller of the two figured syntypes. In this individual the constrictions are relatively farther apart than on the larger one. Near the umbilical shoulders on the largest syntype are some poorly defined transverse markings which Winchell called "wrinkles."

The shape of the external suture is given in Figure 1C. The second lateral saddle is very asymmetrical, much as it is in *G. stummi* of the Marshall sandstone of Michigan and *G. mehli* of the Chouteau limestone of Missouri. The umbilical lobe is clearly located on the umbilical wall and centers well outside the umbilical seams. On the syntype we do not figure, the internal sutures form three rather closely spaced, pointed-spatulate lobes.

Remarks.—Although certain features of the sutures of *G. andrewsi* are reminiscent of *G. stummi,* sp. nov., and *G. mehli,* the three species are actually not very close. The conch of *G. stummi* is wider and that of *G. mehli* is narrower than in this species. Furthermore, the umbilicus of the holotype of *G. stummi* is twice as large and no transverse constrictions are visible on the type specimen of *G. mehli.*

Occurrence.—Waverly group (upper Cuyahoga or possibly lower Logan) at or near Newark, Licking County, Ohio. Smith (1903, p. 13), presumably through error, listed this species from the Marshall sandstone at some unspecified locality or localities in Michigan; hence, its inclusion here.

Types.—Syntypes, No. 26794.

Gattendorfia ohiensis (Winchell)

(Pl. VI, Fig. 8)

Goniatites Ohiensis Winchell, 1870*a,* Amer. Philos. Soc., Proc., Vol. 11, p. 259.
Prionoceras? ohioense Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 29, 59–60.

The paleontological collections of the University of Michigan contain two specimens which are stated to be syntypes of this species and there is good reason to believe that the labels are correct. The better individual, an internal mold which consists of some five volutions, is illustrated (Fig. 1A and Pl. VI, Fig. 8). The other specimen is only a fragment of a distorted internal mold of a relatively large phragmocone.

The conch is subglobular and the phragmocone is estimated to have attained a diameter of at least 30 mm. The body chamber is at least a quarter

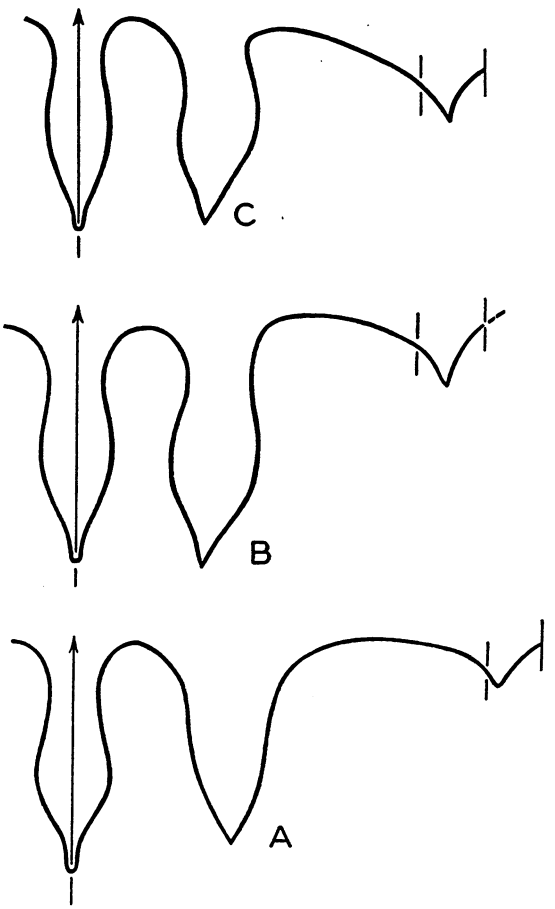

FIG. 1. Mature external sutures of three species of *Gattendorfia*.

A—*G. ohiensis* (Winchell) where conch is about 11 mm. high, based on a syntype, No. 26798; from Waverly group, Newark, Ohio; × 5.

B—*G. stummi* Miller and Garner, sp. nov., where conch is about 7 mm. high, based on holotype, No. 30691; from Marshall sandstone, Marshall; × 5.

C—*G. andrewsi* (Winchell) where conch is about 10 mm. high, based on largest syntype, No. 26794 (Pl. I, Figs. 4,5); from Waverly group, Newark, Ohio; × 7.

of a volution in length and the whorls are rounded ventrally and considerably flattened laterally. The maximum diameter of the umbilicus of the figured specimen is about 5 mm. In the unfigured one, the maximum width of the conch, attained at the umbilical shoulders, is about 23 mm., the

corresponding estimated height of the conch and the depth of the impressed zone are some 17 mm. and 10 mm. At this place the diameter of the umbilicus is about 8 mm.

The umbilical shoulders are subangular during early maturity and abruptly rounded at full maturity. Where the shoulders are subangular the umbilical walls are essentially flat, but where they are rounded the walls are slightly but distinctly convex exteriorly. Throughout maturity the walls are approximately normal to the plane of bilateral symmetry of the conch.

On the outer volution of the figured syntype, an internal mold, are four shallow rounded transverse constrictions; between them are several smaller ones which are less well defined and presumably represent increments of growth. All of these markings radiate from the umbilicus and are essentially straight and directly transverse to the long axis of the conch.

Each mature suture has eight pointed lobes and eight rounded saddles. The lobe on the umbilical wall is moderately prominent in this species (Fig. 1A). The three lobes of the internal suture are closely spaced and the saddle which separates them from the umbilical lobe is rather broad.

Remarks.—Although the name of this species was written *"ohioensis"* by Miller and by Weller in their well-known catalogues, and *"ohioense"* by Smith (1903) in his classical monograph, Winchell spelled it *"ohiensis"* in two papers that were published in 1870. We retain the original spelling since it is clearly not a misprint. Winchell noted that this form is similar only to *G. andrewsi.* In that species, however, the conch is not appreciably flattened laterally, the umbilicus appears to be smaller, and the sutures differ in detail. A description of *G. ohiensis* is included here because all the known representatives of the species belong to the University of Michigan.

Occurrence.—Waverly group (upper Cuyahoga, or possibly lower Logan) at or near Newark, Licking County, Ohio.

Types.—Syntypes, No. 26798.

Gattendorfia? shumardiana (Winchell)

(Pl. V, Fig. 1)

Goniatites Shumardianus Winchell, 1862, Amer. Journ. Sci. and Arts, Ser. 2, Vol. 33, pp. 364–65.

Goniatites Shumardianus [part] Winchell, 1870*a,* Amer. Philos. Soc., Proc., Vol. 11, pp. 258–259.

Aganides? shumardianus [part] Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 30, 117.

The specimen on which Winchell based most, if not all, of the original description of this species is illustrated. In order to remove any doubt as

to its status, we here designate it the holotype, in spite of the fact that its preservation leaves much to be desired. This type specimen is a "worn" internal mold that is completely septate. The maximum overall measurement is about 25 mm., and near its adoral end the conch is about 12 mm. high and 7 mm. wide and is impressed dorsally to a depth of some 7 mm. The conch is subdiscoidal as the whorls are narrowly rounded ventrally, and laterally are compressed and slightly but distinctly convex. The maximum width of the conch is attained well outside the umbilical shoulders.

Winchell stated that the holotype has a "moderately open umbilicus, which reveals a small portion of two or three preceding whorls," and his observation seems to be substantiated by the specimen, which, of course, has not improved since he studied it over ninety years ago. The umbilical shoulders are not prominent. This specimen, the only representative of this species, does not reveal the precise shape of the various elements of the sutures. It can, however, be said that the ventral lobe is moderately deep and is most probably undivided; the first lateral saddles are narrowly rounded; the first lateral lobes are shallow and subangular; the second lateral saddles are broadly rounded; and the umbilical lobes appear to be located on or near the umbilical seams (Fig. 6B).

Remarks.—Winchell stated that this species is close to his *Goniatites allei,* which, however, has a bifid ventral lobe and belongs in a different genus. Because of the poor preservation of the holotype, it is doubtful if additional specimens can ever be definitely referred to the species. At least superficially *Gattendorfia? shumardiana* is similar to *G. mehli* of the Chouteau limestone of Missouri. If, as is quite possible, the umbilicus of the holotype of *G.? shumardiana* was closed, we would refer it to the genus *Imitoceras.*

Occurrence.—Marshall sandstone at Pointe Aux Barques, Huron County, Michigan. Winchell referred to this species some specimens from the Waverly group of Ohio, but the only one of them now recognizable is not conspecific with the holotype.

Type.—Holotype, No. 13977.

Gattendorfia stummi Miller and Garner, sp. nov.

(Pl. VI, Figs. 6, 7)

This new species is based primarily on the holotype, but there are a number of fragmentary topotypes. The holotype is a rather well preserved, incomplete internal mold that is entirely septate. It has a maximum overall measurement of about 22 mm. The conch is rounded ventrally and ventrolaterally and near its adoral end is about 7 mm. high and 11 mm. wide and is impressed dorsally to an estimated depth of some 3 to 4 mm.

The open umbilicus of the holotype has a maximum diameter of at least 10 mm. The umbilical shoulders are subangular and the umbilical walls are nearly flat and are almost normal to the plane of bilateral symmetry of the conch.

No trace of the surface markings of the test can be discerned on any of the specimens. On the holotype, however, there are rounded transverse constrictions, about a third of a volution apart, which are essentially straight and directly transverse. The shape of the external sutures of the holotype, No. 30691, is shown in Figure 1B. The complete suture of a somewhat larger conspecific individual (Fig. 2A) and its cross section during the ontogenetic development of the phragmocone are also given (Fig. 2B)—certain of the details in these drawings are based on two specimens in the same small slab. Note (1) that the umbilical lobes center well outside the umbilical seams and (2) that during early ontogenetic development the whorls were much wider than high but these relative proportions were reversed within a single volution.

Remarks.—If we make the fairly safe assumption that the growth lines are more or less parallel to the transverse constrictions, this species belongs in *Gattendorfia,* regardless of the morphological characters used to delineate that genus. The holotype was extracted from an 8-inch limonitic sandstone slab which contained unquestionable representatives of *Imitoceras, Kazakhstania,* and *Münsteroceras.* Furthermore, this slab came from the type locality of the Marshall sandstone, and it is from a 6-inch bed there which yields, in addition to members of the above genera, specimens belonging in *Beyrichoceras* and *Merocanites.*

Gattendorfia stummi resembles the type species of *Gattendorfia* but has a somewhat narrower umbilicus. It is also similar to *G. ohiensis* (Winchell) in which, however, the conch is flattened laterally.

Occurrence.—Marshall sandstone at Marshall, Calhoun County, Michigan.

Types.—Holotype No. 30691; three paratypes from a slab No. 27051; and paratype No. 27049. The slab from which the holotype came contained representatives of *Gattendorfia, Imitoceras, Kazakhstania,* and *Münsteroceras.*

Gattendorfia? sp. [of Michigan]

(Pl. VII, Figs. 3, 4)

The Coldwater shale near Coldwater, Michigan, yielded a single specimen that is probably referable to *Gattendorfia.* It is a calcareous internal mold that, unfortunately, does not retain more than traces of the sutures.

The conch is subglobular and the whorls are helmet-shaped in cross

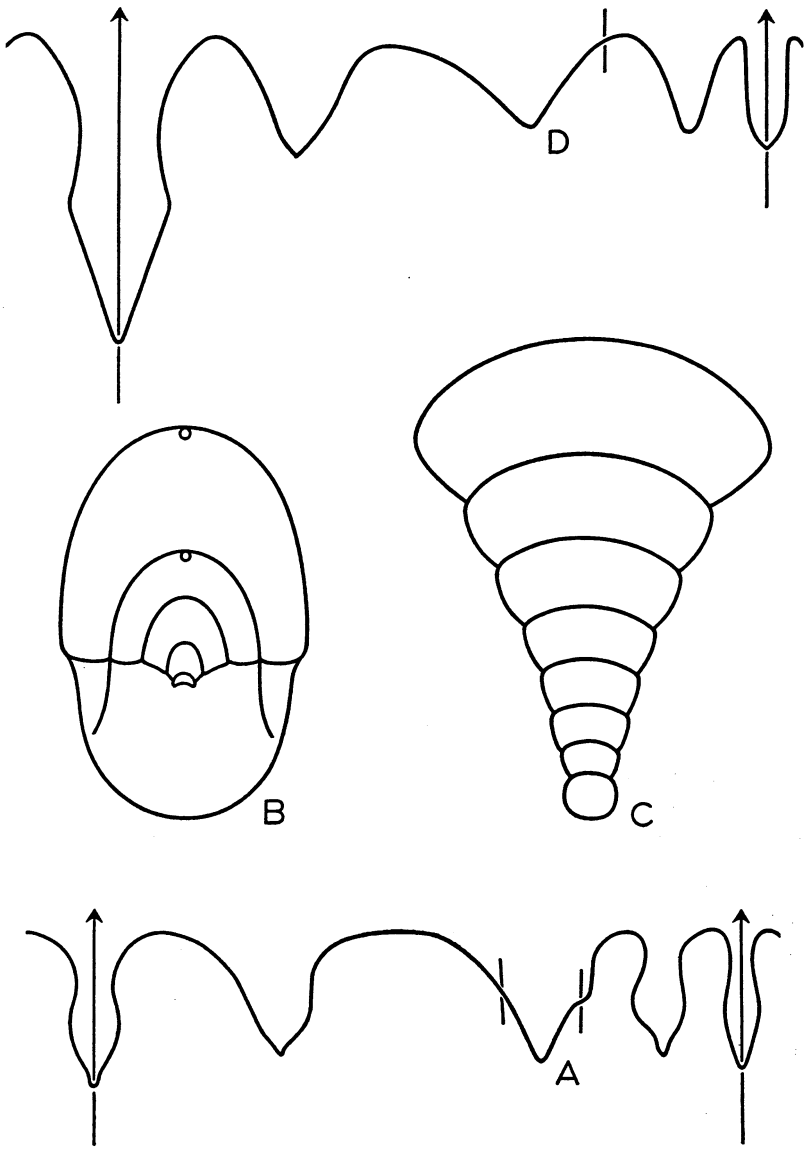

FIG. 2. Sutures and partial sections of a species of *Gattendorfia* and one of *Kazakhstania*.

A,B—*G. stummi* Miller and Garner, sp. nov., based on three paratypes, No. 27051; from small slab of Marshall sandstone, Marshall; × 5 and × 1.

C,D—*K. americana* Miller and Garner, sp. nov., based on the paratype, No. 30693*b*; from Marshall sandstone, Marshall; × 10 and × 20.

section, being broadly rounded ventrally and ventrolaterally and impressed dorsally. The maximum dimension of the specimen is about 38 mm.; near its adoral end the conch is about 15 mm. high and 26 mm. wide, and the depth of the dorsal impressed zone is some 6 mm.

The umbilicus is open and its diameter is equal to a little more than a third that of the specimen. The umbilical shoulders are abrupt and subangular. The umbilical walls are very steep and their surface bears fine transverse lirae.

Remarks.—We are questionably associating this specimen with *Gattendorfia* because (1) its conch is subglobular, (2) its umbilicus is open and moderately large, and (3) the faint suggestions of its sutures seem to indicate that the ventral lobe is pointed. None of our other specimens from either the Coldwater shale or the Marshall sandstone resemble this one very closely. Superficially, at least, it is reminiscent of *G. bransoni* Miller and Youngquist (1947), of the Caballero formation of New Mexico, and of a form, from the Chouteau limestone of Missouri, believed by Miller and Collinson (1951, p. 468, Pl. 69, Figs. 1, 2) to be related to *G. bransoni.*

Occurrence.—Coldwater shale in the abandoned Wolverine Portland Cement Company quarry about 1¼ miles southwest of Coldwater, Branch County, Michigan.

Figured specimen.—No. 30692.

Gattendorfia? sp. [of Ohio]

Goniatites Shumardianus [part] Winchell, 1870*a*, Amer. Philos. Soc., Proc., Vol. 11, pp. 258–59.

Aganides? shumardianus [part] Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 30, 117.

