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CARPOID ECHINODERMS FROM THE SILURIAN AND DEVONIAN OF AUSTRALIA

By

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March 1, 1960

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TEXT-FIGURES

CARPOID ECHINODERMS FROM THE SILURIAN AND DEVONIAN OF AUSTRALIA

Edmund D. Gill

and

Kenneth E. Caster

ABSTRACT

The Silurian and Devonian carpoid echinoderms described in this paper are the first representatives of the class to be recorded from Australia. A new genus and species of the Carpoidea Mitrata, *Victoriacystis wilkinsi* (Upper Silurian, Lower Silurian?, and Lower Devonian?) are diagnosed. The Carpoidea Soluta genus *Rutroclypeus* (type species *R. junori* Withers), formerly assigned to the Xiphosura, is reanalyzed and two new species, *R. victoriae* and *R. withersi*, (Lower Devonian all) described. The Rhenish Lower Devonian *Dendrocystites globulus* Dehm is provisionally referred to the genus *Rutroclypeus*, and definitely to the new family based thereon. A new classification of the Carpoidea is proposed: two new subclasses, Homostelea and Homoiostelea are defined, and two new superorders of the Homoiostelea, Stylophora and Astylophora, proposed. In the order Soluta two new families, Iowacystidae and Rutroclypeidae are diagnosed and the new genus of the Dendrocystitidae, *Heckericystis* (type species *Dendrocystites kuckersianus* Hecker), from the Russian Ordovician, proposed. Certain new names required by the Rules of Zoological Nomenclature are introduced. The distribution of the Carpoidea is considered, and the significance of the Australian forms for paleogeography is assessed.

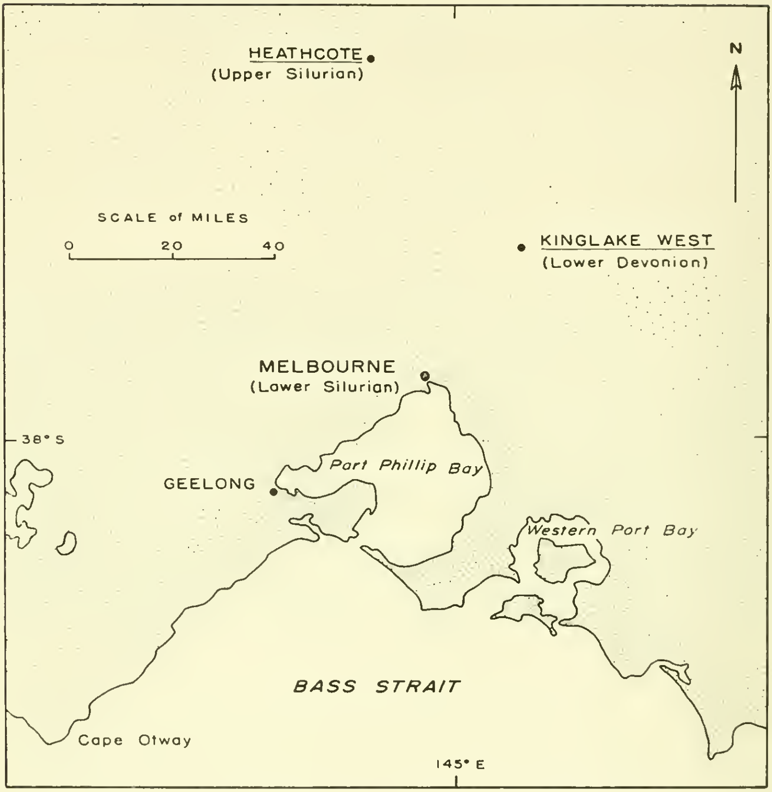
INTRODUCTION

Les Hétérostelea constituent un groupe étrange, très hétérogène.—Cuénot

This is the first account of carpoid echinoderms from the Australasian region, and indeed only two previous occurrences have been reported from the Southern Hemisphere, both from the Lower Devonian, viz. the Bokkeveld beds of South Africa (Cowper Reed, 1925; Rennie, 1936; Caster, 1956); and the Paraná beds of Brazil (Caster, 1954; 1956). *Victoriacystis*, new genus, is the first carpoid of Silurian age to be described from the Southern Hemisphere.

The Australian carpoid fauna now presented consists of:

SILURIAN	*Victoriacystis wilkinsi*, new genus and new species *Victoriacystis* aff. *wilkinsi*
DEVONIAN	*Victoriacystis* aff. *wilkinsi* *Rutroclypeus junori* Withers, 1933 *Rutroclypeus victoriae*, new species *"Rutroclypeus" withersi*, new species



Text-fig. 1.—Map of a part of the State of Victoria, Australia, showing the localities from which carpoid echinoderms have been collected.

All these fossils come from the State of Victoria (see text-figure 1), and search through collections from other parts of Australia failed to reveal any further material. Accompanying the carpoids are many other echinoderms—cystoids, blastoids, crinoids, machaerideans, starfish, and brittle stars.

Rutroclypeus was originally described as a King Crab, but later F. W. Whitehouse (1941), fresh from his study of primitive Cambrian echinoderms in Queensland, recognized *R. junori* as a carpoid. The specimen described herein as *R. victoriae* holotype was recorded by Gill, (1947) as *Rutroclypeus* sp.

CLASSIFICATION

Ces sont des animaux marins benthiques si singuliers, qu 'on les croirait originaires d'une autre planète.—Chauvel from Lameere.

The carpoids embrace some of the most enigmatic organisms that have lived on earth. Among the echinoderms they constitute an assemblage of archaic departures from the better known routes of evolution and before their extinction in the Middle Paleozoic demonstrated an amazing diversity of organizational plans. Their rarity as fossils has undoubtedly militated against the recognition and acceptance of their higher categorical significance in echinoderm classification. Yet when confronted by a demonstrably unique and basically new scheme of organization, even though a paucity of material is at hand, there is much to be said for pointing up the evolutionary import of the novelty by creating the taxonomic structure seemingly required.

As currently conceived, the Carpoidea may be considered as a natural class of Echinodermata, albeit not nearly so close-knit as most other classes of the phylum. In this respect they are most like the Cystoidea, if in truth this latter be a natural grouping. A flattish theca seems to be the carpoid prototype, in keeping with their early exploration of the "flat-fish" niche of marine ecology. Their other common trait is the differentiated tail or stele (heterostele), in the morphogenesis of which several evolutionary lines were followed.

The Carpoidea are exceptional among echinoderms in showing no pentaradial symmetry. Bilateral organization, rather than radial symmetry is general and no doubt correlates with the eleutherozoic condition of all known carpoids. From the evolutionary viewpoint they are an illustration of seemingly profitless experimentation; despite the many morphologic changes rung on the organization of the Middle Cambrian prototypes, none of the mutational energy lead to numerical success at any time, or indeed to survival beyond the Lower Devonian.

Jaekel (1900) proposed the Carpoidea as a separate class of the Echinodermata to embrace his orders Heterostelea and Eustelea. Bather (1900), on the other hand, considered the genera involved in Jaekel's new class as aberrant representatives only of Haeckel's (1896) cystidean order Amphoridea. This was still essentially Bather's evaluation in 1913 when he admitted the existence of the heterosteles as a separate entity, equivalent to a delimited Carpoidea, subordinate to the Amphoridea. The remainder of

Jaekel's carpoid classification Bather peremptorily dropped. In reviewing the Carpoidea in 1921, Jaekel accepted Bather's restriction of the Carpoidea to the Heterostelea, but stressed the class attributes of the group. This evaluation Bather (1929) finally accepted.