In 1870 Winchell briefly described some fragmentary specimens from the Waverly group of Ohio as *"Goniatites Shumardianus."* Only one of them can now be recognized. It is an internal mold of part of one volution of a phragmocone and it is preserved in limonitic sandstone. The maximum dimension of the volution, when complete, is estimated to have been at least 17 mm. The conch is rather thickly subdiscoidal as the whorls are somewhat compressed, are rounded ventrally and laterally, and impressed dorsally. Where the conch is about 8½ mm. wide, its height is 10 mm. and the depth of the impressed zone is some 5 mm. The umbilicus is small but probably not quite closed and the umbilical shoulders are rounded.

No trace of any surface markings or constrictions can be discerned on the mold. Its sutures are unique; their shape is elucidated in Figure 3.

Remarks.—This specimen is not referable to any species known to us, nor are we certain whether to refer it to *Gattendorfia* or *Imitoceras*. The

most outstanding characteristics of its sutures seem to be their simplicity, the fact that the umbilical lobes center on or very near the umbilical seams, and the shape of the dorsal lobe. A description is included here because the only known specimen belongs to the University of Michigan.

Occurrence.—Waverly group (upper Cuyahoga, or possibly lower Logan) at or near Newark, Licking County, Ohio.

Figured specimen.—No. 26751.

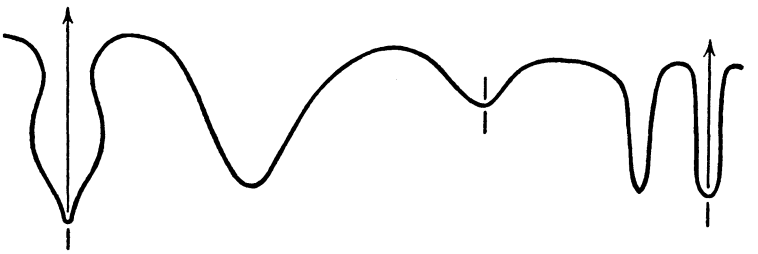

FIG. 3. *Gattendorfia?* sp.

Complete suture where conch is about 10 mm. high, based on a specimen, No. 26751; from Waverly group, Newark, Ohio; × 5.

Genus *Kazakhstania* Librovitch

In his 1940 monograph on the "Carboniferous Ammonoids of North Kazakhstan," in Middle Asia, Librovitch proposed the name *Kazakhstania* for goniatites with sutures resembling those of *Gattendorfia* but with very large umbilici and whorls that are only slightly involute. Transverse constrictions are present on some forms and these, as well as details of the sutures, differentiate kazakhstanias from prolecanitids, with which they occur in direct association. The conch is subdiscoidal and the inner whorls are exposed in the umbilicus.

Librovitch regarded *Kazakhstania* as a subgenus of *Gattendorfia,* but Miller and Collinson (1951, p. 457) raised it to the rank of a genus. Only two forms have previously been referred to it, *K. karagandaensis* (the type species; Pl. VI, Fig. 1) and *K. depressa,* both of Librovitch and both from the early Lower Carboniferous of north Kazakhstan. We are describing below a third species from beds of comparable age in Michigan and we know of no other forms that should be assigned to the genus.

Kazakhstania americana Miller and Garner, sp. nov.

(Pl. I, Fig. 3; Pl. VI, Figs. 2, 3)

From a small slab of limonitic sandstone collected by Winchell almost a hundred years ago, we extracted the two specimens which represent the

only known occurrence of *Kazakhstania* outside Kazakhstan in Middle Asia. The specimens lay on the same bedding plane about 2 inches apart. They represent different portions of the conch, and, indeed, may be parts of the same individual. Nevertheless, in order to eliminate any possibility of confusion, we designate the larger of the two the holotype (Pl. VI, Figs. 2, 3).

The conch of this species is subdiscoidal, and the phragmocone attained an overall dimension of at least 24 mm. The early volutions are strongly depressed dorsoventrally (Fig. 2C), but during ontogenetic development the whorls become progressively less so. In the mid-portion of the holotype the conch is about 7 mm. wide and 6 mm. high, and the dorsal impressed zone is some 1 mm. deep (Fig. 4C).

The umbilicus is large and open and reveals that the conch consists of many volutions. The protoconch is globular, with the transverse dimension the greater.

Both specimens are internal molds without any trace of growth lines but with rounded constrictions that are approximately straight and directly transverse. A few constrictions can be seen on the paratype; on the holotype there are two very distinct ones about a quarter of a volution apart.

Remarks.—It is clear from the *Gattendorfia*-like sutures and the constrictions on the specimens that any resemblance to the associated prolecanitids, that is, the representatives of *Merocanites,* is very superficial and is merely a matter of the general physiognomy of the conch. Although the sutures of *Protocanites lyoni* (Meek and Worthen), a prolecanitid that is abundant and widespread in the early Mississippian of the United States (Fig. 15), have the same number of lobes and saddles as do those of *Kazakhstania americana,* the shape of the various sutural elements is quite different. The conch of the type species of *Kazakhstania, K. karagandaenis,* although very similar to that of *K. americana,* is slightly narrower (cf. Figs. 4B and 4C).

The mature sutures, like the cross sections, of *K. karagandaenis* and *K. americana* are much alike (cf. Figs. 4A and 4D). Each has eight lobes and eight saddles, the shape of which can be seen from the text figures referred to. The second lateral lobes are located well outside the umbilical seams. Because of the narrowness of the impressed zone at full maturity, though not during early ontogenetic development (Fig. 2C), the dorsal lobes become very closely spaced transversely and in the holotype of *K. americana* the dorsal lobes of adjacent sutures are telescoped for about half their length. The lobes of the external sutures are, however, rather distantly spaced.

Occurrence.—Marshall sandstone at Marshall, Calhoun County, Michigan.

Types.—Holotype, No. 30693*a*; paratype, No. 30693*b*.

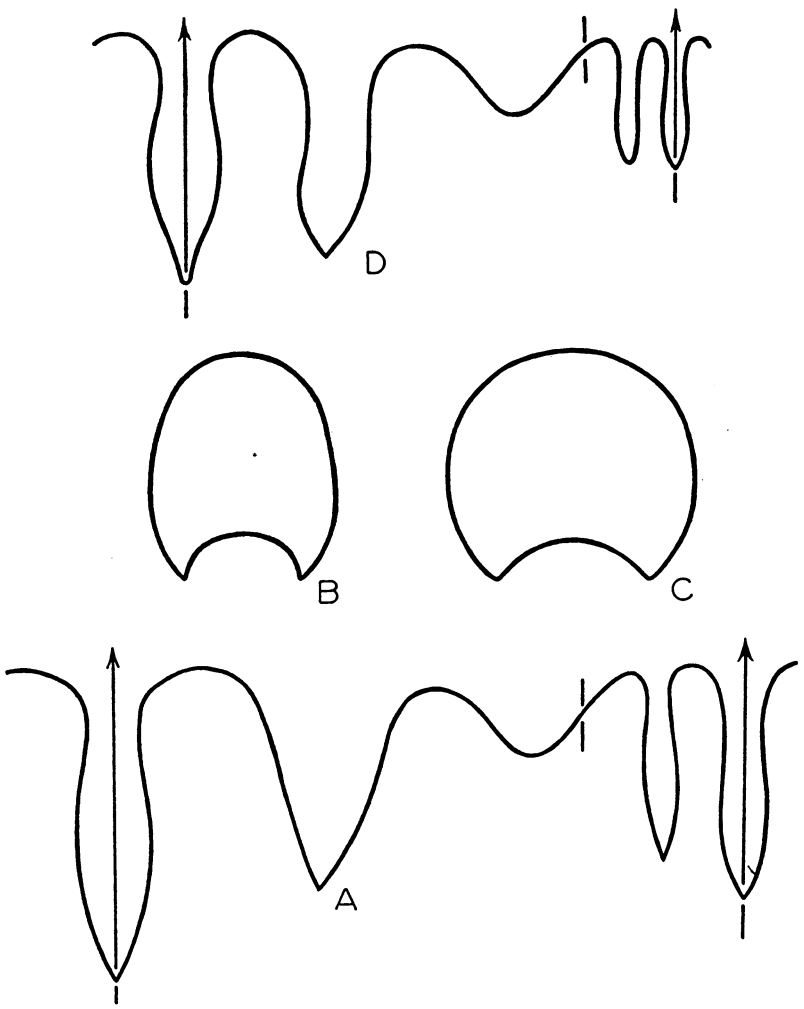

FIG. 4. Sutures and cross sections of two species of *Kazakhstania*.

A,B—*K. karagandaensis* (Librovitch), the type species of the genus; from the early Lower Carboniferous of north Kazakhstan; × 6 and × 2½. Adapted from Librovitch.

C,D—*K. americana* Miller and Garner, sp. nov., where conch is about 6 mm. high, based on holotype, No. 30693*a*; from Marshall sandstone, Marshall; × 5 and × 8.

Genus *Imitoceras* Schindewolf

The genus *Imitoceras* was proposed by Schindewolf in 1923; later (1926, p. 70), he designated *Ammonites rotatorius* de Koninck, from the Tournaisian of Belgium, as the type species. Miller and Collinson (1951, pp. 458–60) recently considered *Imitoceras* at some length, and a re-examination of it at this time would only result in undue repetition. We interpret the genus rather broadly, as did Miller and Collinson, and are referring to it species in which the sutures consist of eight undivided lobes and eight rounded saddles, the umbilical lobes center on or near the umbilical seams, and the umbilicus is closed. *Imitoceras* is nearly world-wide in distribution and ranges from the Upper Devonian to the Middle Permian.

Remarks.—The genus *Irinoceras* (Ruzhencev, 1947), which was based on specimens from the Namurian of the Ural region and was unknown to Miller and Collinson, does not seem to us to differ sufficiently from typical *Imitoceras* to be regarded as generically distinct. The sutures of the type species are much like those of *Imitoceras romingeri* (Winchell) of the Marshall sandstone of Michigan.

Imitoceras romingeri (Winchell)

(Pl. I, Figs. 7, 8)

Goniatites Romingeri Winchell, 1862, Philadelphia Acad. Nat. Sci., Proc., 1862, pp. 427–28.
Aganides romingeri Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 116.

The holotype, the only known representative of this species, is a completely septate internal mold of half a volution of a thickly subdiscoidal conch that is rounded ventrally and more broadly rounded laterally. Its maximum overall dimension is about 20 mm.; near its mid-length the height and width of the conch are about 11 mm. and 10 mm. The umbilicus is small, closed, and inconspicuous. No trace of markings other than the sutures can be discerned on the specimen, which, though incomplete, is well preserved. The shape of the internal suture can not be ascertained; that of the external suture is illustrated (Fig. 6C).

Remarks.—As noted by Winchell this form is similar to *I. rotatorium* (de Koninck). It differs from that species, however, in that its conch is wider and the ventral lobe of its sutures is longer and is expanded near its mid-length (cf. Figs. 6C with 6A, 5A, and 5B).

Occurrence.—Marshall sandstone at Marshall, Calhoun County, Michigan.

Type.—Holotype, No. 13979.

Imitoceras rotatorium (de Koninck)

(Pl. I, Figs. 9–14; Pl. III, Fig. 6)

Ammonites rotatorius de Koninck, 1844, Descr. des anim. foss. ..., terr. Carbonifère de Belgique, pp. 565–66, Pl. 51, Figs. 1*a*, 1*b*.

Goniatites rotatorius de Verneuil, 1847, Soc. Géol. France, Bull., sér. 2, t. 4, pp. 682–93.

Aganides rotatorius d'Orbigny, 1850, Prodr. de paléont. stratigr. univer. ..., Vol. 1, p. 115.

Goniatites rotatorius Roemer, 1852–1854, Bronn's Lethaea geognostica, ed. 3, Bd. 1, Theil 2, p. 516, Pl. 1, Figs. 16*a*, 16*b*.

Goniatites rotatorius? Hall, 1860, N. Y. State Cabinet Nat. Hist., Ann. Rept. 13, pp. 101–2.

Goniatites ixion Hall, 1860, N. Y. State Cabinet Nat. Hist., Ann. Rept. 13, p. 125.

Goniatites propinquus Winchell, 1862, Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, p. 365.

Goniatites propinquus Winchell, 1870*a*, Amer. Philos. Soc., Proc., Vol. 11, pp. 258, 259.

Goniatites Ixion Hall, 1876, Illustrations of Devonian fossils ..., Pl. 73, Figs. 12–14.

Goniatites rotatorius Roemer, 1876, Lethaea geognostica ..., Theil I, Lethaea palaeozoica, Pl. 46, Figs. 12*a*, 12*b*.

Goniatites Ixion Hall, 1879, N. Y. Geol. Surv., Palaeontol., Vol. 5, Pt. 2, pp. 474–76, Pl. 73, Figs. 12–14; Pl. 74, Fig. 12.

Goniatites rotatorius de Koninck, 1880, Mus. roy, hist. natur. Belgique, Ann., Sér. paléont., t. 5, pp. 94, 124, Pl. 47, Figs. 12, 12*a*.

Brancoceras Ixion Hyatt, 1884, Boston Soc. Nat. Hist., Proc., Vol. 22, p. 326.

Goniatites (Brancoceras) rotatorius Zittel, 1884, Handb. Palaeont., Bd. 2, p. 419.

Goniatites rotatorius Hoernes, 1884, Elem. Palaeontologie, p. 331.

Goniatites rotatorius Quenstedt, 1885, Handb. Petrefakt., ed. 3, p. 537, Pl. 42, Fig. 7.

Goniatites Ixion Hall, 1886, New York Assembly Doc. 105 [Fifth Ann. Rept. State Geol.], Pl. (128)13, Fig. 3.

Goniatites Ixion Beecher, in Hall, 1888, New York Geol. Surv., Palaeontol., Vol. 5, Pt. 2, Suppl., p. 40, Pl. 128, Fig. 3.

Goniatites (Brancoceras) rotatorius Zittel, 1895, Grundzüge der Palaeontologie ..., p. 398.

Brancoceras rotatorium Foord and Crick, 1897, Catalogue Fossil Cephalopoda British Museum, (Nat. Hist.), Pt. III, pp. 139–41.

Brancoceras Ixion Foord and Crick, 1897, Catalogue Fossil Cephalopoda British Museum (Nat. Hist.), Pt. III, pp. 141–42.

Aganides rotatorius Haug, 1898, Soc. géol. France, Mém., Paléont., t. 7, No. 18, pp. 38, 39.

Brancoceras rotatorius Hyatt, 1900, Zittel-Eastman Text-book of Palaeontology, Vol. 1, p. 552.

Aganides rotatorius Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 37, 112–14, 116, 121, 145, Pl. 16, Fig. 19; Pl. 19, Figs. 12–14.

Aganides propinquus Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 115–16, 145.

Goniatites (Brancoceras) rotatorius Hoernes, 1910, Paläontologie, ed. 2, p. 131.

Aganides rotatorius Smith, 1913, Zittel-Eastman Text-book of Paleontology, ed. 2, Vol. 1, p. 630.

Imitoceras rotatorium Schindewolf, 1923, N. Jahrb. f. Min., Geol. u. Paläont., Beil.-Bd. 49, pp. 326, 327.

Imitoceras rotatorium Schindewolf, 1926, Senckenbergiana, Bd. 8, p. 70.

(?) *Aganides rotatorius* Menchikoff, 1930, Rev. géol. phys. et géol. dynam., Vol. 3, Fasc. 2, pp. 161, 197–98, Pl. 15, Figs. 1*a*, 1*b*.

Imitoceras rotatorium Delépine, 1940, Mus. roy. hist. natur., Belgique, Mém. 91, pp. 8, 9, 27, 28, 36, 37–38, Pl. 3, Figs. 1, 2.

(?) *Imitoceras* aff. *I. rotatorium* Delépine, 1941, Ann. and Mag. Nat. Hist., Ser. 11, Vol. 7, pp. 387, 390–91, 393, 394, Pl. 5, Figs. 7, 8.

Imitoceras rotatorium Miller and Collinson, 1951, Journ. Paleontol., Vol. 25, p. 458.

(?) *Imitoceras rotatorium* Follot, 1952, Cong. géol. internat., XIX, Monog. région., sér. 1, Algérie, No. 1, p. 38.

A great deal has been written about this species, and there has been considerable difference of opinion, both in regard to its generic affinities and to the relationship between the American specimens from the Rockford limestone of Indiana and the types from the upper Tournaisian of Belgium. It now seems to be generally agreed, however, that the proper generic appellation is *Imitoceras* and that the Indiana and Belgian specimens are so much alike that they can be regarded as conspecific. To be sure, the number of camerae to a volution is not quite the same in certain of the Indiana specimens as in the Belgian holotype, but neither is this feature constant among individuals from Indiana. Some have the same number as de Koninck's type.

A direct comparison of the holotype and topotypes of *Goniatites propinquus* Winchell with specimens of *I. rotatorium* from Indiana has convinced us that they are conspecific and that the Michigan specimens also should be referred to de Koninck's species (cf. Pl. I, Figs. 9–11, with Pl. I, Figs. 12–14, and Pl. III, Fig. 6). We are, therefore, suppressing the name *Goniatites propinquus* Winchell. The very close relationship between the Michigan and Indiana specimens has not been recognized, because, heretofore, no large individuals from Michigan have been studied and no Michigan specimens have been illustrated. A large individual, No. 14196 (Pl. I, Fig. 12), from the Marshall sandstone at Grindstone City, has a maximum overall measurement of about 50 mm., and near the mid-length of its adoral half-volution the height and width of its conch are about 33 mm. and 23 mm. The shape of its suture is illustrated (Fig. 5A). The slight differences between this suture drawing and that of a comparable Indiana specimen (Fig. 5B) may be ascribed to variations in preservation and interpretation. Another drawing (Fig. 6A) represents the external suture of a Michigan specimen at an earlier stage of ontogenetic development.

Remarks.—As Delépine (1940, pp. 37, 38) emphasized, the specimen from the Lower Carboniferous of central European Soviet Russia which Tzwetaev (1898, pp. 28–29, 30, 46, Pl. 5, Fig. 19) referred to this species should be removed. It appears to have an open umbilicus and a relatively wide conch.

Occurrence.—Representatives of *Imitoceras rotatorium* are known from the Marshall sandstone of Michigan at the following localities in Huron

County: (1) Grindstone City (1 specimen), (2) Pointe Aux Barques (1 specimen, the holotype of *"Goniatites propinquus"* Winchell), and (3) Burnt Cabin Point (5 specimens). We have also a questionable representative from near the Marshall-Coldwater boundary on the northeast side of Holland, Ottawa County, Michigan. In Indiana the species is abundant in the Rockford limestone at Rockford, Jackson County. In Belgium it occurs in the upper Tournaisian at Barges?, Calonne, Chercq, and/or Vaulx,

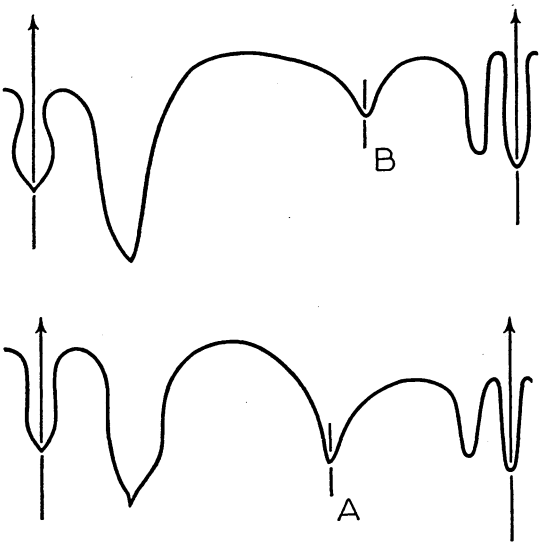

FIG. 5. Fully mature sutures of *Imitoceras rotatorium* (de Koninck).

A—Where the conch is about 33 mm. high, based on a hypotype, No. 14196 (Pl. I, Fig. 12); from the Marshall sandstone, Grindstone City; × 1¼.

B—Where the conch is about 37 mm. high, based on a hypotype (State Univ. Iowa, No. 13974); from Rockford limestone, Rockford, Indiana; × 1¼.

and specimens that may belong to it have been found in the upper Tournaisian of the "Vallée de la Saoura" in western Algeria, at Mouydir in southern Algeria, and in the Werrie Basin of New South Wales.

Types.—Hypotype (Pl. III, Fig. 6), No. 13978; hypotype (Pl. I, Fig. 12), No. 14196; hypotype (Holland specimen), No. 27047; hypotype (Pl. I, Figs. 13, 14), No. 30694; three unfigured hypotypes, from Burnt Cabin Point, No. 30695.

Genus *Münsteroceras* Hyatt

This genus has recently been discussed by Miller and Collinson (1951, p. 471). After their work was published, Bisat (1952, pp. 163–66) proposed several new genera for forms that are more or less intermediate between

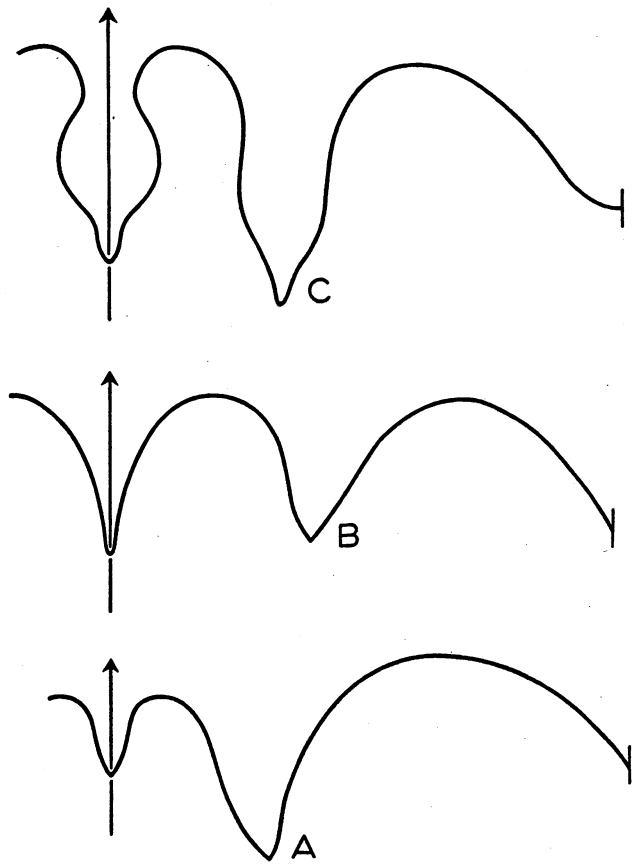

FIG. 6. Mature external sutures of two species of *Imitoceras* and one of *Gattendorfia*.

A—*I. rotatorium* (de Koninck) where the conch is about 14 mm. high, based on the holotype of *Goniatites propinquus* Winchell (a name we are suppressing), No. 13978; from the Marshall sandstone, Pointe Aux Barques; × 3.

B—*G.? shumardiana* (Winchell) where the conch is about 12 mm. high, based on the holotype, No. 13977; from the Marshall sandstone, Pointe Aux Barques; × 6.

C—*I. romingeri* (Winchell) where the conch is about 10 mm. high, based on the holotype, No. 13979, Marshall sandstone, Marshall; × 6.

typical *Münsteroceras* and typical *Beyrichoceras,* which are themselves somewhat gradational. The type species of *Münsteroceras* is *M. parallelum* (Hall) of the Kinderhook of Indiana; that of *Beyrichoceras* is *B. obtusum* (Phillips) of the middle Viséan of England. The most easily recognized and perhaps the most significant difference between these two species seems to be the shape of the bifid ventral lobe of the sutures, which in *M. parallelum* is narrow, with almost parallel flanks and prongs (Fig. 7C), and in *B. obtusum* is moderately wide, with flanks that diverge orad and prongs that diverge apicad. Species such as *M. medium* Miller and Collinson of the Chouteau limestone of Missouri are more or less intermediate (Fig. 9B).

The type species of *Bollandites* Bisat, 1952, is *Beyrichoceratoides castletonense* Bisat of the middle Viséan of England. In it the conch is thickly subdiscoidal and is rounded ventrally, the umbilicus is open and large, and neither the prongs nor the flanks of the ventral lobe of the sutures diverge appreciably (according to Bisat's drawing, 1924, Pl. 9, Fig. 14). We doubt that the differences between this species and the type species of *Münsteroceras* are of more than specific value.

The type species of *Bollandoceras* Bisat, 1952, is *Beyrichoceras submicronotum* Bisat of the middle Viséan of England. In it the conch is subdiscoidal and is rounded ventrally, the umbilicus is open but small, and the sutures are much like those of the type species of *Münsteroceras,* though the ventral lobe is a little wider and its flanks are not quite parallel (see Bisat, 1934, Fig. 19 on p. 288). Again, the differences seem to us specific rather than generic.

The type species of *Beyrichoceratoides* Bisat, 1924, is *Goniatites implicatus* Phillips from the middle Viséan in England. Its conch, which was described by Phillips (1836, p. 235) as "subglobose," has an open but small umbilicus and sutures in which the ventral lobe is strikingly similar to that of *Beyrichoceras submicronotum* (cf. Phillips, 1836, Pl. 19, Fig. 25; Bisat, 1934, Fig. 19 on p. 288). Bisat (1924, p. 88) stated that this "genus approaches very closely in its sutures to forms of Hyatt's genus *Munsteroceras,* which, however, is apparently of Tournaisian age and differs somewhat in shape." We certainly agree with the first part of this statement; but we do not wish to differentiate genera on the basis of whether they occur in presumed Tournaisian or Viséan equivalents on opposite sides of the Atlantic, or because of slight variations in the shape of the conch. Moreover, Bisat (1924, p. 88) questioned the reported shape of the conch of the holotype of the type species of *Beyrichoceratoides.*

It seems almost certain that the Michigan strata which yielded the specimens we are studying are intermediate in age between those from which the type species of *Münsteroceras* came and those which produced the

type species of Bisat's genera just discussed. But the problem of generic differentiation is more acute, because we have intermediate stages. After careful consideration we decided that, with the exception of typical *Beyrichoceras*, the British forms mentioned above and our related ones should all be referred to a single genus, for which Hyatt's name *Münsteroceras* is quite appropriate and has priority. In line with this conclusion, we are placing in *Münsteroceras* and *Beyrichoceras* certain specimens from the Coldwater shale and the Marshall sandstone. Representatives of these two genera occur in direct association in both formations, for example in the Coldwater shale near Coldwater and in a 6-inch bed of limonitic sandstone in the type section of the Marshall sandstone.

There has been much difference of opinion as to the precise orthography of Hyatt's name for the genus *Münsteroceras*. The case has recently been submitted to the International Commission on Zoological Nomenclature by Miller (1952, pp. 356–57) with the request that *Münsteroceras* be placed on record as the correct spelling. Accordingly we are employing the name that way, but Article 20 of the recently issued "Copenhagen Decisions on Zoological Nomenclature" indicates that in the future the preferred spelling will probably be *Muensteroceras*.

As we interpret *Münsteroceras,* it is limited to the early Lower Carboniferous (Kinderhook and Osage) in North America, and in Europe it appears in the Tournaisian and ranges well up in the Viséan. It is also known from Asia, Africa, and Australia, in beds of presumably about the same age.

Münsteroceras oweni (Hall)

(Pl. II, Figs. 1–7; Pl. III, Figs. 7–15; Pl. IV, Figs. 15, 16; Pl. VI, Figs. 4, 5)

Goniatites oweni [part] Hall, 1860, New York State Cabinet Nat. Hist., Ann. Rept. 13, pp. 300–301.

Goniatites Oweni Winchell, 1862*a*, Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, p. 364.

Goniatites Oweni parallela (parallelus?) Winchell, 1862*a*, Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, p. 364.

Goniatites Oweni Hall, 1876, Illustrations of Devonian fossils ..., Pl. 73, Figs. 3–8.

Goniatites Oweni Hall, 1879, New York Geol. Surv., Palaeontol., Vol. 5, Pt. 2, pp. 470–72, Pl. 73, Figs. 3–8; Pl. 74, Fig. 9.

Goniatites oweni White, 1881, Indiana Dept. Statistics and Geol., Ann. Rept. 2, pp. 514–15, Pl. 7, Figs. 3, 4.

Munsteroceras Oweni Hyatt, 1884, Boston Soc. Nat. Hist., Proc., Vol. 22, p. 326.

Munsteroceras Whitei Hyatt, 1884, Boston Soc. Nat. Hist., Proc., Vol. 22, pp. 326–27.

Goniatites Oweni Hall, 1886, New York Assembly Doc. 105 [Fifth Ann. Rept. State Geol.], Pl. (128)13, Figs. 4–7.

Goniatites Oweni Beecher, 1888, New York Geol. Surv., Palaeontol., Vol. 5, Pt. 2, Suppl., p. 40, Pl. 128, Figs. 4–7.

Glyphioceras Oweni Foord and Crick, 1897, Catalogue Fossil Cephalopoda British Museum, Pt. III, pp. 188–89.

Pericyclus [*Munsteroceras*] *Oweni* Haug, 1898, Soc. géol. France, Mém., Paléont., t. 7, no. 18, p. 102, Pl. 20, Figs. 43*a*, 43*b*.

Glyphioceras Oweni Frech, 1902, Beitr. Paläont. Geol. Österr.-Ung. Orients, Bd. 14, p. 84.

Muensteroceras oweni Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 37, 55, 120–21, 122, 145, Pl. 19, Figs. 3–8.

(?) *Muensteroceras Oweni* Menchikoff, 1930, Rev. géog. phys. et géol. dynam., Vol. 3, Fasc. 2, pp. 161, 198, Pl. 15, Figs. 2*a*, 2*b*.

(?) *Munsteroceras* sp. Delépine, 1941, Ann. and Mag. Nat. Hist., Ser. 11, Vol. 7, pp. 387, 391, 394, Pl. 5, Fig. 9.

In publications which are readily available, both Hall and Smith deal extensively and in detail with this species. Accordingly, we limit our discussion to the Michigan specimens, of which we have approximately seventy-five. These specimens show a certain amount of variation, particularly in the relative proportions of the conch, the diameter of the umbilicus, and the details of the transverse constrictions and sutures. All these features are somewhat affected by preservation. The diameter of the umbilicus ranges from about one-fifth to one-third of the maximum overall dimension of the specimen. During immaturity the conch is relatively wide (Pl. VI, Figs. 4, 5). The sinuous transverse constrictions, present throughout ontogenetic development, form slight lateral and well-developed ventral sinuses. The number and prominence of these constrictions varies not only from specimen to specimen but in different parts of the same individual. The sutures are essentially identical with those in conspecific specimens from the Rockford limestone of Indiana. Whatever differences they show seem to be due largely to preservation (cf. Figs. 7E and 9C). *M. pfefferae* (Miller and Werner) of the Fern Glen limestone of Illinois and the St. Joe limestone of Missouri also has similar sutures (Fig. 7F).

Remarks.—Certain Michigan specimens show a somewhat gradational sequence between typical *M. oweni* (Hall) and *M. parallelum* (Hall), both originally described from the Rockford limestone of Indiana. Others are more or less intermediate between forms that we regard as unquestionably belonging either to *Münsteroceras* or to *Beyrichoceras* (cf. sutures of representatives of the two, Figs. 7A–F and 9A–C). Because the variations within the group of specimens that we refer to *M. oweni* do not seem to follow any recognizable pattern or patterns, we are allowing this species considerable latitude (see illustrations). Certain variants differ so much from the norm that they could well be regarded as varieties, but it has been our experience that trinomials are too cumbersome to be practicable.

Occurrence.—In Michigan this species is known from the Marshall sandstone at Pointe aux Barques (3 specimens) and Burnt Cabin Point

(some 70 specimens), both in Huron County, and at Marshall, in Calhoun County (1 specimen). Conspecific specimens are abundant in the Rockford limestone at Rockford, Indiana; and similar, if not identical, forms are known from the upper Tournaisian in the "Vallée de la Saoura" of western Algeria and the Werrie Basin of New South Wales.

Types.—Hypotype (Pl. III, Figs. 7, 8), No. 2413; hypotype (Pl. III, Figs. 9–11), No. 2442; hypotypes (two of Winchell's hypotypes), No. 21969; hypotype (Pl. III, Fig. 12), No. 21970; hypotype (Pl. III, Figs. 13–15), No. 30696*a*; hypotype (Pl. II, Figs. 6, 7), No. 30696*b*; hypotype (Pl. IV, Figs. 15, 16), No. 30696*c*; hypotype (Pl. II, Figs. 4, 5), No. 30697; hypotype (Pl. VI, Figs. 4, 5), No. 30698*a*; hypotypes (four specimens), No. 30698*b*; hypotypes (thirteen, collected by W. A. Kelly), No. 30699; hypotypes (forty-seven, collected by Garner), No. 30700.