In Jaekel's (1900) original paper on carpoid classification, three suborders of the Heterostelea were erected, viz:

1. *Cornuta* for the ceratocystids and balanocystids
2. *Marginata* for the trochocystids, mitrocystids, anomalocystids
3. *Soluta* for the rhipidocystids and dendrocystitids

Following Bather's (1913) careful analysis of the Caradocian cystideans of Girvan, Jaekel (1921) abandoned his Marginata in favor of two new suborders, viz:

1. *Mitrata* for the mitrocystids, lagynocystids, and anomalocystids
2. *Cincta* for the trochocystids and gyrocystids

Clearly there was considerable reshuffling of genera (family types) in this reorganization. Gislén (1927), Thoral (1935), Rennie (1936), Chauvel (1941), and Caster (1952; 1954; 1956) added genera to Jaekel's list. Hecker (1940) clarified the morphology of *Rhipidocystis* of the Estland Ordovician and removed it from Jaekel's Soluta to form the basis for a new order *Digitata*. The implication of this move was to elevate all of Jaekel's suborders to ordinal rank. Thus Caster (1952) dealt with the Mitrata as an order in his restudy of the Ordovician *Enoploura* and at the same time proposed several new mitrate suborders—*Mitrocystida, Lagynocystida, Anomalocystida*, and *Placocystida*. To these he subsequently (1956) added the suborder *Paranacystida* for a new Brazilian Lower Devonian mitrate.

Jaekel no doubt had in mind the globose Eustelea when he proposed (1900) the class name Carpoidea (*lit.* fruitlike), but it now belongs by elimination to the mainly flat "Heterostelea". Whether the Carpoidea-Heterostelea in turn should be fractionated at the class level has received some consideration. However, accepting the Carpoidea (Heterostelea) as currently defined by Chauvel (1941) and the chief texts, such as the chapter by Guénot (1948) in the *Traité de Zoologie*, Moore, Lalicker, and Fischer (1952), and Shrock and Twenhofel (1953), the forms here considered can be accommodated in the class.

Carpoid fossils are seldom abundant, either in nature or museums. This sparsity may in part reflect low population densities, possibly coupled with specialized ecologic demands. But there can be little doubt that their rarity is in part artifactual: it has often been demonstrated that carpoid materials are overlooked by collectors due to their unfamiliarity with carpoid anatomy and preservation. The class may have a considerable bearing on the eventual delimitation of Paleozoic faunal provinces.

Stylocone and styloid.—Jaekel (1921, pp. 115-116) proposed these terms, employing them with discrimination for quite different structures, but in the literature they have often been taken as synonyms. It is important to re-establish the original nomenclature, which is as follows:

1. *Stylocone.* The cone-shaped ossicle forming the middle region of the stele, as in *Cothurnocystis.* Jaekel wrote, "Es ist als Stylokonus kreiselformig bei *Ceratocystis* und *Cothurnocystis* (Fig. 113) und von oben her zentral ausgehöhlt, wohl zum Ansatz von Muskeln, die wahrscheinlich bis zu den Basalien der Theca verliefen."

2. *Styloid.* The organ of the middle region of the stele with teeth or blades on the ventral side (meaning here the side in contact with the substratum), as in *Enoploura.* Jaekel wrote, "Bei den Mitrata ist dagegen nur ein halbseitiges Stück von eigentümlicher Form (Styloid) vorhanden, das an der Innenfläche ebenfalls ausgehöhlt ist, aber auswärts mit zwei Zapfen vorragt, so dass es zugleich als ein Art Anker dienen mochte (Fig. 110, 112), der den Bewegungen der Theca und des obersten Abschnittes auch darin als Stützpunkt diente."

Jaekel carefully observed this terminology when defining the various orders of Carpoidea. Stylocone and styloid are both mesial stele structures, possibly homologous, but they can be contrasted thus:

STYLOCONE	STYLOID
1. Typified by structure in *Cothurnocystis*	Typified by structure in *Enoploura*
2. Cone-shaped and without projections	Great variety of form and possessing blades, teeth, or such projections
3. Constitutes a segment of the stele	Inserted along ventral midline (*Enoploura*) or composed of a series of segments with ventral projections (*Victoriacystis*)
4. Hollow structure	Solid structure
5. Functions probably supporting and articulatory	Functions probably anchoring and/or providing fulcrum for movement over sea floor

In many carpoids the stylocone or styloid, as the case may be, has not been observed, or has not been adequately described, and until these important structures are better known, it will not be possible to study adequately their evolutionary significance. However, the stylocone appears to characterize the Cornuta (three genera at least), while the styloid characterizes the Mitrata (nine genera at least). Cuénot called the smooth, rather parallel-sided part of the stele of *Mitrocystites* a stylocone, but this does not appear to be one in the sense of Jaekel.

New classification.—Jaekel called the Carpoidea "heterosteles" because the stele is composed essentially of dimeres[1] in contrast to other stele organizations in the Carpoidea. Within this heterostelous group there are two other features of the stele which appear to be good *fundamenta divisionis* for classification purposes, viz:

1. Longitudinal variation and specialization in the stele. In the Cincta (for example), the annuli of the stele do not vary in essentials from one end to the other, but in the Soluta and Mitrata (for example) there is a longitudinal two-fold or three-fold differentiation of the stele (proximal, mesial, distal). The class Carpoidea (Heterostelea) can thus be divided into two subclasses, the Homostelea[2] (those with all the stele elements the same, *i.e.* supposedly simple dimeres) and the Homoiostelea[3] (those in which there is a longitudinal differentiation of the stele, so that proximal and distal, or proximal, mesial and distal sections can be recognized). The Homostelea are unspecialized, and the Homoiostelea specialized. The homosteles are on the whole earlier than the homoiosteles, the former being limited to the Cambrian and Lower Ordovician, while the latter extend into the Lower Devonian.

2. Presence or absence of stylocone or styloid. Stylocone and styloid are part of the longitudinal differentiation of the stele already referred to, while carpoids having neither may be regarded as maintaining a more generalized condition. So the subclass Homoiostelea may be divided into the superorders *Stylophora* and *Astylophora* according to whether a stylo-

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[1] In *Enoploura*, and perhaps in all mitrate carpoids by implication, Caster (1952) demonstrated a tetramerous condition of the stele rather than the supposed dimerous organization. The lateral sutures of the component bodies of the stele annuli appear to fuse more rigidly, and perhaps earlier in evolution, than the dorso-ventral ones, thus creating the dimerous plan.

[2] From *homos* (Gr.)—*same*, indicating a stele made of the same kind of elements.

[3] From *homoios* (Gr.)—*similar*, indicating a stele made of homologous units which have become differentiated.

cone or styloid is present or not. The classification of the carpoids based on these features is as follows:

Phylum **ECHINODERMATA** Klein, 1734 (in form "Echinodermatum")
Subphylum **PELMATOZOA** Leuckart, 1848
Class **CARPOIDEA** Jaekel, 1900, emend. 1921 (= Heterostelea)

I. Subclass **HOMOSTELEA**, new (stele not longitudinally differentiated)
  1. Order *Cincta* Jaekel, 1921
  2. Order *Digitata* Hecker, 1940

II. Subclass **HOMOIOSTELEA**, new (stele longitudinally differentiated)
  A. Superorder **STYLOPHORA**, new (with stylocone or styloid)
    3. Order *Cornuta* Jaekel, 1900
    4. Order *Mitrata* Jaekel, 1921
  B. Superorder **ASTYLOPHORA**, new (without stylocone or styloid)
    5. Order *Soluta* Jaekel, 1900

In this classification, carpoids are distinguished from other echinoderms by their heterostele condition, *i.e.* lateral differentiation of the stele, while the subclasses are recognized by their longitudinal differentiation of the stele. There was a great deal of evolution in the carpoid stele, which thus contrasts with the conservative stem of crinoids. The evolution was apparently consequent upon the assumption of a free condition, whereby the stele changed from a mere organ of adhesion (if such it was) to an organ of locomotion. Superorders of the Carpoidea are recognized by whether a generalized condition is maintained, or the specialization of the stele continues by the production of a stylocone or styloid. The philosophy of this classification is to establish the higher categories on the stele and to establish the orders on the theca chiefly. This is in keeping with Jaekel's establishment of the class itself on a feature of the stele, viz. the presence of "pronouncedly biserial columns". Perhaps Jaekel's point could be expressed more aptly as "columnals with two or more elements in each annulus", because commonly it is only the distal stele which consists of dimeres.