Münsteroceras pergibbosum Miller and Garner, sp. nov.

(Pl. II, Figs. 12, 13; Pl. VII, Figs. 1, 2)

This species is based on two wholly septate internal molds. Both are fragmentary and incomplete but, nevertheless, elucidate most of the significant specific characters. The larger of the two (Pl. II, Figs. 12, 13), even though somewhat crushed, is chosen as the holotype because it is the more nearly complete.

The conch is globular as the whorls are helmet-shaped in cross section, being broadly rounded ventrally and laterally and impressed dorsally. The

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FIG. 7. Mature sutures of one species of *Beyrichoceras* and four of *Münsteroceras*. →

A—*B. allei* (Winchell) where the conch is about 11 mm. high, based on the holotype, No. 22045; from the Marshall sandstone at Marshall; × 3½.

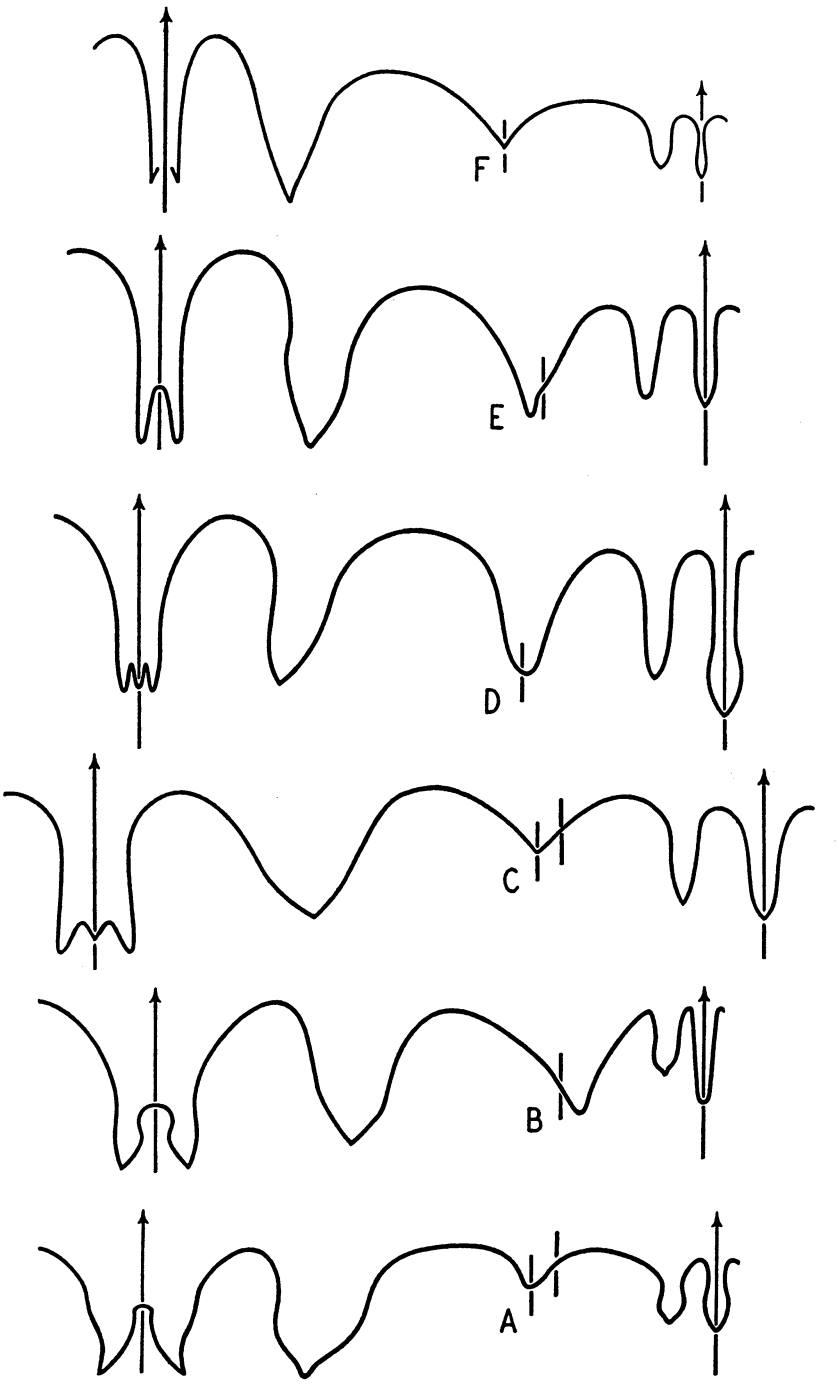
B—*B. allei* (Winchell) where the conch is about 8 mm. high, based on a hypotype, No. 30703*c*; from the Coldwater shale, about 1¼ miles southwest of Coldwater; × 5.

C—*M. parallelum* (Hall), the type species of the genus, based on a hypotype in the J. P. Smith collection; from the Rockford limestone, Rockford, Indiana; × 3¾. Adapted from J. P. Smith.

D—*M. pergibbosum* Miller and Garner, sp. nov., where the conch is about 30 mm. high, based on the holotype, No. 30701*a*; from the Coldwater shale, about 1¼ miles southwest of Coldwater; × 1½.

E—*M. oweni* (Hall) where the conch is about 13 mm. high, based on a topotype (State Univ. Iowa, No. 13976); from the Rockford limestone, Rockford, Indiana; × 3.

F—*M. pfefferae* (Miller and Werner) where the conch is about 40 mm. high, based on a hypotype (State Univ. Iowa, No. 1910); from the St. Joe limestone, some 10 miles east of Cassville, Missouri; × 1.


F
E
D
C
B
A

phragmocone attains a diameter of at least 75 mm. (estimated) and the height and width of the conch are approximately equal. The maximum width of the conch is attained just outside the umbilical shoulders. The umbilicus is open, and its diameter is estimated to be something like one-fifth that of the maximum overall measurement of the conch. The umbilical shoulders are rounded and indefinite and the umbilical walls are very narrow. Neither of the specimens reveals traces of markings other than the sutures. The shape of the complete mature suture is diagrammed (Fig. 7D). Note that all of the lobes are long and narrow and all of the saddles are more or less U-shaped.

Remarks.—Although clearly referable to *Münsteroceras,* this form differs from all previously described American species of the genus in that its conch is relatively wide.

Occurrence.—Coldwater shale in the abandoned Wolverine Portland Cement Company shale quarry about 1¼ miles southwest of Coldwater, Branch County, Michigan.

Types.—Holotype (Pl. II, Figs. 12, 13), No. 30701*a*; paratype (Pl. VII, Figs. 1, 2), No. 30701*b*.

Münsteroceras? pygmaeum (Winchell)

(Pl. IV, Figs. 17, 18)

Goniatites pygmaeus Winchell, 1862*a*, Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, p. 366.
Glyphioceras pygmaeum Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 65–66.

Of this species, we have two syntypes. The larger one (unfigured) retains sutures and is an internal mold that is only moderately well preserved. All but the adoral quarter-volution of it is septate. The conch is thickly subdiscoidal and is rounded ventrally and even more broadly rounded laterally. The greatest overall measurement of this specimen is about 7 mm. and near its adoral end the height and width of the conch both are about 4 mm. The maximum width of the conch is attained just outside the rounded indefinite umbilical shoulders.

The umbilicus is small, inconspicuous, and almost certainly closed. No trace of growth lines can be discerned on either specimen, but both bear rounded transverse constrictions which are approximately a quarter of a volution apart and which are almost straight but form very slight ventral sinuses.

The camerae are rather short. Each mature external suture consists of a moderately shallow wide bifid ventral lobe, and on either side of it a broadly rounded first lateral saddle, a rather shallow rounded first lateral lobe, and a low broadly rounded second lateral saddle which extends to the

umbilical seam. The umbilical lobe centers (Fig. 8) on or inside the umbilical seam.

Remarks.—When Winchell established this species he mentioned a "sole specimen." His original description, nevertheless, seems to have been based on these two specimens and we therefore regard them as syntypes. The smaller specimen we are illustrating (Pl. IV, Figs. 17, 18). It resembles the larger one but lacks any trace of sutures and has more prominent transverse constrictions.

Because the umbilicus is almost certainly closed, this species is not typical of *Münsteroceras*. Our examples resemble immature representatives of *Beyrichoceras allei* (Winchell), in which, however, the umbilicus is dis-

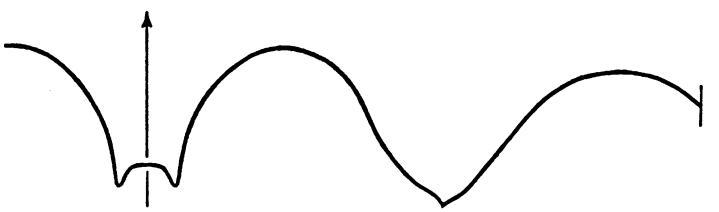


FIG. 8. *Münsteroceras? pygmaeum* (Winchell).

External suture where conch is about 4 mm. high, based on the unfigured syntype, No. 26708*b*; from the Marshall sandstone at Battle Creek; × 35.

tinctly larger, the umbilical shoulders much more abrupt, and the first lateral lobes of the sutures subangular rather than rounded (Fig. 10C and Pl. IV, Figs. 1–5).

Occurrence.—Marshall sandstone at Battle Creek, Calhoun County, Michigan.

Types.—Syntype (Pl. IV, Figs. 17, 18), No. 26708*a*; syntype (unfigured), No. 26708*b*.

Genus *Beyrichoceras* Foord

Foord proposed this genus in 1903 and some years later Bisat (1924, p. 84) selected *Goniatites obtusus* Phillips of the middle Viséan of England for its type species. In that form the conch is subglobular and it has a small open umbilicus and sutures that presumably consist of eight lobes separated by rounded saddles. The ventral lobe, one of the most distinctive characters of the genus, is moderately wide, is bifid, and has flanks that diverge orad and prongs that diverge apicad. All of the other lobes of the sutures are presumably undivided and pointed. The umbilical lobes appear to

center on or near the umbilical seams (see Phillips, 1836, Pl. 19, Figs. 10–13; Miller, 1947, Figs. 1A and 1B on p. 20).

Foord and Crick (1897, p. 169) and Foord (1903, p. 163) regarded *B. obtusum* as a synonym of *Ellipsolites ovatus* Sowerby, a conclusion that was rejected by Spath (1934, p. 15). Sowerby's species has priority; it is the type species of *Nautellipsites* Parkinson, 1822. But Sowerby's illustration and description leave so much to be desired that we are not able to ascertain what its affinities are. His type specimen, which came from the Viséan of Ireland and is in the British Museum of Natural History, needs to be restudied. Even if it is not conspecific with the holotype of *B. obtusum,* it may well be congeneric with it. In which case the name *Beyrichoceras* will have to be suppressed as a synonym of *Nautellipsites,* which has priority. Meanwhile, we propose to use the name *Beyrichoceras,* as do our British colleagues.

In the British Isles, western continental Europe, and northern Africa, this genus is widely used as a guide to a middle Viséan faunal zone that is named for it. In America, however, only one specimen of the genus has heretofore been reported. This is the holotype of *B. hornerae* Miller, which comes from the lower part of the Boone formation of southwestern Missouri, which may be upper Tournaisian or, more probably, lower Viséan in age.

Beyrichoceras allei (Winchell)

(Pl. I, Figs. 1, 2; Pl. II, Figs. 8–11; Pl. III, Figs. 1–5; Pl. IV, Figs. 1–14; Pl. V, Figs. 2–11)

Goniatites Allei Winchell, 1862*a,* Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, pp. 363–64.
(?) *Goniatites sulciferus* Winchell, 1862*a,* Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, p. 365.
Goniatites sinuosus? Winchell, 1862*a,* Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, pp. 365–66.
Goniatites Whitei Winchell, 1862*a,* Philadelphia Acad. Nat. Sci., Proc., 1862, p. 428.
Goniatites Allei Winchell, 1865, Philadelphia Acad. Nat. Sci., Proc. 1865, p. 133.
Goniatites Allei Winchell, 1870*a,* Amer. Philos. Soc., Proc., Vol. 11, p. 258.
Goniatites Allei Winchell, 1870*b*, Sketches of Creation ..., p. 116, Fig. 50.
Goniatites whitii Miller, 1877, The American Palaeozoic fossils ..., p. 170.
Gonioloboceras? allei Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 60, 123.
(?) *Goniatites? sulciferus* Smith, 1903, U. S. Geol. Surv., Monogr. 42, p. 142.

One of the specimens, No. 22045, in the paleontological collections is labeled the "holotype" of this species. We propose to regard it as such for presumably it is one of the original type specimens and it is the only one that can be recognized (Pl. IV, Figs. 9, 10). This individual is a rather well-preserved completely septate internal mold which has a maximum overall measurement of about 18 mm. It is subdiscoidal in shape as its whorls are narrowly rounded ventrally, compressed and flattened laterally, and deeply

impressed dorsally. Near its adoral end the height and corresponding width of the conch are about 11 mm. and 7 mm., and the depth of the impressed zone is equal to about half the height of the conch. The maximum width of the conch is attained near the abruptly rounded umbilical shoulders. The umbilicus is small and rather inconspicuous but does not appear to be closed. Faint traces of growth lines and transverse constrictions can be discerned, and they are strongly sinuous forming shallow broadly rounded lateral sinuses and a much deeper narrowly rounded ventral one; the dorsolateral and especially the ventrolateral salients are narrowly rounded and prominent. The shape of the adoral sutures of the holotype is elucidated (Fig. 7A). The sutures have eight lobes and eight rounded saddles; the ventral lobe is rather wide and bifid with flanks which diverge orad and prongs which diverge apicad; all of the other lobes are undivided and pointed; and the umbilical lobes center on the umbilical shoulders.

The collections under consideration contain well over a hundred specimens that we believe to be conspecific with the holotype. These individuals exhibit a variety of ontogenetic stages. Some are internal molds, others are testiferous, and they vary greatly in size, in the prominence of the sinuous transverse constrictions, and in the relative diameter of the umbilicus. Winchell believed them to represent four or five distinct species. The largest specimen, No. 30704 (Pl. V, Fig. 8), is about 68 mm. in diameter and retains the surface markings of the test exceptionally well, because it is primarily an external mold on which is impressed the characters of the internal mold.

A peculiarity of this species and one that almost certainly misled Winchell, is that during early ontogenetic development the umbilicus was small and most probably closed, but after the conch attained a diameter of some 20 mm. the umbilicus became open and its size increased greatly within a single volution (see Pl. III, Fig. 4, and Pl. V, Figs. 5–7). The umbilicus then remained open and quite prominent throughout the remainder of ontogenetic development, and its shoulders became almost nodose, for the increments of growth are accentuated there. These growth increments (and the parallel transverse constrictions) form a very deep, narrowly rounded ventral sinus and quite prominent, narrowly rounded ventrolateral salients during late growth stages.

The number and prominence of the sinuous transverse constrictions vary greatly in different members of this species and in the same individual during ontogenetic development; some specimens show no constrictions. Accordingly, the number, arrangement, and prominence of these markings are not of much taxonomic value.

During rather early ontogenetic development, when the conch is 5 to

10 mm. in diameter, the dorsal impressed zone bears large prominent longitudinal lirae. Because of the presence of these ridges and of the transverse growth markings, the dorsal portion of the test is reticulate. For the most part, this reticulate surface can only be observed in the dorsal impressed zone of small individuals. Figure 10 A–C elucidates the very early

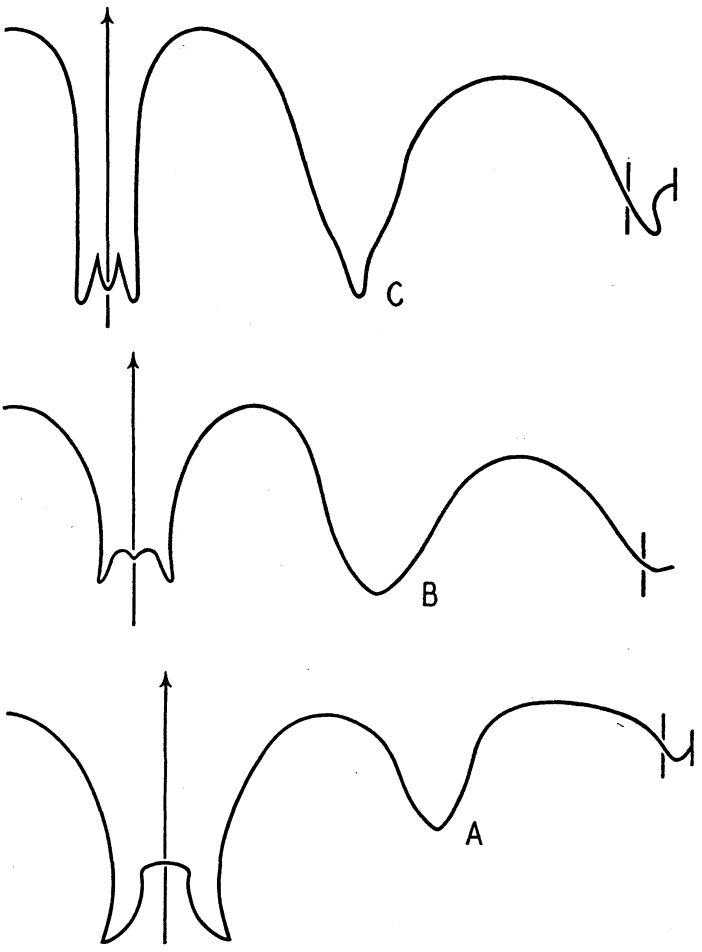


FIG. 9. Mature external sutures of one species of *Beyrichoceras* and two of *Münsteroceras*.

A—*B. allei* (Winchell) where the conch is about 16 mm. high, based on a typical specimen from the Coldwater shale of Michigan; × 4.

B—*M. medium* Miller and Collinson where the conch is about 6 mm. high, based on the holotype from the Northview shale of Missouri; × 7½.

C—*M. oweni* (Hall) where the conch is about 14 mm. high, based on a specimen from the Marshall sandstone of Michigan; × 4.

ontogenetic development of the sutures, while the umbilicus is small and closed, or nearly so. It portrays the nature of the sutures from very near (within three septa of) the protoconch to a conch diameter (overall measurement) of some 2½ mm. The shape of the early mature and late mature sutures is shown in other diagrams (Figs. 7A, 7B, 9A, and 11) and as can be seen from these drawings, there is a certain amount of variation in the width of the ventral lobe.

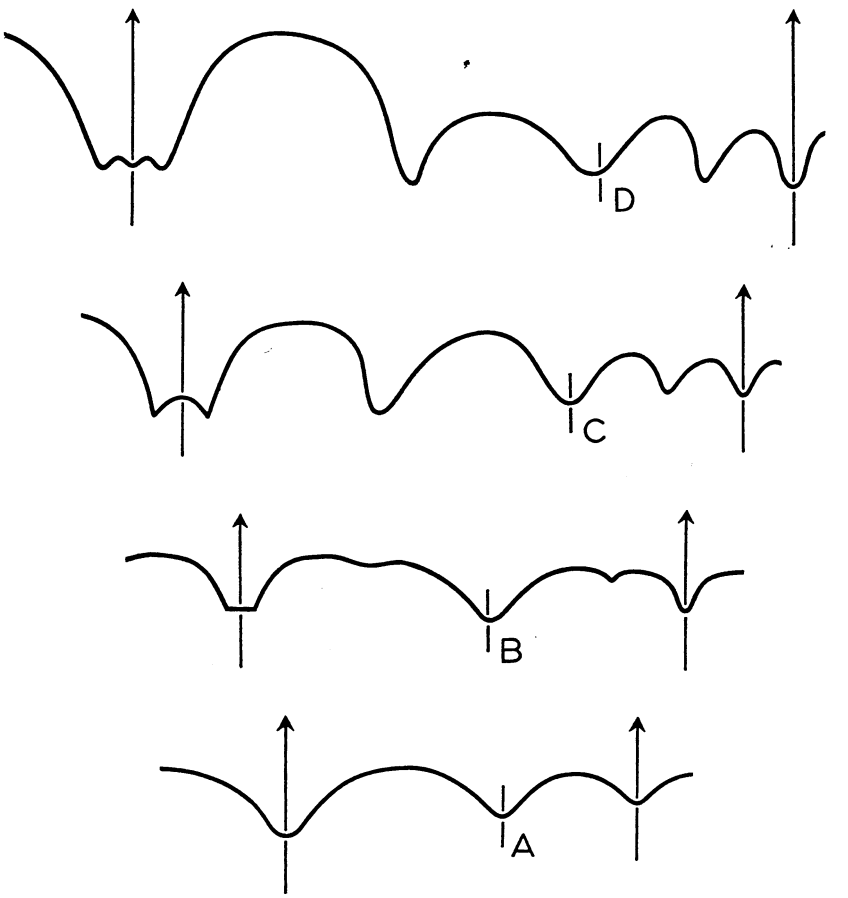


FIG. 10. Very early ontogenetic development of sutures of *Beyrichoceras allei* (Winchell). A to C, and most of D are based on a single specimen; it and the other one from which D was partly derived are from the Coldwater shale about 1¼ miles southwest of Coldwater.

A—Third suture; × 70.

B—Near adoral end of first whorl; × 50.

C—Near mid-length of second whorl; × 45.

D—Adoral portion of third whorl, where diameter of conch (overall measurement) is about 2½ mm.; × 35.

Remarks.—The general form of the conch, and especially the shape of the ventral lobe of the sutures, indicate clearly that this species belongs in the genus *Beyrichoceras*. Its most diagnostic characteristics are the marked sinuosity of the growth lines and constrictions and, particularly, the very unusual expansion of the umbilicus during early maturity. Only one other representative of *Beyrichoceras* is known from America, *B. hornerae* Miller, and that has a relatively wide conch and is indeed different. The Michigan species does not seem very close to any of the congeneric forms described from Europe and Africa, most of which are more or less subglobular in shape.

Occurrence.—Locally abundant in the Coldwater shale and the Marshall sandstone of Michigan; it is the most common goniatite in both formations. In the Coldwater shale, it is known from Union City (5 syntypes of *"Goniatites whitei"*) and the abandoned Wolverine Portland Cement Company shale quarry, about 1¼ miles southwest of Coldwater (87 specimens), both in Branch County. From the Marshall sandstone it has been secured at the following localities: (1) Marshall, Calhoun County (11 specimens,

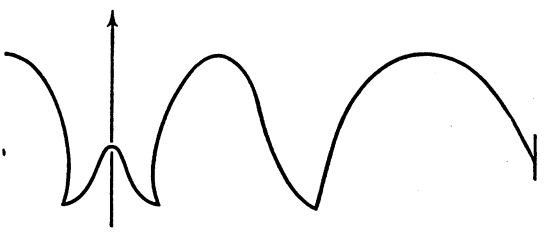


FIG. 11. *Beyrichoceras allei* (Winchell).

Mature external suture where conch is about 30 mm. high, based on a hypotype, No. 30704 (Pl. V, Fig. 8); from Coldwater shale about 1¼ miles southwest of Coldwater; × 3.

including the holotype and several specimens identified by Winchell as *"Goniatites sinuosus?"*); (2) Battle Creek, Calhoun County (10 specimens); (3) Holland, Ottawa County (1 specimen); and (4) Germain's quarry, Hillsdale, Hillsdale County (11 specimens).

Types.—Hypotype (Pl. I, Figs. 1, 2), No. 2936*a*; hypotype (Pl. II, Figs. 10, 11), No. 2936*b*; hypotypes (thirty-one specimens), No. 2936*c*; hypotype (Pl. IV, Fig. 1–3), No. 3630*a*; hypotype (Pl. IV, Fig. 4), No. 3630*b*; hypotypes (forty-seven specimens), No. 3630*c*; hypotypes (five syntypes of *Goniatites Whitei* Winchell, one figured in Pl. IV, Fig. 5), No. 15350; holotype (Pl. IV, Figs. 9, 10), No. 22045; hypotypes (six specimens identified by Winchell as *Goniatites sinuosus?* Hall), No. 26706; hypotype (Pl. IV, Figs. 11, 12), No. 26821*a*; hypotype (Pl. IV, Figs. 13, 14), No. 26821*b*; hypotype (Pl. V, Figs. 2, 3), No. 26821*c*; hypotypes

(eight specimens), No. 26821*d*; hypotype (Pl. V, Fig. 7, homeotype of Winchell), No. 27048*a*; hypotypes (nine specimens, homeotypes of Winchell), No. 27048*b*; hypotype (Pl. II, Figs. 8, 9), No. 30702*a*; hypotype (Pl. III, Figs. 4, 5), No. 30702*b*; hypotype (Pl. V, Figs. 4, 5), No. 30702*c*; hypotype (Pl. V, Fig. 6), No. 30702*d*; hypotype (Pl. III, Figs. 1, 2), No. 30703*a*; hypotype (Pl. III, Fig. 3), No. 30703*b*; hypotype (Pl. IV, Figs. 6–8), No. 30703*c*; hypotype, No. 30703*d*; hypotype (Pl. V, Fig. 8), No. 30704; hypotype (Pl. V, Figs. 9–11), No. 30705.

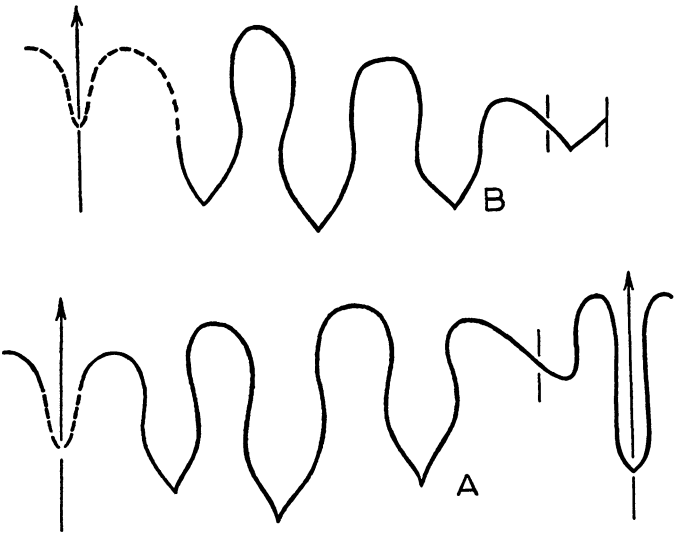


FIG. 12. Sutures of two species of *Merocanites*.

A—*M.* sp., based on a figured specimen (State Univ. Iowa, No. 1907—Pl. VI, Fig. 11); from Reeds Spring limestone, southwestern Missouri; × 3.

B—*M. compressus* (Sowerby); from the lower Viséan, southern Ireland; × 1½. Adapted from Foord and Crick.

Genus *Merocanites* Schindewolf

When Schindewolf (1922, p. 15) established this genus, he designated as its type species *Ellipsolites compressus* Sowerby of the lower Viséan of southern Ireland (and elsewhere in the British Isles and possibly continental Europe). Although both syntypes of that species are poorly preserved, Foord and Crick (1894, pp. 11–17, Pl. 1) carefully restudied them and concluded that they are conspecific with a septate specimen from essentially the same horizon and locality. These authors ascertained the nature of only the external suture of this specimen (Fig. 12B); but, as Schindewolf pointed

out in 1922, in typical forms the complete mature suture consists of ten lobes and ten saddles.

No representatives of this genus have heretofore been described from America. However, the collections that are now available to us for study contain two species of it from the Marshall sandstone of Michigan (Pl. VI, Figs. 9, 10; and Pl. VII, Figs. 5–14), one from the Reeds Spring limestone of Missouri (Pl. VI, Fig. 11), and one or two from the New Providence shale of Kentucky (as well as one from the Isle of Man).

From an examination of all these specimens and the published data in regard to the type species and similar forms, we have drawn up a concise diagnosis of the genus. Conch discoidal, coiled, with volutions that are compressed and flattened laterally (with lateral zones almost parallel), very broadly rounded ventrally, and slightly impressed dorsally. Umbilicus large and open and umbilical shoulders rounded. Body chamber at least half a volution in length. Test thin and marked only by fine growth lines which form shallow rounded ventral and lateral sinuses. Sutures consist of ten lobes and ten saddles; the lobes are for the most part pointed and spatulate and saddles more or less U-shaped.

Representatives of this genus have been found in the British Isles, Belgium?, Spain, Germany, and Soviet Russia (Kirghiz Steppes and Tien Shan), and in North America in Missouri,[1] Kentucky, and Michigan. In all of these many localities the age is, presumably, not greatly different and is early Osage or Viséan.

Merocanites houghtoni (Winchell)

(Pl. VI, Figs. 9, 10; Pl. VII, Figs. 10–14)

Goniatites Houghtoni Winchell, 1862*a*, Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, p. 363.
Prolecanites Houghthoni Karpinsky, 1896, Acad. Imp. Sci. St.-Pétersbourg, Bull., T. 4, pp. 183, 191.
Prolecanites houghtoni Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 29, 53–54.

From the original description it is impossible to determine whether Winchell based this species on one or several specimens. The collections contain five specimens labeled syntypes. They coincide in general but not in detail with his description of the species and all of them belong to it. Accordingly, we illustrate the best of the lot and continue to regard it as a syntype (Pl. VI, Figs. 9, 10). In addition to the five specimens just mentioned, all of which are from the type section of the Marshall sandstone, we have seven topotypes and eight specimens which come from three other

[1] Only a single specimen that is referable to *Merocanites* is known from Missouri (Fig. 12A; Pl. VI, Fig. 11). It is a crushed etched portion of one septate whorl preserved in gray limestone. Its conch is a little less than half as wide as high.

Michigan localities. Two of the last are much more nearly complete than any of the labeled syntypes. The following description of the species is based upon a careful examination of all this material.

Conch discoidal as whorls are very strongly compressed and flattened

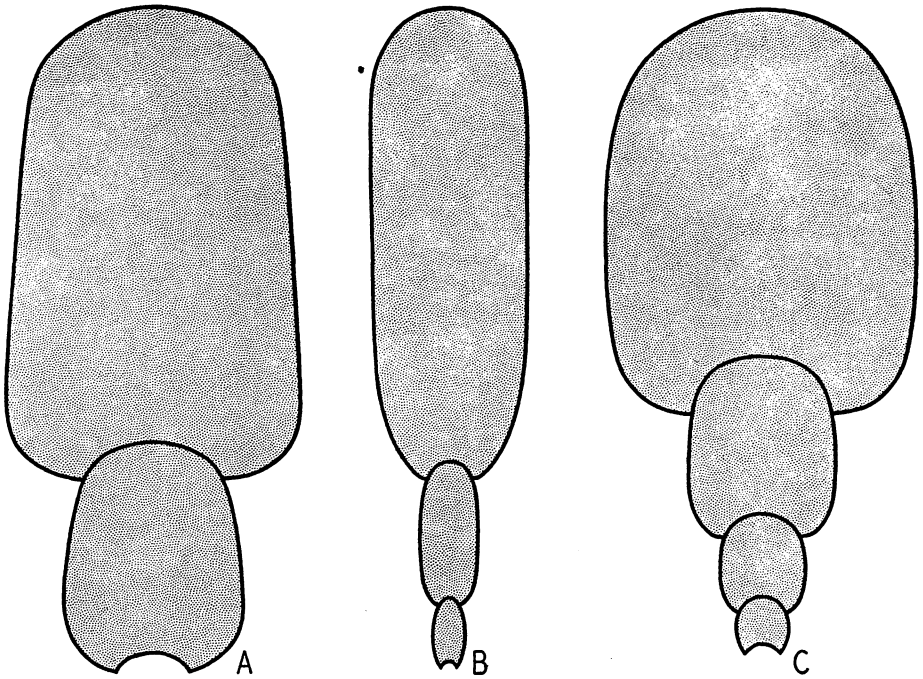


FIG. 13. Cross sections of one species of *Protocanites* and two of *Merocanites*. For sutures of these three species see Figures 15, 14, and 16.

A—*P. lyoni* (Meek and Worthen), the type species of the genus, based on a topotype (State Univ. Iowa, 13890); from Rockford limestone, Rockford, Indiana; × 3.

B—*M. houghtoni* (Winchell), based on the figured topotype, No. 30706*b* (Pl. VII, Fig. 14); from Marshall sandstone, Marshall, × 3.