SYSTEMATIC PALEONTOLOGY

> *"We have here probably the most aberrant type of evolution found among the Echinodermata, and one which in the nature of things, one would least expect. To find among the Pelmatozoa a group of organisms that are perhaps more highly specialized for purposes of locomotion than a large proportion of the Eleutherozoa is a novel experience. So unlike Echinoderms are they in certain respects that some of them have been described as Crustacea, which indeed they closely simulate."* Kirk, 1911, p. 21.

Class **CARPOIDEA** Jaekel, 1900, emend. 1921

(=Heterostelea)

Diagnosis.—Primitive, aberrant, eleutherozoic echinoderms; flattened and tending toward bilaterality; theca and stele sharply differentiated, the theca tending to be rigid, and the contiguous part of the stele flexible.

Jaekel stressed the nature of the stele in setting up both the Carpoidea (in his original wider sense) and the Heterostelea (=Carpoidea, *s.s.*). In carpoids the tail is heterostele (see text-figure 3), differing in more than lack of fixation from the supposedly homologous column of other (?) pelmatozoans. (Such resemblances as exist could be wholly analogous.) The carpoid stele is bilaterally organized and commonly depressed in accordance with the overall flattening of the carpoid body. The component plates of the stele are arranged in biserial, tetraserial (or octaserial?) plan (dimeres, tetrameres, octameres), and from distal to proximal zones may possess all three plans. To this extent Jaekel's (1900) definition of the carpoids as having "pronouncedly biserial columnals" requires revision. The pelmatozoan pentaradial scheme is unknown in the class.

Comparisons have been traditionally drawn between the carpoid stele and the peduncle of the amphoridean cystoids, the assumption having been that the amphoridean grade of organization reflects the possible gross organization of the hypothetical fixed ancestor of the carpoids. It has been widely, and for long, held also that the carpoids were attached. In the Amphoridea there is a regular transition from peduncle to theca, and from the regularized circlets of plates of the peduncle (alternating for the most part proximad from the seat of fixation) to the nonregular polyplacate condition of the theca. No doubt plates of the peduncular region were somewhat more tightly ankylosed than those of the thecal region, in keeping with their columnal function. Among the pseudocarpoids of the Rhombifera, such as *Pleurocystites*, the columnals were radially organized and presumably of five-part plan. In *Pleurocystites* the proximal columnals are progressively expanded in diameter as the calyx is approached. In the expanded zone they are much shortened and possess a large lumen. That they are often preserved bent in this area suggests a flexible zone analagous functionally to that of the proximal carpoid stele.

The commonly flattened carpoid heterostele (see text-figure 2) is often regionally differentiated. The distal stele is dimerous in all forms where this part is described. In the dimerous region, the distal section commonly exhibits *opposite* dimeres which proximally grade into an *alternating* sequence. In older carpoids and the more generalized ones, the dimeres are fused to form a telson-like organ in the proximal part of which the plates are alternate or even form a tetramerous series of alternating plates. In the Mitrata, and perhaps elsewhere, the distal stele is often flexible throughout, and commonly enrolled, as in *Rhenocystis*. In some forms it is aborted to a mere rudiment (*e.g. Enoploura*).

The mesial stele region of carpoids varies considerably, and no doubt the morphology of this zone will play a more prominent role in ordinal and family diagnosis in the future. In dendrocystitids the dimeres of the distal stele give way to the tetrameres or polymeres (*e.g. Heckericystis kuckersiana*) and no separate mesial area can be distinguished. In the Marginata (*Cothurnocystis*) a new mesial structure appears in the form of a conical annulus (stylocone) which serves as an accommodator between the narrow, terete and biserial, flexible distal stele of this order and the rapidly expanding proximal stele. In the cone the lumen rapidly expands, and at about the same angle, apparently, as in the proximal stele.

In the Mitrata (placocystitids) the mesial area is occupied by a styloid. This is a solid calcareous rod from the inferior surface of which two or three (perhaps more) prominences (spinelike, denticles, or ploughshare blades) are developed*. In some forms (*e.g. Enoploura*) the styloid is inserted on the inferior axial suture between imbricated proximal stele plates and apparently was held in position by muscles. The ends of the styloid axis were inserted, piston-like, in the lumen of the proximal stele. It would appear that the styloid functioned as an anchor and perhaps also as a locomotor organ (Kirk, 1911; Caster, 1952). It seems likely that the styloid is to be homologized with the stylocone in the Cornuta and the mesial stele in the Soluta.

The proximal stele of the most generalized carpoids (*e.g. Dendrocystites, s.s.,* see text-figure 2) comprises a series of integumentary rings. Alternate rings bear small plates and large respectively. The large plates are arranged in a single series on their annuli and many are required to complete a circle. The smaller ones cover the wider rings and are unorgan-

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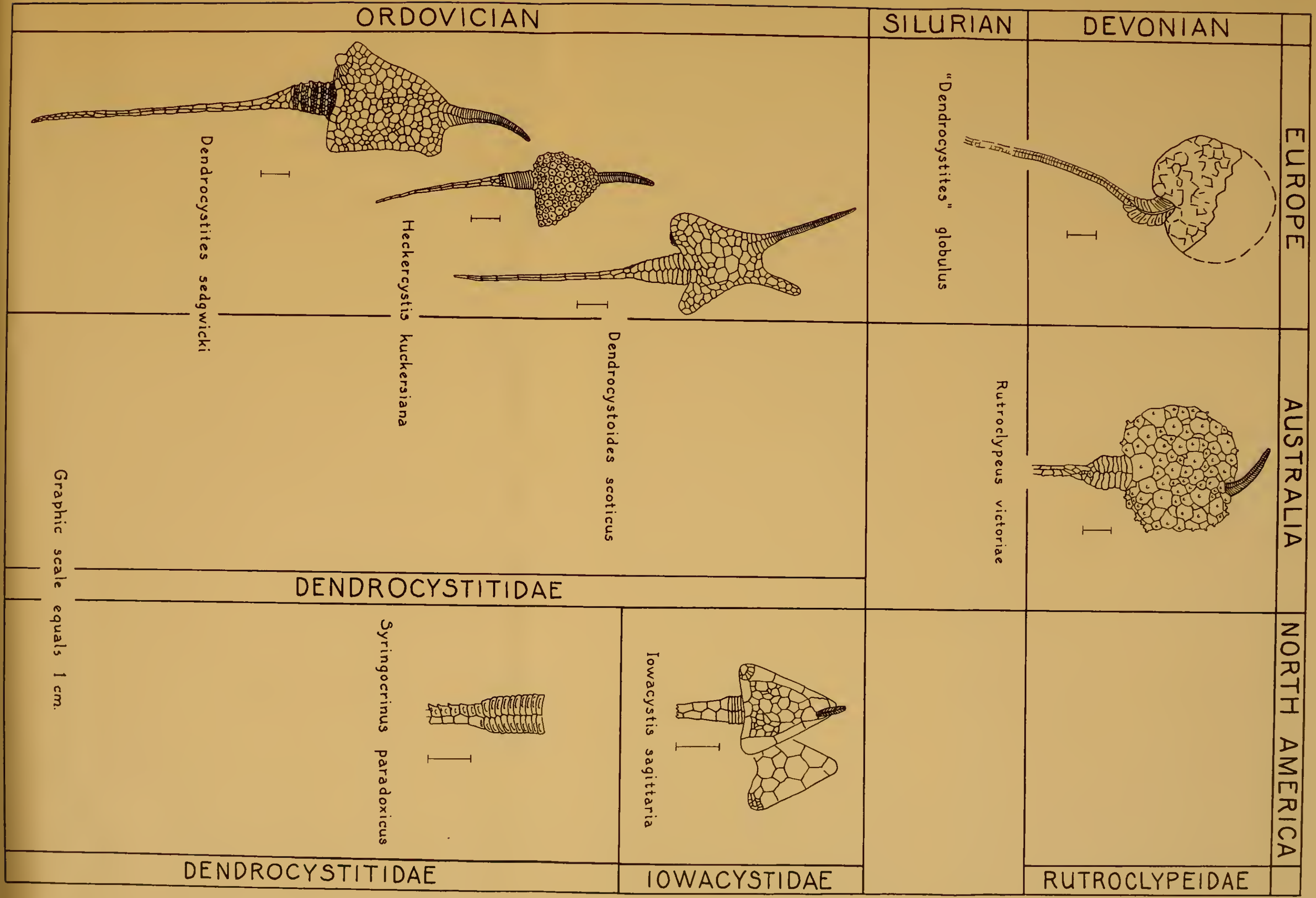
* *Note.*—New materials of the genus *Enoploura* from the Upper Ordovician of the Cincinnati area show the styloid to be composed of several sclerites which disaggregate upon weathering. The styloid blades contain coarse radial canals the function and homologies of which are still obscure. K. E. C.