C—*M. marshallensis* (Winchell), based on a figured syntype, No. 26685*a* (Pl. VII, Fig. 9), and an unfigured syntype, No. 26685*b*; both from Marshall sandstone, Marshall; × 4.

laterally (Fig. 13B). The complete phragmocone probably attained a diameter of at least 125 mm. The conch of one of the figured specimens (Pl. VII, Figs. 10, 11) appears to be practically free from distortion; near its adoral end it is about 20 mm. high and 7 mm. wide, and the dorsal impressed zone is less than 1 mm. deep. The ventral zone of the conch is rounded, but in some instances the internal mold is flattened ventrally and

more or less subangular ventrolaterally. None of the specimens retain traces of growth lines or more than small portions of the body chamber.

In late adolescence each suture has eight pointed lobes and eight rounded saddles (Fig. 14A). On each side of the conch an additional lobe is then developed just outside the umbilical seam. Therefore, at full maturity each suture consists of a rather small V-shaped ventral lobe and on either side of it, three deep pointed-spatulate external lobes, separated by similar but rounded saddles. These are followed by a low asymmetrical lobe on the umbilical zone and a narrow U-shaped internal lateral saddle which extends to a deep narrow compressed-V-shaped dorsal lobe. The ventral lobe is relatively shallow and the second lateral lobe is the deepest.

Remarks.—Winchell stated that *Merocanites houghtoni* is close to *Goniatites henslowi* Sowerby = *Ellipsolites compressus* Sowerby, the type species of *Merocanites*. The sutures of that species are similar to those of the one under consideration, but the conch in *M. houghtoni* is much narrower. In *M. marshallensis,* which occurs in direct association with *M. houghtoni,* the conch is even wider than that of the type species, and the ventral lobe of its suture is deep, spatulate, and extremely attenuate, rather than V-shaped (cf. Figs. 14E and 16D). The ventral lobe of the suture in *M. houghtoni* is very similar to that of the type species of *Protocanites, P. lyoni* (Meek and Worthen)—cf. Figs. 14 A–E and Fig. 15. This resemblance may mean that *M. houghtoni* arose more nearly directly from typical *Protocanites* than did *M. marshallensis*. In both Michigan species, the ventral lobes assume their characteristic shape during early ontogenetic development.

Occurrence.—Marshall sandstone at Marshall, Calhoun County, and Burnt Cabin Point, Huron County, Michigan; and drift from the same formation in gravel pits about 6 miles southeast of Jackson and 1 mile south of Waterloo, Jackson County, Michigan. The species is not particu-

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FIG. 14. Ontogenetic development of sutures in *Merocanites houghtoni* (Winchell); based largely on a single specimen, No. 30709, from a glacial boulder of Marshall sandstone about 1 mile south of Waterloo, but supplemented by two others from comparable sources. →

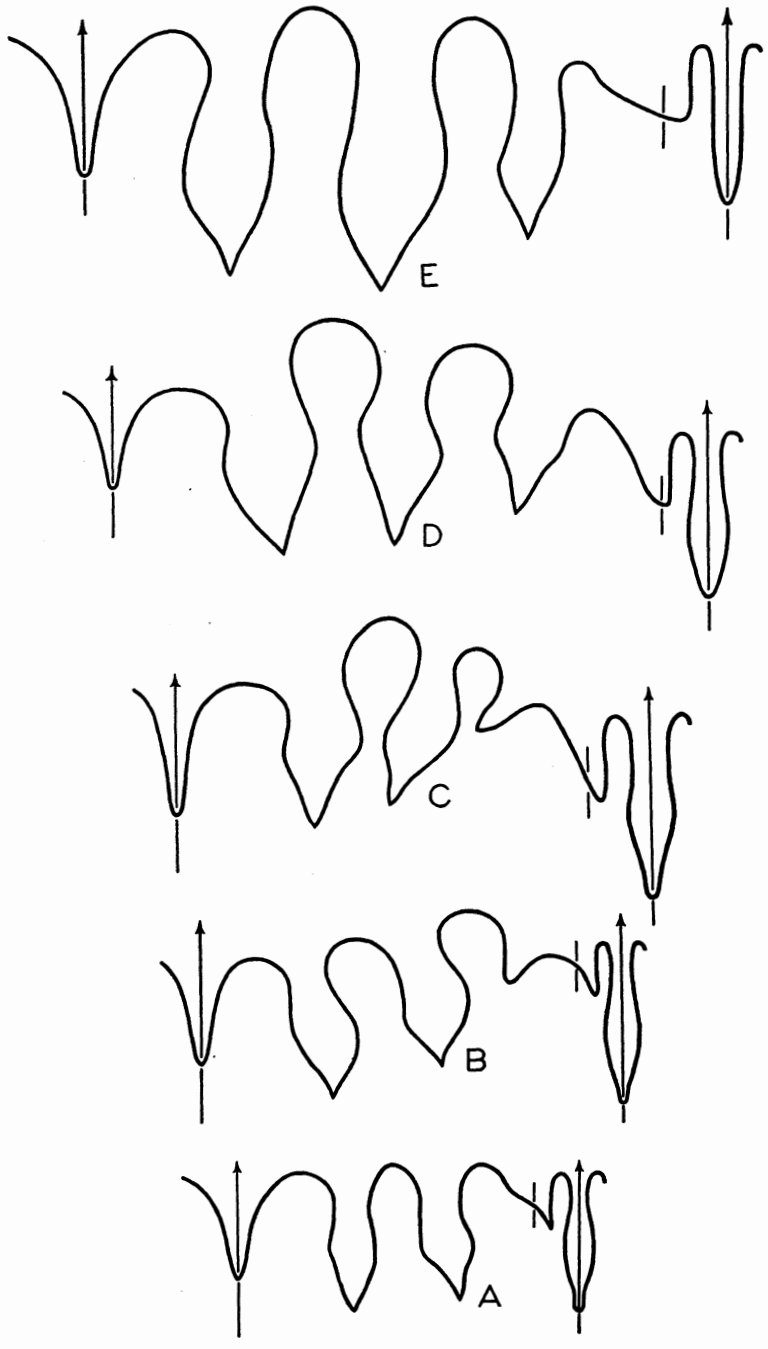
A—Near mid-length of first volution of phragmocone, where conch is about 5 mm. high; × 8.

B—Near adoral end of first volution, where conch is about 7 mm. high; × 7.

C—Near mid-length of second volution, where conch is about 10 mm. high; × 7.

D—Near adoral end of second volution, where conch is about 17 mm. high; × 3.

E—Near mid-length of third volution, where conch is about 25 mm. high; × 4.


E
D
C
B
A

larly rare at Marshall and in the gravel pits near Jackson and Waterloo, but only one specimen (Pl. VII, Fig. 13) is known from Burnt Cabin Point.

Types.—Syntype (Pl. VI, Figs. 9, 10), No. 26707*a*, Marshall; syntypes (three unfigured), No. 26707*b*, Marshall; hypotype (Pl. VII, Figs. 10, 11), No. 30706*a*, Marshall; hypotype (Pl. VII, Fig. 14), No. 30706*b*, Marshall; hypotype (Pl. VII, Fig. 13), No. 30707, Burnt Cabin Point, Huron County; hypotype (Pl. VII, Fig. 12), No. 30708, near Jackson; hypotypes (three specimens serving as basis for Figure 14), No. 30709, near Waterloo; hypotypes (five unfigured), No. 30710, Marshall; hypotypes (three unfigured), No. 30711, near Waterloo.

FIG. 15. *Protocanites lyoni* (Meek and Worthen), the type species of the genus. Mature suture, based on a topotype (State Univ. Iowa, No. 9545); from Rockford limestone, Rockford, Indiana; × 3.

Merocanites marshallensis (Winchell)

(Pl. VII, Figs. 5–9)

Goniatites Marshallensis Winchell, 1862*a*, Amer. Journ. Sci. and Arts, 2d Ser., Vol. 33, pp. 362–63.

Goniatites Marshallensis Winchell, 1865, Philadelphia Acad. Nat. Sci., Proc., 1865, p. 133.

Goniatites Marshallensis Winchell, 1869, Amer. Philos. Soc., Proc., Vol. 11, p. 67.

Goniatites Marshallensis Winchell, 1870*a*, Amer. Philos. Soc., Proc., Vol. 11, p. 258.

Goniatites Marshallensis Winchell, 1870*b*, Sketches of Creation ..., p. 119, Fig. 53*c*.

Prolecanites Marshallensis Karpinsky, 1896, Acad. Imp. Sci. St.-Pétersbourg. Bull., T. 4, pp. 183, 191.

Prolecanites marshallensis Smith, 1903, U. S. Geol. Surv., Monogr. 42, pp. 13, 29, 55–56.

Although very abundant in the Marshall sandstone, especially at the type locality, most of the specimens of this species are fragments. The syntype illustrated is the one that seems to be the best (Pl. VII, Fig. 9). The conch, which consists of several volutions, is rather thickly discoidal as the whorls are distinctly higher than wide and are flattened laterally, with nearly parallel flanks. The phragmocone probably attained a diameter

of at least 75 mm. The length of the body chamber has not been ascertained. The test is thin and smooth, or almost so. No trace of surface markings can be discerned on any of the many specimens, most of which are internal molds.

In adolescence the sutures pass through a *Protocanites* stage of development (Fig. 16A) and then they add an additional lobe (on each side of conch) just outside the umbilical seam (as noted by Winchell, 1869, p. 67). The fully mature suture consists of ten pointed lobes and ten rounded saddles. All of the lobes, except those on the umbilical zones, and most of the saddles are spatulate. The ventral lobe is very acuminate, the second lateral lobe is the deepest, and the dorsal lobe (as well as the internal saddles) are very narrow. Details of the sutures during ontogenetic development are elucidated in the illustrations (Figs. 16 A–D) better than they can be described.

Remarks.—Winchell compared *M. marshallensis* to several Lower Carboniferous British species, but it is not particularly close to any of them. It is readily differentiated from *M. houghtoni,* with which it occurs in direct association, by the shape of ventral lobe and by its much wider conch (see Figs. 13B, 13C, 14E, and 16D). The acuminate ventral lobe of *M. marshallensis,* which is unique among all of the merocanitoids known to us, is perhaps the most distinctive character of the species.

Occurrence.—Marshall sandstone at the following localities in southern Michigan: Marshall, Calhoun County (some 50 specimens, including the syntypes); Stony Point quarry, Hillsdale County (3 specimens); Napoleon Cut (2 specimens) and Columbia (1 specimen), Jackson County; and Grindstone City (3 specimens) and Flat Rock Point (1 specimen), Huron County. Winchell indicated that this species occurs also in the same formation at Moscow, Hillsdale County, and at Battle Creek, Calhoun County, and in the Waverly group at "Weymouth, Medina County, Ohio, 80 feet below the conglomerate" and in the same group at Newark, Licking County, Ohio. We have not seen any representatives of the species from these last four localities, and its occurrence in Ohio needs confirmation.

Types.—Hypotype (unfigured), No. 2444, Grindstone City, Huron County; hypotype (unfigured), No. 2449, probably Grindstone City; hypotype (infigured), No. 2450, Grindstone City; syntype (Pl. VII, Fig. 9), No. 26685*a,* Marshall; syntype (unfigured), No. 26685*b,* Marshall; syntypes (thirteen, unfigured), No. 26685*b,* Marshall; hypotype (unfigured), No. 27034; Flat Rock Point, Huron County; hypotypes (two unfigured), No. 27040, Napoleon Cut, Jackson County; hypotype and homeotype of Winchell (unfigured), No. 27042, Columbia, Jackson County; hypotypes (three, unfigured), No. 30712, Stony Point Quarry, Hillsdale County;

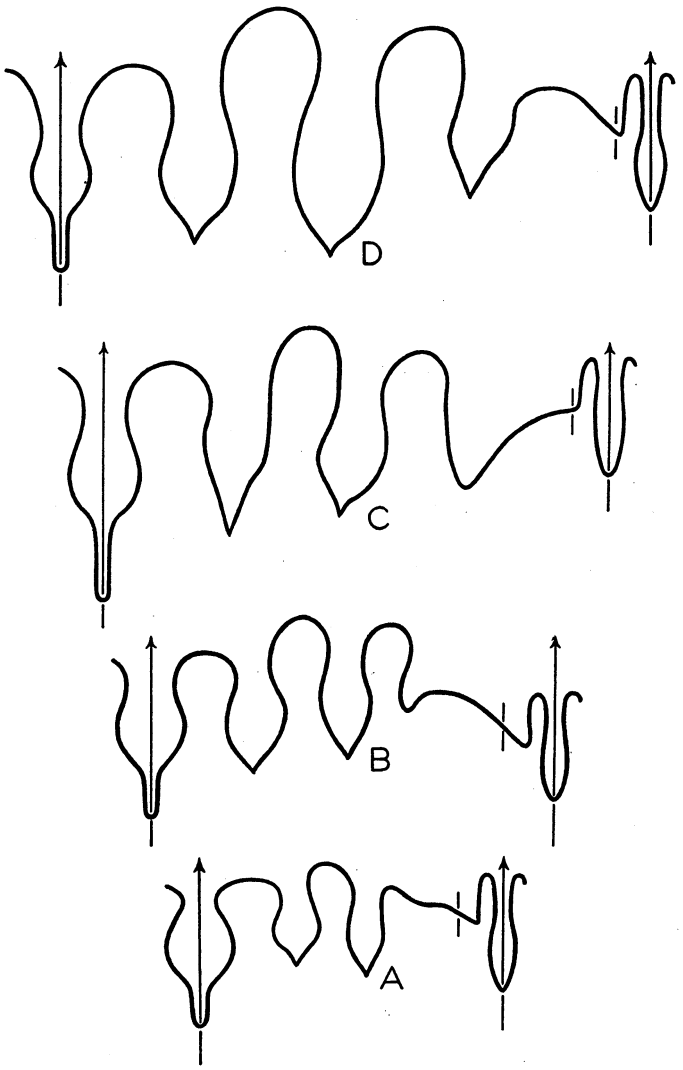


FIG. 16. Ontogenetic development of sutures of *Merocanites marshallensis* (Winchell), based on two specimens from a 6-inch bed in the Marshall sandstone at Marshall. A and B are from a single individual; C and D are from the figured syntype, No. 26685*a* (Pl. VII, Fig. 9).

A—Where conch is some 2 mm. high; × 10.
B—Where conch is some 6 mm. high (about 1½ volutions orad of A); × 5.
C—Where conch is some 7 mm. high; × 5.
D—Where conch is some 13 mm. high (about 1 volution orad of C); × 4.

hypotype (Pl. VII, Figs. 5, 6) No. 30713*a*, Marshall; hypotype (Pl. VII, Figs. 7, 8), No. 30713*b*, Marshall; hypotypes, (thirty-four, unfigured) No. 30714, Marshall.

ADDENDUM

Several months after this study was completed, the Ohio Division of Geological Survey published a large volume on the "Mississippian formations of central and southern Ohio" and their faunas. That report is by the late Jesse Earl Hyde, who died in 1936, but it was edited by Mildred Fisher Marple. It contains accounts of a considerable number of cephalopods that are related to Michigan forms. Almost all of the nautiloids (4 species of orthoceracones) are from the Byer member of the Logan formation at Sciotoville, and the great majority of the goniatites (7 species) are also from the Byer. One of the same nautiloid and two of the same goniatite species occur also in the Cuyahoga formation, which has yielded an additional goniatite species.

The senior author of the present report plans to undertake, in collaboration with Walter C. Sweet, a restudy of all of the cephalopods known from the Mississippian of Ohio. In that work detailed comparisons will of course be made with the Michigan faunas, and therefore it seems best not to attempt at this time a discussion of the relationship of the forms under consideration with those described in the Hyde-Marple volume.

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PLATES

EXPLANATION OF PLATE I

PAGE

Beyrichoceras allei (Winchell) 144

FIGS. 1, 2. Typical specimen, No. 2936*a*, from Coldwater shale, Branch County. × 1.

Kazakhstania americana Miller and Garner, sp. nov. 129

FIG. 3. Lateral view of paratype, No. 30693*b*, from Marshall sandstone, Marshall. × 3.

Gattendorfia andrewsi (Winchell) 121

FIGS. 4–6. Two syntypes (No. 26794), from Waverly group, Newark, Ohio. Figures 4, 5 are of one specimen. All × 1½.

Imitoceras romingeri (Winchell) 132

FIGS. 7, 8. Holotype, No. 13979, from Marshall sandstone, Marshall. × 1½.

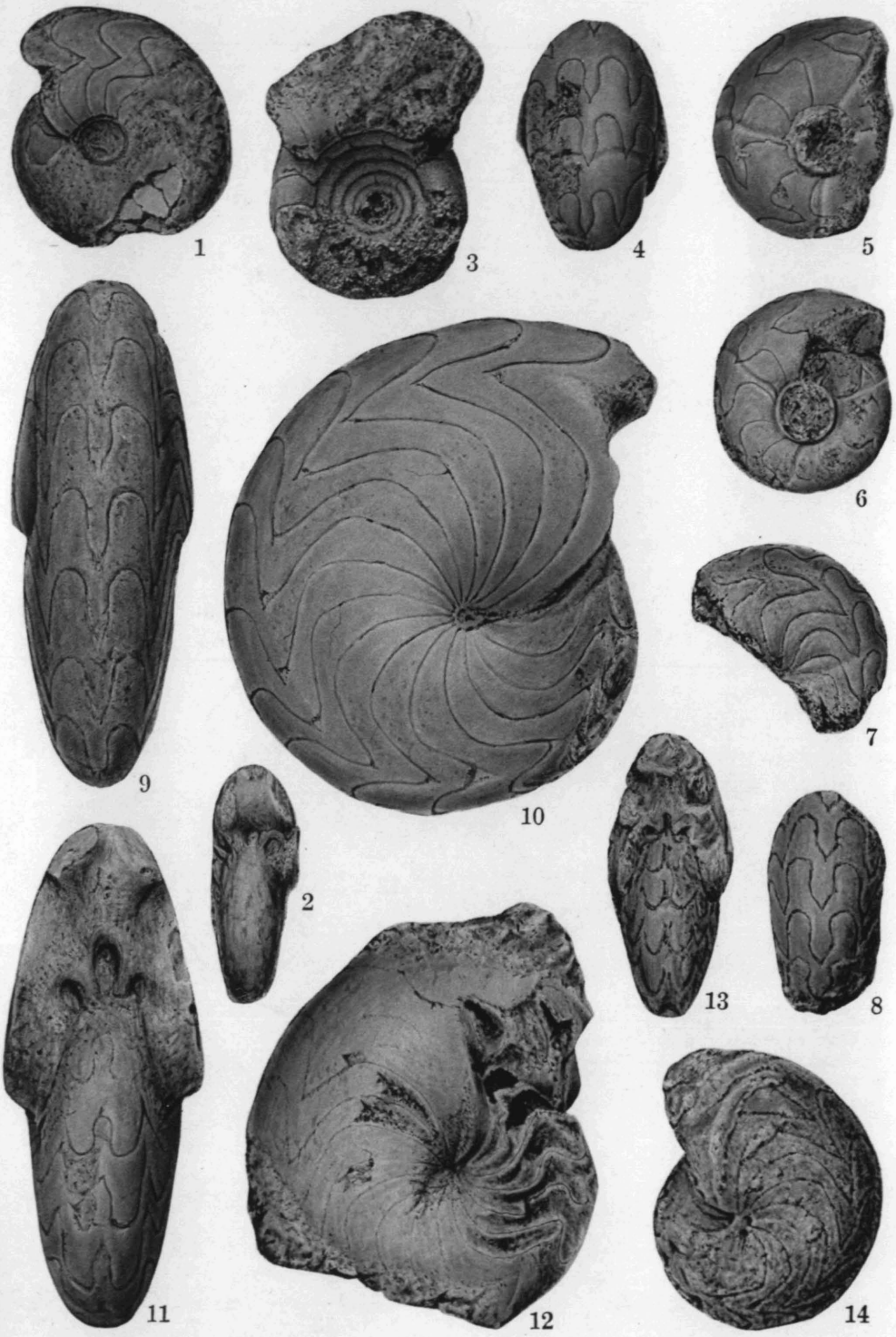
Imitoceras rotatorium (de Koninck) 133

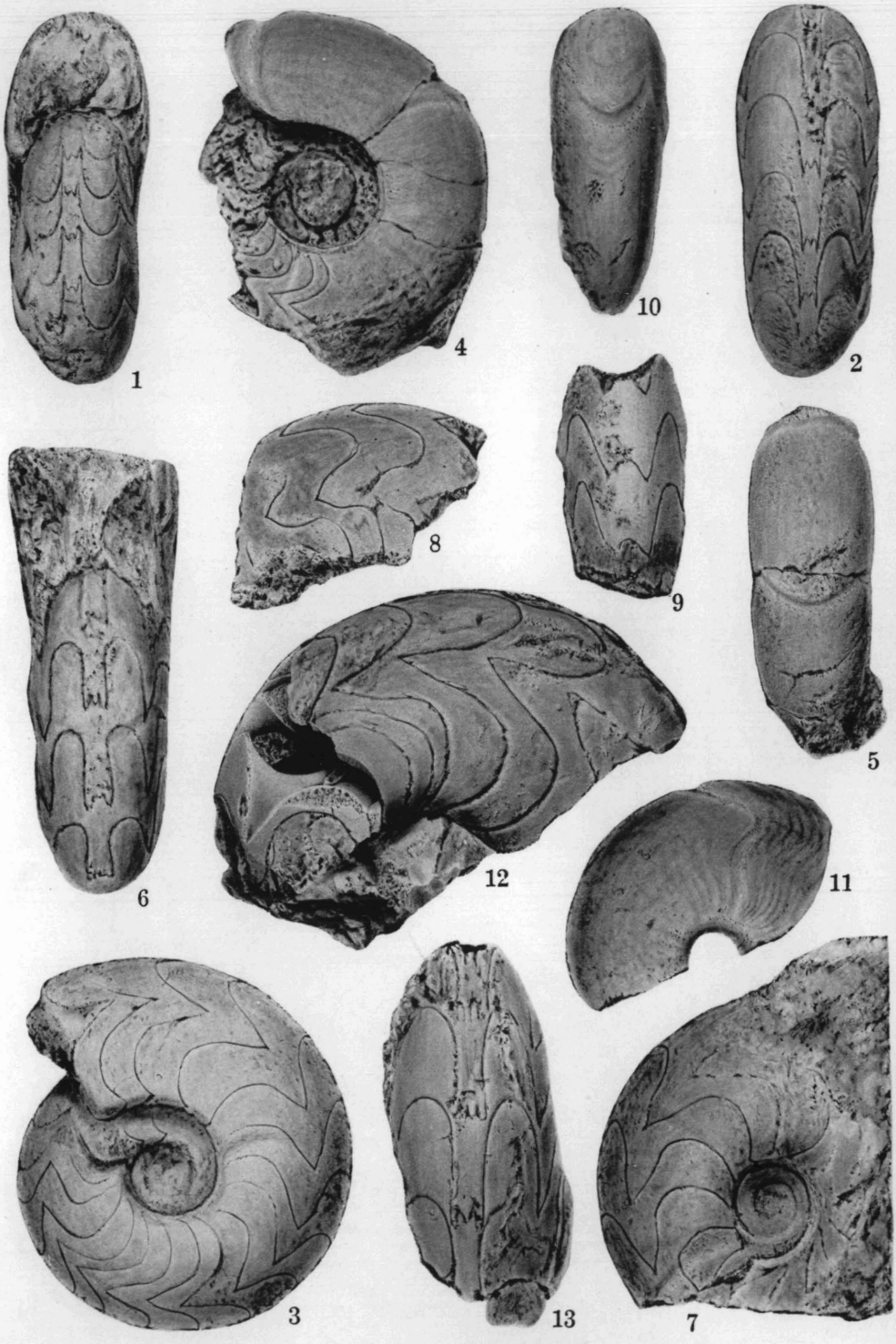
FIGS. 9–11. Large, well-preserved phragmocone, No. 13882 (State Univ. Iowa), from Rockford limestone, Rockford, Indiana. × 1.

FIG. 12. Comparable specimen, No. 14196, from Marshall sandstone, Grindstone City. × 1.

FIGS. 13, 14. Early-mature individual, No. 30694, Marshall sandstone, Burnt Cabin Point. × 1.

PLATE I

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EXPLANATION OF PLATE II

PAGE

Münsteroceras oweni (Hall) 138

FIGS. 1–3. Typical specimen, No. 13886 (State Univ. Iowa), from Rockford limestone, Rockford, Indiana. × 1.

FIGS. 4, 5. Comparable individual, No. 30697, from Marshall sandstone, Burnt Cabin Point. × 1.

FIGS. 6, 7. Hypotype, No. 30696*b*, from Marshall sandstone, Burnt Cabin Point. × 2.

Beyrichoceras allei (Winchell) 144

FIGS. 8, 9. Septate fragment, No. 30702*a*, from Marshall sandstone, Marshall. × 1½.

FIGS. 10, 11. Part of body chamber, No. 2936*b*, from Coldwater shale, Coldwater. × 1½.

Münsteroceras pergibbosum Miller and Garner, sp. nov. 140

FIGS. 12, 13. Holotype, No. 30701*a*, from Coldwater shale, near Coldwater. × 1.

EXPLANATION OF PLATE III

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Beyrichoceras allei (Winchell) 144

FIGS. 1, 2. Hypotype, No. 30703*a*, from Coldwater shale, Coldwater. × 2.

FIG. 3. Hypotype, No. 30703*b*, from Coldwater shale, Coldwater. × 1½.

FIGS. 4, 5. Comparable individual, No. 30702*b*, from Marshall sandstone, Marshall. × 1.

Imitoceras rotatorium (de Koninck) 133

FIG. 6. The specimen, No. 13978, on which Winchell based his species *"Goniatites propinquus,"* from Marshall sandstone, vicinity of Pointe Aux Barques. × 1½.

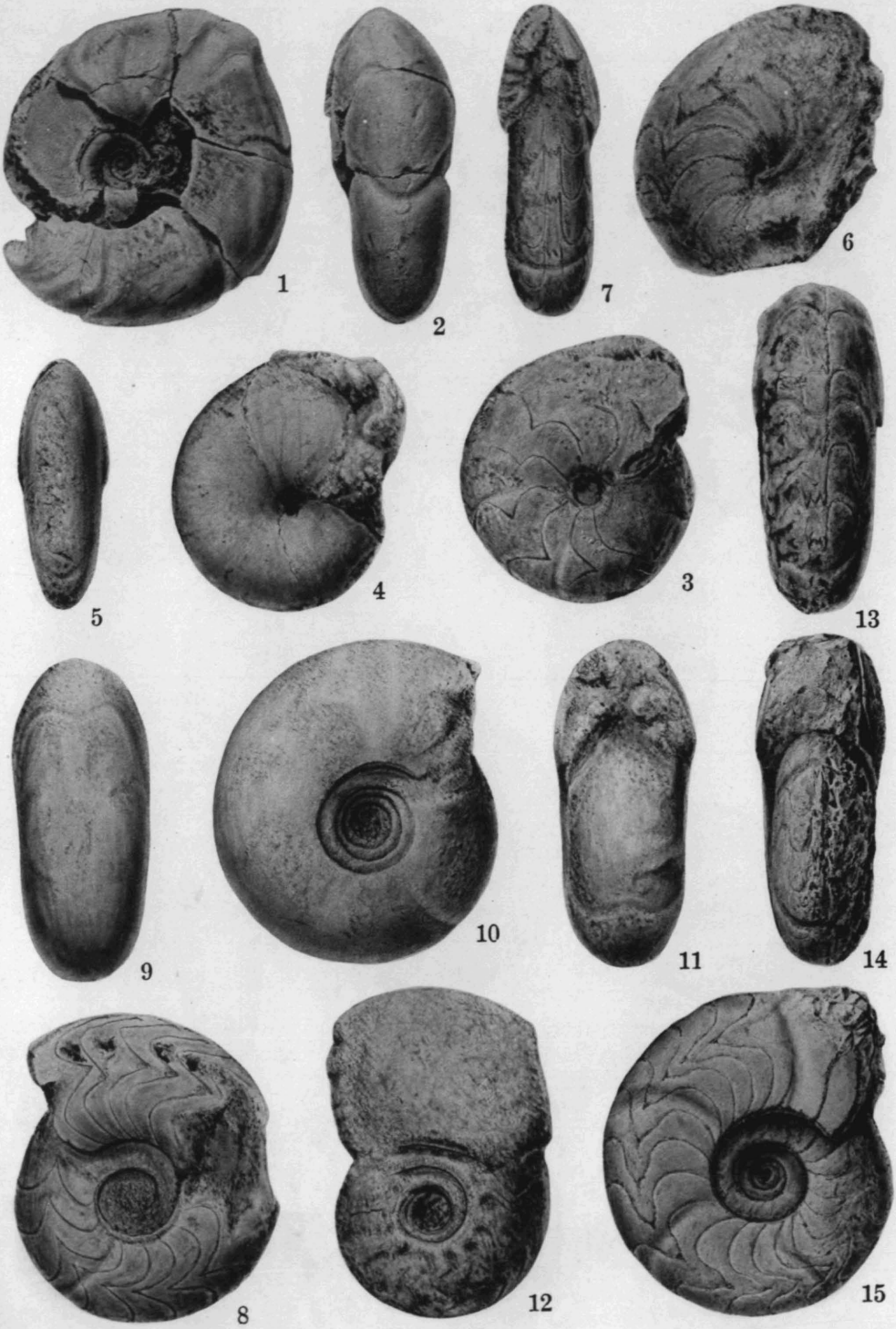
Münsteroceras oweni (Hall) 138

FIGS. 7, 8. Hypotype, No. 2413, from Marshall sandstone, near Pointe Aux Barques. × 1.

FIGS. 9–11. Hypotype, No. 2442, from Marshall sandstone, near Pointe Aux Barques. × 1½.

FIG. 12. Hypotype, No. 21970, from Marshall sandstone, near Pointe Aux Barques. × 1.

FIGS. 13–15. Hypotype, No. 30696*a*, from Marshall sandstone, Burnt Cabin Point. × 1.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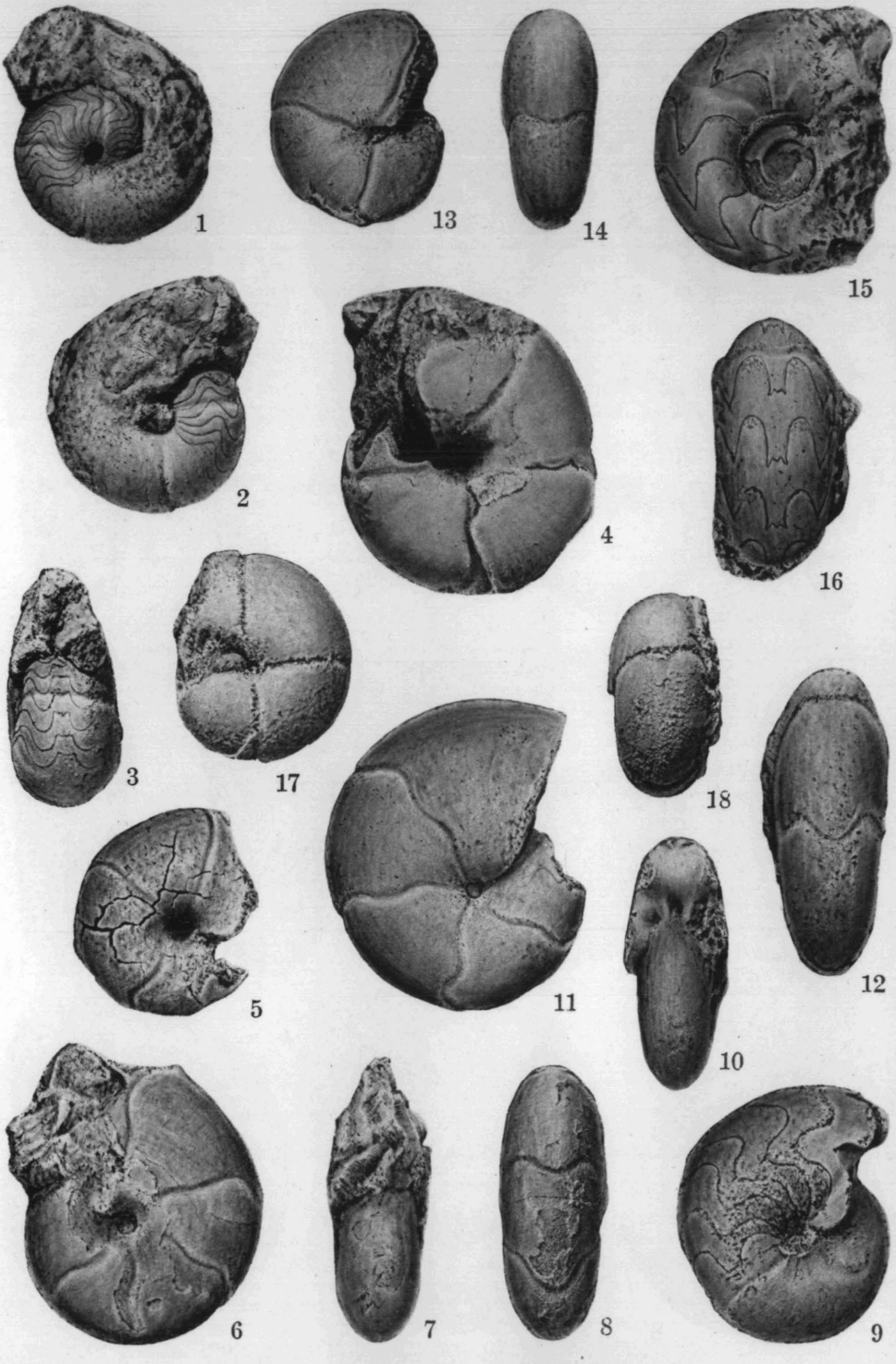
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EXPLANATION OF PLATE IV

Beyrichoceras allei (Winchell) 144

FIGS. 1–3. Hypotype, No. 3630*a*, from Coldwater shale, 1¼ miles S.W. of Coldwater. × 5.