ized apparently, to be likened to granules rather than plates. At this grade of organization the proximal stele was terete. In forms which retained the terete section (*e.g. Heckericystis kuckersiana*, see text-figure 2) plates of varying size are fused to form telescoping annuli. Hecker (1940) said that the proximal stele "is composed of narrow rings made up of small, tightly fused plates of uneven size and varying shape. These rings are superimposed on each other in a way resembling the sections of a telescope." (Translation from Russian). By reduction of the granular annuli to integumentary zones of connecting tissue (*Dendrocystites*), an imbricate series of rings was apparently here also achieved.

In the Mitrata, the terete proximal stele is tetrameral, with axial and lateral sutures between the annulus-forming plates. In many carpoids the "dorso-ventral" flattening pervades the proximal stele, and an arthropod-like series of broad imbricating scutes results. These show conspicuous axial and lateral sutures, and there is a hint of fused sutures (or so they appear to be) on the two flat surfaces which would constitute an octameral organization.

Bather (1913) stressed the existence in carpoids of two planes of symmetry which intersect along the main axis of the animal. On one, Bather's extensiplane, the body is compressed; on the other, the symmetry plane, there is a tendency towards bisymmetry. The distal dimerism of the stele reflects the latter tendency, as also does the bilateral outline of many mitrates. Bisymmetry is by no means common, however; perfect bilaterality never. Contrary to the views held by Bather, it now seems probable that all known carpoids were free during life, although there may have been precarpoid ancestors, still unknown, which were fixed. Textbooks have been particularly reluctant to face up to the eleutherozoic habitus of these early echinoderms (*e.g.* Cuénot, 1948, p. 11; Hyman, 1955, p. 17).

The internal organization of carpoid plates needs more attention. Barrande (1887) was of the opinion that surface pores were present in certain Bohemian dendrocystitids but thought the plates to be noncanaliculate. Bather (1913) denied both pores and canals for the carpoids as a whole, and this trait has often been used as a signal distinction between the Carpoidea and the Cystoidea. Caster (1952) found pseudo-pores (or punctae) in the Ordovician mitrate *Enoploura* and subsequently (1954) pointed out the existence of a labyrinthine felt of canals in the plates of *Paranacystis*, a Brazilian Lower Devonian mitrate. Caster and Eaton (1956)



Text-fig. 2.—Distribution and principal evolution of the Carpoidea Soluta.

discussed this canal system in greater detail†. Evidence is presented in this paper for a comparable system in the Australian solute *Rutroclypeus*. It would indeed be strange if a similar organization did not prevail throughout the class, just as it appears to do in the amphoridean cystids, whence they may have been derived. The chief difficulty in the path of the histological study of the carpoid skeleton is the nearly universal lack of suitably preserved material. The poor quality of the fossils may well derive from the porous and canal-riddled nature of the test; at any rate, molds and limonite pseudomorphs are the usual carpoid relics.

Order **SOLUTA** Jaekel, 1900, emend. 1921

Diagnosis of order.—Polyplacate heterostele (homoiostele and astylophorous) echinoderms in which no fixed plan of thecal plate organization was achieved. A single tetraserial brachiole is eccentrically developed distally on the theca.

Three families of the Soluta are recognized in the present study, as follows:

DENDROCYSTITIDAE Bassler, 1938
Dendrocystites Barrande, 1887, Ordovician
Dendrocystoides Jaekel, 1921, Ordovician
Heckericystis Gill and Caster, new, Ordovician

IOWACYSTIDAE Gill and Caster, new family
Iowacystis Thomas and Ladd, 1926, Silurian

RUTROCLYPEIDAE Gill and Caster, new family
Rutroclypeus Withers, 1933, Devonian
"*Rutroclypeus*" (new genus?), Devonian

Comment.—Bather's (1913) diagnosis of the dendrocystitids, hence of the Soluta as constituted since 1940 when Hecker excised the rhipidocystids from Jaekel's class, will very nearly serve today. Bather aligned the dendrocystitids with the "Amphoridea", but the hierarchy of classification

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† *Note.*—The histology of carpoid plates needs investigation. However, it is now clear that the Carpoidea shared with other Echinodermata a commingling of calcareous stereom and fleshy stroma throughout the calicinal plates. The stroma strands occupied labyrinthine and anastomosing canals through the stereom. Such "pores" as have been observed on the exteriors of carpoid thecae, as in the cystoids, are probably exposed by abrasion after death; epistereom and epidermal tissue presumably covered them in life. Probably no carpoids developed the specialized stroma organs, *i.e.* strands (= canals in the fossils) leading to single (haplo-) or double (diplo-) pores and their probably correlated asteroid papules. K. E. C.

has now altered somewhat. The large number of polygonal plates, rather irregular in size, form and arrangement, few of which can be homologized even from individual to individual, point to an archaic plan of which the amphorideans may well be the archetype. The thecae of the earliest Soluta are the most inflated, thus most closely approaching the vasiform of the amphorideans. Likewise the earliest dendrocystitid heterostele is most reminiscent of the amphoridean attenuate, but polyplacate, peduncle. In both, the thecal plates commonly show a tendency to develop central bosses which culminate in the spinose processes of *Rutroclypeus.* The outline of the flattened theca of the Soluta varies from the pyriform quadrilateral of early forms, through cordiform, tetralobate to subcircular in the terminal forms (see text-figure 2).

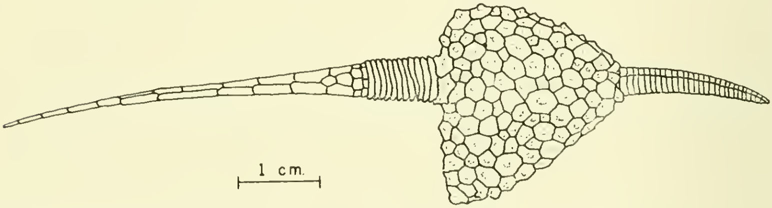
Family **DENDROCYSTITIDAE** Bassler, 1938

Diagnosis.—Soluta having thecae of no definite geometrical form; monobrachial; with a tendency to develop additional nonsubvective thecal extensions; theca composed entirely of polygonal plates; anus at proximal end near stele. Theca and stele somewhat inflated. Proximal and distal parts of stele well differentiated.

Genus **Heckericystis** Gill and Caster, new genus

Diagnosis of genus.—Dendrocystitids with proximal stele consisting of terete annuli of fused plates.

Type species.—Heckericystis kuckersiana (Hecker). Baltic Ordovician.



Text-fig. 3.—*Heckericystis kuckersiana* (Hecker) from the Baltic Ordovician. From Hecker, 1940.

Comment.—Hecker (1940) said of this species:

> Along the longitudinal axis, the theca has the form of a more or less equilateral triangle . . . By all appearances, the shape of the theca in live specimens of *D. kuckersiana* was not circular but flattened in section . . . Plates comprising the theca are placed in a mosaic-like fashion; they are of irregular polygonal shapes usually pentagonal, though not more than heptagonal.—(Translation).