FIG. 4. Hypotype, No. 3630*b*, from Coldwater shale, 1¼ miles S.W. of Coldwater. × 5.

FIG. 5. Syntype, No. 15350, from Coldwater shale, 1¼ miles S.W. of Coldwater. × 5.

FIGS. 6–8. Hypotype, No. 30703*c*, from Coldwater shale, 1¼ miles S.W. of Coldwater. × 2.

FIGS. 9, 10. Holotype, No. 22045, from Marshall sandstone, Marshall. × 2.

FIGS. 11, 12. Hypotype, No. 26821*a*, from Marshall sandstone, Germain's quarry, Hillsdale. × 3.

FIGS. 13, 14. Hypotype, No. 26821*b*, from same formation and locality as the preceding. × 3.

Münsteroceras oweni (Hall) 138

FIGS. 15, 16. Hypotype, No. 30696*c*, from Marshall sandstone, Burnt Cabin Point. × 1½.

Münsteroceras? pygmaeum (Winchell) 142

FIGS. 17, 18. Smaller syntype, No. 26708*a*, from Marshall sandstone, Battle Creek. × 5.

EXPLANATION OF PLATE V

PAGE

Gattendorfia? shumardiana (Winchell) 124

FIG. 1. Holotype, No. 13977, from Marshall sandstone, Pointe Aux Barques. × 1½.

Beyrichoceras allei (Winchell) 144

FIGS. 2, 3. Hypotype, No. 26821*c*, from Marshall sandstone, Hillsdale. × 2.

FIGS. 4, 5. Hypotype, No. 30702*c*, from Marshall sandstone, Marshall. × 1½.

FIG. 6. Hypotype, No. 30702*d*, from same formation and locality as No. 30702*c*. × 1.

FIG. 7. Specimen, No. 27048*a*, from Marshall sandstone, Battle Creek. × 2.

FIG. 8. Artificial internal mold, No. 30704, from Coldwater shale, near Coldwater. × 1.

FIG. 9–11. Hypotype, No. 30705, Marshall sandstone, Holland. × 1.

PLATE V


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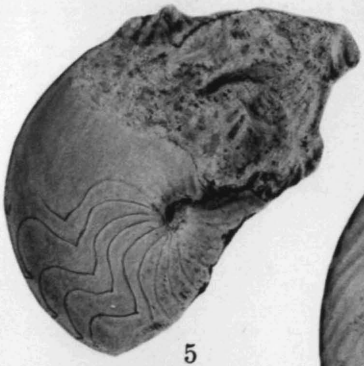
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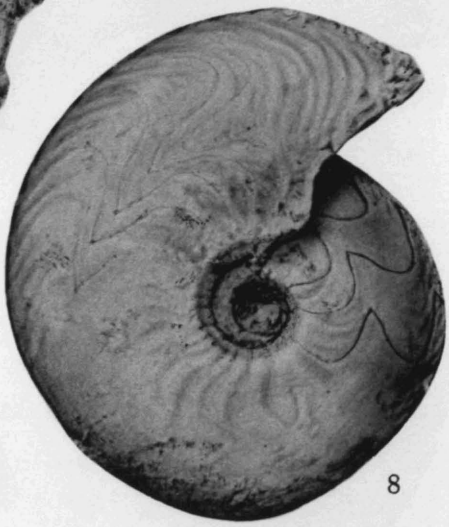
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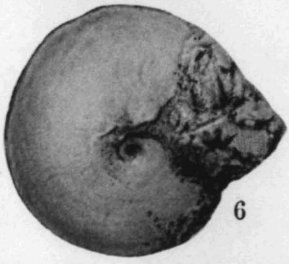
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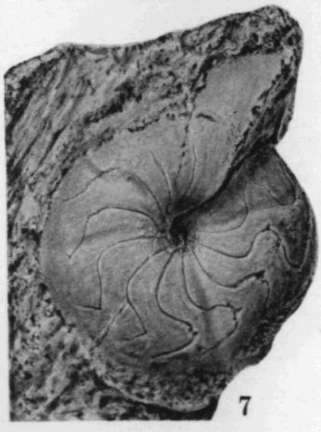
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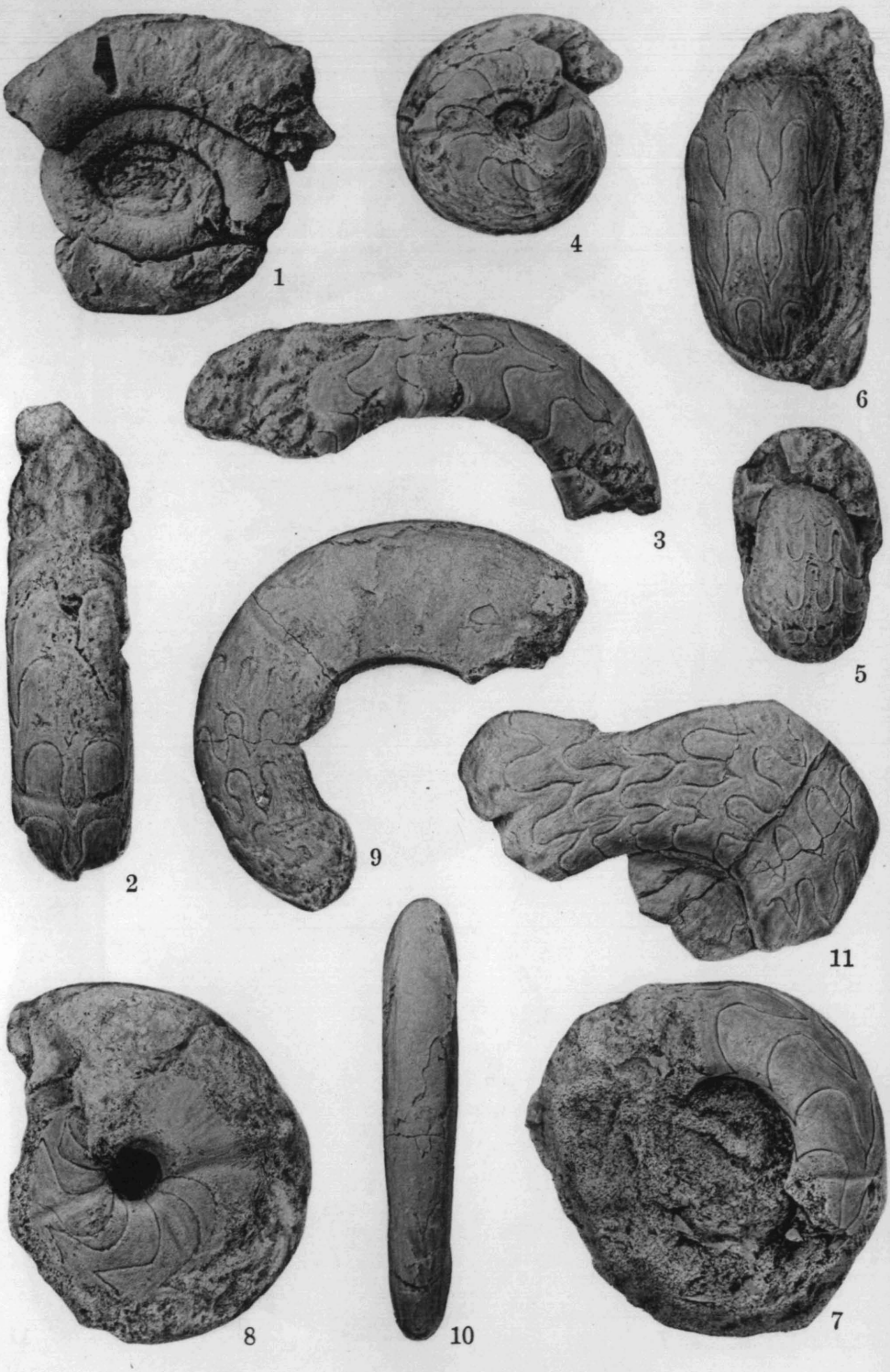
PLATE VI



EXPLANATION OF PLATE VI

PAGE

Kazakhstania karagandaensis (Librovitch) 129

FIG. 1. Holotype of type species of *Kazakhstania,* from early Lower Carboniferous, Ak-Bas-tau Mountains in north Kazakhstan. After Librovitch. × 1.

Kazakhstania americana Miller and Garner, sp. nov. 129

FIGS. 2, 3. Holotype, No. 30693*a,* from Marshall sandstone, Marshall. × 2½.

Münsteroceras oweni (Hall) 138

FIGS. 4, 5. Immature specimen, No. 30698*a,* showing both internal and external sutures, from Marshall sandstone, Burnt Cabin Point. × 3.

Gattendorfia stummi Miller and Garner, sp. nov. 125

FIGS. 6, 7. Holotype, No. 30691, from Marshall sandstone, Marshall. × 2.

Gattendorfia ohiensis (Winchell) 122

FIG. 8. The better syntype, No. 26798, from Waverly group at or near Newark, Ohio. × 1½.

Merocanites houghtoni (Winchell) 150

FIGS. 9, 10. The best of the syntypes, No. 26707*a,* from Marshall sandstone, Marshall. × 2.

Merocanites sp. 150

FIG. 11. Moderately well-preserved fragment, No. 1907 (State Univ. Iowa), from the Reeds Spring limestone in the SW.¼SW.¼NE.¼ sec. 27, T. 22 N., R. 27 W., on Highway 112 in Roaring River State Park, Barry County, Missouri. × 1.

EXPLANATION OF PLATE VII

PAGE

Münsteroceras pergibbosum Miller and Garner, sp. nov. 140

FIGS. 1, 2. Paratype, No. 30701*b*, from Coldwater shale, near Coldwater. × 1.

Gattendorfia? sp. 126

FIGS. 3, 4. Michigan specimen of uncertain affinities, No. 30692, from same horizon and locality as preceding. × 1.

Merocanites marshallensis (Winchell) 154

FIGS. 5, 6. Specimen, No. 30713*a*, from Marshall sandstone, Marshall. × 1.

FIG. 7. Specimen, No. 30713*b*, from Marshall sandstone, Marshall. × 1.

FIG. 8. Adoral half of specimen in Figure 7. × 1.

FIG. 9. Syntype, No. 26685*a*, from Marshall sandstone, Marshall. × 1.

Merocanites houghtoni (Winchell) 150

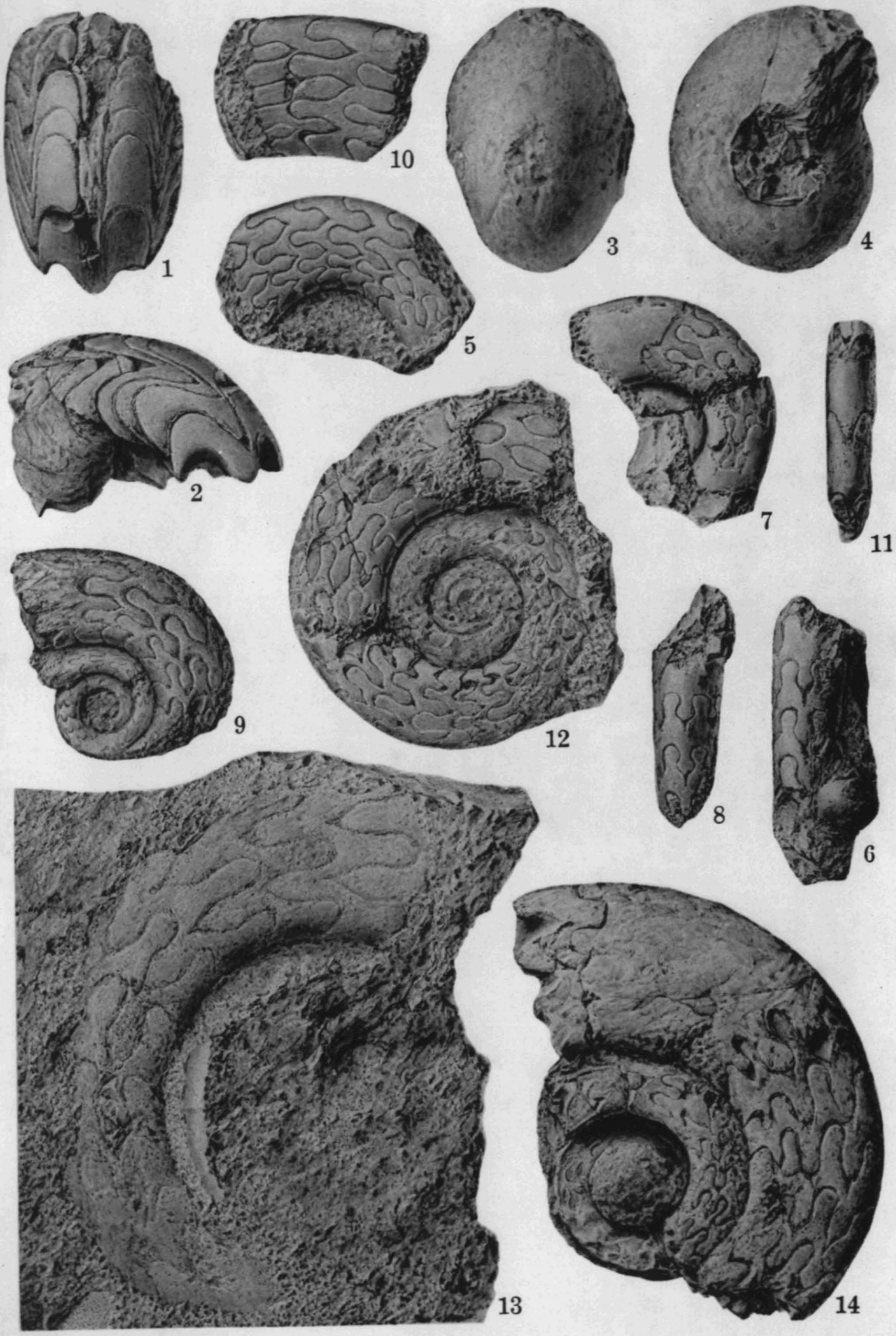
FIG. 10, 11. Specimen, No. 30706*a*, from Marshall sandstone, Marshall. × 1.

FIG. 12. Specimen, No. 30708, from Marshall sandstone, gravel pit 6 miles SE. of Jackson. × 1.

FIG. 13. Specimen, No. 30707, Marshall sandstone, Burnt Cabin Point. × 1.

FIG. 14. Hypotype, No. 30706*b*, from Marshall sandstone, Marshall. × 1.

PLATE VII



COMPREHENSIVE INDEX TO PARTS I, II, AND III*

* Roman numerals refer to the respective parts. Figures in boldface indicate detailed descriptions.