The species is diagnosed thus:

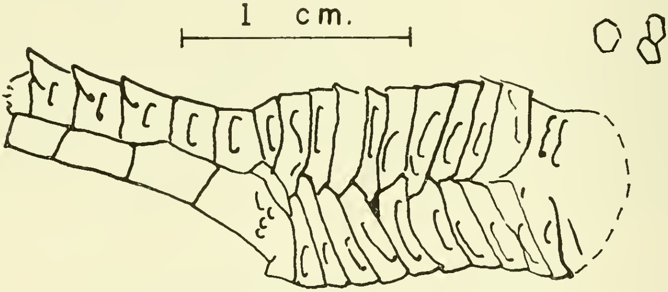
> A triangular theca with extended anal pyramid; antibrachiole projection apparently undeveloped; the junction of stem and theca not depressed. Thecal plates of varying size (up to 5 mm.), thicker in the middle and with one or a few nipple-like nodules. Plates adjoining the stem are longer, have smaller nodules and form a rim with an indented massive edge. The brachiole consists of four rows of narrow plates (over 20 in number). Stem length apparently more than double that of the theca's height. The stem's proximal section consists of unbroken narrow rings and segments, divided by spacers made of small plates; the distal section is made up of two rows of flattened plates, alternating variously, without a fin. Kuckers (C2) and Itfer (C3) layers of the Baltic Lower Silurian (Leningrad region and Estonia). (Translation).

Comment.—The evolutionary position of *Heckericystis* is shown in text-figure 2. In *Dendrocystites* the proximal stele consists of a series of annuli of tiny plates, and in *Dendrocystoides* of tetrameral imbricating plates, while in *Heckericystis* it comprises a series of terete annuli. The two last-named genera appear to be discrete lines of evolution from *Dendrocystites.* On one line the tiny separate plates of *Dendrocystites* fuse to give the relatively smooth annuli of *Heckericystis*, whereas in the other line they become organized into sutured plates ancestral to those of the Iowacystidae and Rutroclypeidae.

Genus **Syringocrinus** Billings, 1859

Along with a number of other echinoderms, Billings (1859) described a fragment of a carpoid which he named *Syringocrinus paradoxicus.* It consists of a complete, but damaged proximal stele, and a part of the distal stele. Billings was sure the fossil was part of a crinoid (hence the generic name) but was puzzled by its form (hence the specific name). This intriguing relic of Middle Ordovician life came from the "Trenton Limestone" (Sherman Fall member) of Quebec, but Billings' figure provides no adequate idea of the nature of the fossil. In 1900 Bather referred the fragment to the genus *Dendrocystites*, for which he had a wide connotation, and did so again in his 1914 study. Even so, Jaekel (1921) listed *Syringocrinus* as a genus of the family Dendrocystitidae. In 1928 Bather dealt with *S. paradoxicus* more thoroughly after he had further cleared the fossil of its matrix, revealing a fragment of the theca which showed small polygonal plates 1.25 mm. in diameter. Billings' figure shows a second part of the distal stele separated from that in contact with the proximal stele. This was missing when Bather examined the fossil, but it indicates that the distal stele was long, as is usual in the Dendrocystitidae. In *Syring-*

ocrinus the distal stele was at least four times the length of the proximal stele. Bather figured the remaining piece of the distal stele, showing the relative sizes of the plates and indicating the presence of transverse ridges on the left row of plates but overlooking detail which appears to us significant. Bather was not sure whether *S. paradoxicus* should be referred to *Dendrocystites* (in his wide sense), but inclined to that view, so called the fossil "*Dendrocystis* (?) *paradoxica*". This lead was followed by Bassler (1938) who listed *Syringocrinus* as a synonym of *Dendrocystites* (original spelling of the genus which Bather altered to "*Dendrocystis*"). Chauvel (1941) listed *Syringocrinus* as a genus in the family Dendrocystidae (= Dendrocystitidae), but Regnéll (1945, p. 195) followed Bather.



Text-fig. 4.—*Syringocrinus paradoxicus* Billings from the Sherman Fall member of the Trenton limestone (Mohawkian, Middle Ordovician) of Quebec, Canada. Traced from photograph of holotype.

Dr. George Hanson, Director, Geological Survey of Canada, obliged us with the photograph of *Syringocrinus paradoxicus* reproduced in Plate 6, figure 3 (No. 1521*a*, National Museum of Canada). The label states that this holotype came from the "Sherman Fall beds, Beauport, P. Q." The photograph shows well the differentiated proximal and distal steles. The proximal stele consists of at least ten transverse rows of longitudinally overlapping plates, a point that was not evident in earlier figures. On the side of the type specimen in view, two plates show in each transverse row, which with the corresponding two plates on the opposite side make a tetrameral arrangement. The fossil cannot, therefore, be referred to *Dendrocystites* or *Heckericystis* as herein defined, in both of which the proximal stele is terete and composed of a series of telescoping annuli. The apparently flattened condition of the proximal stele, as well as the tetrameral and imbricate nature of the transverse rows of plates in *Syringocrinus* recalls the scheme of *Dendrocystoides scotica* (Bather). (See text-figure 2.) As in this latter, the distal stele appears to show a dimeral arrangement of the plates. However, in *Syringocrinus*, the plates on the left side are wider, more numerous, and more complex than those on the right. Moreover, in contrast with *Dendrocystoides,* and all other known Soluta, spinose structures suggesting an incipient styloid appear on the last three (left side as seen in specimen) of the distal stele plates preserved on the holotype. They consist of laterally directed flanges or spurs. These flanged dimeres are preceded by two simple dimeres on the left side. All of the left dimeres, and likewise all of the proximal stele plates revealed in the holotype, bear transverse elevated bosses or bars of a unique character. The distal stele is asymmetrical as seen in the specimen, the left series of plates are wider, more numerous, and more complex than those on the right. Except for the most proximal dimere of the right row of distal plates, which carries a line of three nodes, the right row is unornamented.

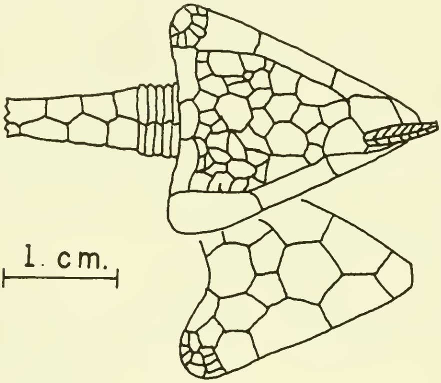
If the flange-bearing distal dimeres represent an incipient styloid, then the distal stele at least must be twisted to one side, for this process is universally developed on the inferior surface. Moreover, it is normally developed from or associated with mesial stele plates, but there is no separable mesial stele in *Syringocrinus.*

The prosopon (for term see Gill, 1949) of the stele plates, and the styloid-like flanges, would appear sufficient basis to consider the Canadian specimen as generically distinct from any hitherto described dendrocystitid, although an adequate generic diagnosis must await the discovery of the complete theca. The genus is of particular interest in that it is the only dendrocystitid so far recorded from the American continent. Wilson (1946) recorded three additional specimens, and extended the range of *Syringocrinus* to the Cobourg member of the Trenton limestone, but stated, "The Ottawa form does not add to the knowledge of the Calyx of the Canadian species."

The question might legitimately be raised as to whether the *Syringocrinus* stele could perchance belong to some carpoid other than a dendrocystitid. The only other carpoid at present known from the Middle Ordovician of America is Billings' (1858) *Ateleocystites*, likewise from the Ottawa Valley Trentonian (Cobourg beds). After a long period of submergence in synonymy, the genus was shown by Caster (1952, p. 90) to be valid and to possess the mitrate organization. Although the details of the *Ateleocystites* stele, known only from the holotype and paratypes (Wilson, 1946, pl. 2, figs. 1*a*, *b*) are imperfectly understood, it appears to conform to the conventional mitrate organization (see Caster, 1952, fig. 2A, B). The *Syringocrinus* stele is far too generalized to fit into the Mitrata scheme. Moreover, the many small polygonal plates which Bather revealed at the proximal end of the specimen fortify the assignment to the Soluta-Dendrocystitidae.

Family **IOWACYSTIDAE** Gill and Caster, new family

Diagnosis.—Soluta with differentiated anal and antianal thecal faces, one having few symmetrically organized plates, and the other many polygonal plates; theca triangular in outline, compressed. Brachiole distal but not terminal.



Text-fig. 5.—*Iowacystis sagittaria* Thomas and Ladd, from the Upper Ordovician (Maquoketa shale) of Iowa. Traced from Thomas and Ladd, 1926.

Comment.—Thomas and Ladd (1926) wrote, "This genus exhibits a group of characters which place it close to the family Anomalocystidae and to which it is provisionally referred. However, the triangular outline of the theca, its stem characters, plate markings and single oral process located outside the sagittal plane are foreign to the family. Foerste (1917) suggested relationship to the Mitrocystidae or Lagynocystidae. The genus may eventually be relegated to a new family." Bather (1928) referred the species to "*Dendrocystis*". Dehm (1934) preferred to rank *Iowacystis* as at least a subgenus of *Dendrocystites*. The present authors consider Thomas and Ladd correct in making a new genus because the organization of this carpoid is unique, as they pointed out. However, they agree with Bather and Bassler that its affinities are with the *Dendrocystites* lineage (see text-figure

2), *i.e.* a solute and not a mitrate. The suggestion of a new family is likewise acceptable because the triangular theca with nonterminal brachiole, differentiated anal and antianal surfaces, and specialized marginal plates mark it off just as strongly in the Soluta as the circular theca and spinose plates mark off *Rutroclypeus*. It is significant that Thomas and Ladd, Foerste, and Bather all suggested different and widely separated families in which *Iowacystis* might be accommodated. Their lack of agreement bespeaks lack of success. The form is different from any family so far defined. The new classification of Carpoidea given in this paper, with its emphasis on stele structures for the higher categories, readily sets this genus in its correct associations.

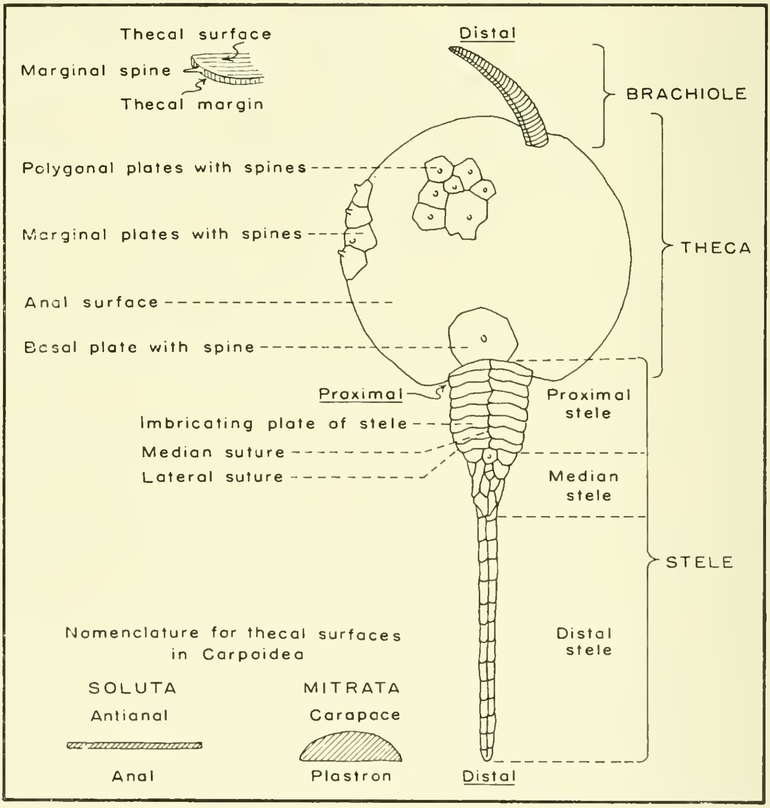
As indicated in text-figure 2, *Iowacystis* fits well into the evolutionary sequence of the Soluta. The plastic and primitive dendrocystitid carpoids evolved in one direction to give the triangular, comparatively highly organized theca of *Iowacystis*, and in another to give the circular theca of *Rutroclypeus* and "*Dendrocystites*" *globulus*. In both lines of development there was a similarly organized stele, surmounted by a compressed theca still with numerous polygonal plates (persistent genes of amphoridean origin?) but with a well-marked basal plate and a well-defined outline bordered by marginals which are well developed in *Iowacystis* and somewhat incipiently in *Rutroclypeus*. The *Dendrocystites, Heckericystis* and *Dendrocystoides* thecae are all wider proximally than distally, and to this extent tend to the triangular thecal outline found perfect in *Iowacystis*.

In addition to the contrasting thecal outlines, there are two other reasons for suggesting that *Iowacystis* and *Rutroclypeus* represent two separate evolutionary lines arising from the dendrocystitids. Firstly, both have the primitive polygonal plates of the dendrocystitids, but *Iowacystis*, in spite of being the older (Ordovician), has its thecal plates much better organized than those in *Rutroclypeus* (Devonian), viz. one side of the theca is covered with symmetrically arranged plates. Secondly, the brachiole on the distal margin of the theca in dendrocystitids finds an analogue in *Rutroclypeus*, but in *Iowacystis* the brachiole is not in the thecal plane but grows out of the thecal face on the anal side within the border of marginal plates. There is thus considerable divergence between the Iowacystidae and the Rutroclypeidae.

In most zoological groups it is unusual to establish families with a single genus, but among these rare carpoids, so much of their evolutionary history remains undeciphered, that solitary genera so diversely organized must be put in different families. Bather criticized Jaekel for so much splitting in his classification of the carpoids, but subsequent work has largely supported Jaekel as new discoveries have demonstrated the need for even further fractionation.

Family **RUTROCLYPEIDAE** Gill and Caster, new family

Diagnosis.—Soluta in which both thecal faces consist of numerous polygonal plates, the thecal outline is circular, the thecal surfaces close and subparallel, and the thecal plates commonly spinose. Proximal stele conspicuously flattened.



Text-fig. 6.—The morphologic terminology of the Rutroclypeidae, a new family of Carpoidea Soluta. Based on *Rutroclypeus junori* Withers from the Lower Devonian of the State of Victoria.

Comment.—The extreme flattening of the theca and stele, the circular thecal outline, and the extraordinary size of the proximal stele area, set this family apart from both the Dendrocystitidae and the Iowacystidae.

Morphologic terminology.—Rugged individualism among specialists and diversity of morphology among the carpoids have contributed to a highly varied and synonymous terminology for carpoid anatomy. The terms adopted for the Soluta in this paper are shown in text-figure 6. The carpoid is fundamentally a bipartite animal composed of a *theca* which presumably held most of the vitals, and a *stele* through which (or the proximal part at least) ran a central lumen. Many synonymous terms have been employed for the stele, such as tail, peduncle, stalk, stem, and column. All carry associations which may be misleading. All, except "tail" imply fixation as used in other echinoderms, whereas "stele" was proposed by Jaekel for the specific organ in carpoids.

Orientation.—In keeping with the convention among echinoderm specialists, the plane of contact between the theca and the stele is taken as *proximal.* Thus all points normal to this plane in theca or stele are *distal.* This obviates the perplexing problem (see Caster 1954, p. 130, f.n. 2) of deciding "anterior" and "posterior", the historical and functional meanings of which have often been at variance in the Echinodermata. Considering the structure and probable mode of life of the rutroclypeids, there can be little doubt but that the brachiole end of the animal was functionally anterior, and the stele end posterior. The inferred anal aperture is proximal lateral, but whether right or left, who can say? To be sure, homology with other carpoids and existing larval forms might be drawn upon, but it is certainly simpler to refer to the vent side as *anal* and the opposite as *antianal.*

Throughout their history, the carpoids became progressively flattened. and the rutroclypeids are the most flattened of all. Among the Soluta, the Iowacystidae and the Rutroclypeidae are so compressed that they must have lived on one side, or the other, or either. The Iowacystidae have the two sides of the theca strongly differentiated by (a) plate arrangement, (b) presence of an anal pyramid on one surface, (c) presence of a brachiole on the anal surface, and (d) overlap of the proximal stele by the anal, but not by the antianal surface. The brachiole appears to have migrated from the terminal marginal position to just inside the marginal plates of the anal surface. To work freely the anal pyramid would need to be on the upper surface, *i.e.* the animal-water interface, and not the animal-sea-floor interface. As the anal surface forms a hood over the proximal stele, this must surely have been the upper surface. It is interpreted, therefore, that *Iowacystis* lived with its anal surface upwards and its antianal surface on the sea floor, in which case the brachiole migration was no doubt to remove the brachiole from contact with the sea floor. If this be so, we may surmise that the function of the brachiole was not locomotory, mudstirring, or other purpose connected with the substratum, but rather some function or functions connected with the surrounding water, such as feeding, respiration, or water-testing.

Furthermore, the many-plated side of *Iowacystis* was the anal surface which faced upwards, and the few-plated side was in contact with the sea floor. This is the orientation observed in the Mitrata, where the few plated plastron is on the sea floor and the many plated carapace is in contact with the surrounding water. Evolutionally, the side in contact with the substratum has been the conservative side, while that in contact with the water has differentiated more. Then why have the plates of the anal side increased in number, a reversal of the process of plate reduction from the polyplacate amphoridean-like ancestor to the more organized skeleton of the carpoid? No clear answer presents itself, but the increase in suture length may be significant. In view of the absence of any discovered water-vascular, branchial or genital pores, it may be that sutures were connected with such functions. The greater flexibility of a polyplacate upper surface would be an advantage if the animal employed a bellows-like operation for drawing water within the theca, then expelling it.

In contrast with *Iowacystis*, the two sides of the *Rutroclypeus* theca are similar. Both are polyplacate and spinose, the brachiole is marginal and terminal, and there is no anal pyramid. The lack of differentiation between the two surfaces, the presence of spines on both, the marginal position of the brachiole, and the lack of extruding plates around the anus (anal pyramid) suggest that *Rutroclypeus* lived without preference on either the anal or antianal side.

Organization.—The polyplated theca of the rutroclypeids is similar to that of the Ordovician dendrocystitids and the Ordovician-Silurian amphoridean cystoids. The addition of plates during ontogeny appears from limited materials to have been not dissimilar to that described by Haeckel (1896), Foerste (1917), and Chauvel (1941) in the "Amphoridea," *i.e.*, Diploporita.

The highly characteristic spinosity of *Rutroclypeus* is also analogous to a repeated trend in early echinoderms. The Lower (?) and Middle Cambrian *Eocystites* [*Eocrinus?*] *longidactylus* Walcott (1886)[4] from North America possessed median worts or bosses on its polygonal plates; the Ordovician amphoridean *Calix sedgwicki* Rouault (1851) (see Chauvel, 1941, p. 29) is prominently spinose. Among the Soluta of the Ordovician, *Heckericystis kuckersiana* (Hecker, 1940) is notably similar to *Rutroclypeus* in development of spines, although they seem not to have reached the aculeate proportions of the Australian forms. Barrande (1887, pl. 26) showed warts or blunt spines on *Dendrocystites sedgwicki.* Spinosity is often cited by evolutionists as evidence of phylogerontism. Certainly it has been developed in numerous lineages toward the close of their geologic record. Such lines appear seldom, if ever, to have survived through rapid mutations into new higher category patterns. It might accordingly be argued that several of the geologically earliest echinodermal lines were already racially old. It is thus questionable whether these highly specialized forms would have produced new lineages which survived long after their extinction. On the other hand, it appears more likely that the spinosity observed in amphorideans in Cambrian and Ordovician times, and in the Devonian Soluta, were recurrent phenomena without phylogenetic import. In discussing these matters it is important to distinguish between *taxonomic group* and *grade of organization.* Although it is probable that the amphoridean Cystoidea are not ancestral to the Carpoidea (indeed the latter, as known from the paleontologic record, appeared a whole period of geological time earlier than the former in the strict sense, *i.e.* excluding the eocystids), their generalized and possibly anachronistic organization in Ordovician and Silurian times may shed great light on the make-up of the as yet undefined carpoid ancestor.

Thecal plate spines are characteristic of *Rutroclypeus*, but apparently absent in the related *"Dendrocystites" globulus* Dehm. Possible functions of the *Rutroclypeus* spines are:

1. To prevent or reduce drift caused by water currents.
2. To elevate the theca slightly above the substratum, thus reducing suction effects and improving respiration and feeding.
3. To increase the surface area of the theca. The presence of canals

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[4] The genus *Eocystites* Billings is based on a single "cystoid" plate from the *Paradoxides* (Middle Cambrian) beds of St. John, New Brunswick. Walcott, 1884, reported the same general type of dissociated plate 1000 feet below the Middle Cambrian in Nevada, associated with *Olenellus gilberti* and at approximately the same horizon in Vermont in association with *O. thompsoni.* The nature of these early "cystoids" remains obscure.

in the skeleton hints that such increase would be advantageous. The flattening of the theca increases surface area relative to volume.

4. To provide a deterrent for predators.

In that there is a definite development of marginal spines in *Rutroclypeus* which could not serve functions 1 and 2, functions 3 and 4 may be the more likely ones. The presence of spines on the proximal stele of *Rutroclypeus junori* is consistent with any of the above functions. The similarly shaped "*Dendrocystites*" *globulus* Dehm succeeded without spines.

The mouth of rutroclypeids, as of all Soluta, is problematic. It is inferred to be near or at the base of the brachiole, the function of which has usually been assumed to have been ambulacral (some writers have suggested it was locomotory in other Soluta). The four sutures between the tetraserial plates are narrow and rectilinear, and certainly do not resemble the usual ambulacral grooves of echinoderm arms. For one or more of them to have functioned efficiently as a food conduit, one would suppose the need for cover plates, no evidence for which exists. On the assumption that the mouth lay at the distal thecal end of the organism, and the anus at the lateral proximal end, the course of the gut would seem to have been diagonal through the thecal cavity. It probably followed a curved or undulatory course. Certainly there is no *a priori* reason to postulate a U-shaped or looped gut in this bottom-crawling creature, whose sessile metamorphosis was in all likelihood briefer than that of most echinoderms. Even the holothurians have lost the looped gut, if they ever had such. If the organization of the Soluta was preceded by the older Marginata plan (*Trochocystis*) where the apertures judged to be mouth and anus lie in close proximity on the distal margin, then their antipodal position in the Soluta would seem to be a good example of the operation of Bather's (1925, 1928a) "great sanitary principle", *i.e.* separation as far as possible of mouth and anus. This principle is wholly inoperative in the evolution of many echinoderms and other organisms, as Gislén (1930) has pointed out. At any rate, in the Soluta, mouth and anus where known, are separated to the maximum feasible distance, whatever the explanation.

Nothing is known of water-vascular, branchial or genital apertures in the Soluta. If such pores existed, they probably occurred between, rather than through, thecal plates.

Mode of Life.—The rutroclypeids lay free on the sea floor, but unlike many other carpoids, show in their body form no preferred orientation with respect to the flattened surfaces. The two surfaces are grossly similar, and apparently either side could lie in contact with the bottom. The flattening of both stele and brachiole, as well as of the theca itself, together with the flexibility of stele and brachiole, suggest that, like many other flexible aquatic creatures of marked flattening, they may have been able to swim a little and thus shift position. Clearly they possessed no anchoring styloid (if that be the function of this mitrate organ) for intermittently holding position. Instead, possibly the whole thecal surface with its numerous spines served this rôle, whichever side happened to lie in contact with the bottom. The rigid distal stele no doubt served as a telson. The imbrication of the plates of the proximal stele indicates their free articulation; that the free edges are distally directed may be evidence of movement in the opposite direction. Many carpoids have nonimbricating plates in the proximal stele, but overlapping plates are found in both mitrates and solutes. This partial telescoping of stele elements probably correlates with increased activity of their possessors.

The flexibility between theca and distal stele, and the flexible brachiole, may well have made it possible for the organism to turn itself over. The flattening of the distal stele could have served a kind of sculling propulsion. Muscles no doubt lay in the lumen of the stele and were attached in part in the thecal investiture. By such organs the telson or theca could have been elevated off the sea floor, and shift in position achieved.

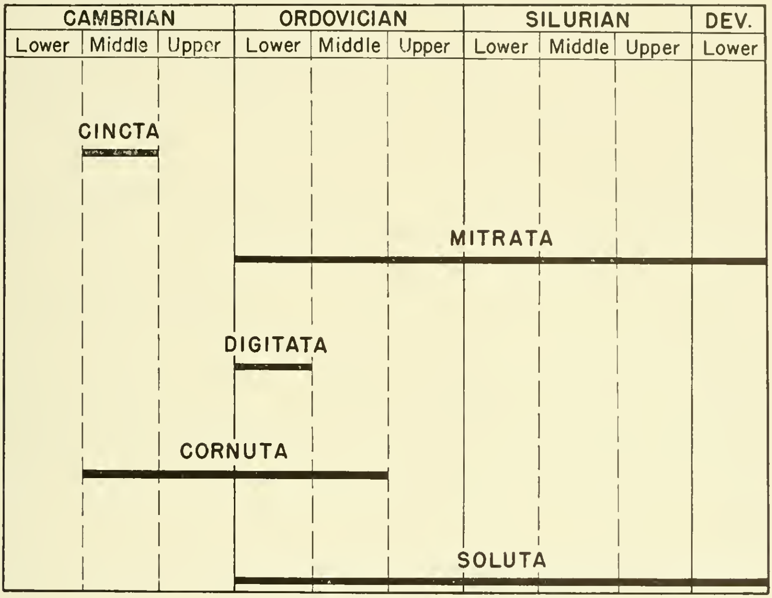
Symmetry.—The Rutroclypeidae are more bilaterally symmetrical than the Diploporita or the Dendrocystitidae. Among the Soluta they are only surpassed in this respect by the Iowacystidae. Their bilaterality, as in all carpoids, is not complete. Like the mobility from which it assuredly stems, their bisymmetry is probably a secondary imposition on a nonbilaterian. Traces of nonbilateral (but not radial) plan and of sessility are the persistent palimpsests of all carpoids. These statozoic inheritances are in turn, as in all Echinodermata, superimpositions on the bilaterian scheme of the vagrant archetype of which the Dipleurula larva is presumably recapitulatory. However, so modified was the plan of the Precambrian archetype during the precarpoid sessile stage of the echinoderms, that for all practical purposes only the latter, and the succeeding mobile stage, need concern us.

Quite possibly the unknown fixed ancestor of the carpoids (Precambrian?) developed an amphora-like form analogous to the simpler amphorideans of the Silurian. In due course this was polyplated. At this organizational grade there were apparently two main courses open to evolution: upright stature or recumbency. In both lineages there was advantage in peduncular attenuation of the body, and the production of either an upright stem or a flexible leash respectively. The latter subsequently became free. The "uprights" spawned the radial plan; the "recumbents" the "flatfish" type of organization. Herein would seem to lie the fundamental distinction between the carpoids and all other echinoderms: the carpoids became recumbents too early to develop any enduring radial organization. When they are first encountered in the geological record, they were already vagile benthos, improving on the bilateral scheme which was in all likelihood already well begun in their recumbent stage of sessility. The history of carpoid skeletal evolution is largely the record of accommodating a more or less chaotic polyplacate skeleton to flattish form and the requirements of limited mobility. A casual survey even of the class Carpoidea will demonstrate that bilaterality is by no means the only result of such accommodations.

The Diploporita demonstrate the manner in which the unorganized plates of the theca first became regularized around the point of fixation; their regularization preceded progressively higher and higher on the peduncle. In the upright forms pentaradial symmetry of the regularized parts soon developed, but no evidence of pentaradial plan has been observed in the Carpoidea. Instead, a simple geometrical progression of plates is the rule. The distal stele is composed of opposite dimeres, succeeded by alternating dimeres; in the proximal part of the distal stele or in the proximal stele, four elements are involved, while in the proximal stele of the rutroclypeids there is evidence that possibly eight elements contributed to each circlet. In *Dendrocystites* (as now defined) the proximal stele is composed of rings of larger and smaller plates in alternating rows, with a large number of scutes participating in each ring.

Bipolar regularization has also taken place in the Soluta, whereby a brachiole is antipodal to a stele, which in many ways it resembles. In the rutroclypeids, the brachiole is composed of opposite tetrameres, thus recalling the condition in the proximal stele of many mitrates. The serially constituted brachioles of the Soluta are easily taken for steles. *The implication of all this is that regularization does not necessarily commence at a point of adhesion, and in a motile organism might even be developed without any reference to a static past.* It should be borne in mind that the thesis of a sessile ancestry for the Carpoidea is still unproved, although a likely one.

In contrast to the Diploporita, the stele and theca of the Carpoidea are sharply delimited. The proximal plane is the cleavage between thecal rigidity and stele mobility. On the theca of the Soluta, the regularization of the plates has progressed far less than on the flexible extremites. Standardization of basal plates, and possibly of marginal plates, occurs in *Rutroclypeus* and *Iowacystis*; adanal and perhaps adoral plates exist; otherwise the number, shape, and arrangement of plates is quite archaic on both faces of *Rutroclypeus* and on the anal one of *Iowacystis*.



Text-fig. 7.—Geologic ranges of the orders of the Carpoidea.

Distribution.—Although carpoids are known from the Middle Cambrian to the Lower Devonian, the Soluta had a rather limited range prior to the Australian discovery of the Rutroclypeidae. The Dendrocystitidae are Ordovician and European except for the imperfectly known *Syringocrinus paradoxicus* Billings from North America and some uncertain fragments from Korea (Kobayashi, 1934, p. 525). The Iowacystidae are exclusively Upper Ordovician and North American. Now there is added the Rutroclypeidae which belong (on present knowledge) to the Lower Devonian of Australia and Europe (*"Dendrocystites" globulus*). It would be of the greatest interest to search the intermediate areas and formations for the linking faunas. The only other carpoids which survived as contemporaries of the Rutroclypeidae are the mitrates, and round the world these carpoids became extinct at the same time. In the Lower Devonian of Europe, North America, South America, South Africa, and Australia, the last of the carpoids are found. The Soluta had their fullest known development in the Ordovician of Europe, but suffer their demise in the Lower Devonian of Europe and Australia.

Genus **Rutroclypeus** Withers, 1933, emend. Gill and Caster

Diagnosis of genus.—The family is monotypic; the generic and familial traits are taken as the same for the time being.

Type species.—Rutroclypeus junori Withers, 1933. Lower Devonian, Victoria.

Rutroclypeus junori Withers Pl. 1, figs. 1-3; Pl. 2, figs. 2-3

1933. *Rutroclypeus junori* Withers, Roy. Soc. Victoria, Proc., vol. 45 (n.s.), pt. 1, pp. 18-22, pl. 5, figs. 1, 2.

Diagnosis of species.—Rutroclypeus with spinose proximal stele having ten (or thereabouts) segments, the more distal of which may be deflected distally.

Material.—1. Holotype. External mold of nearly complete specimen, P13681 [5]; 2. Paratype. External mold of fragment of theca, the proximal stele, and part of the distal stele, P13682; 3. Hypotype. External mold of a nearly complete young specimen, P16792, collected by Mr. F. S. Colliver; 4. External mold of part of the stele of a young specimen, P16447 (not a type).

Localities.—1. The holotype and paratype came from Collins Quarry, 1½ mile northwest of Kinglake West Post Office, on the west bank of King Parrot Creek where crossed by the north boundary of the Parish of Kinglake. (Military Map, Kinglake Sheet, grid reference 254,799.) This quarry is on the south side of a road leading to a permanent camp of the Forest Commission of Victoria. 2. The other specimens came from Middendorp's (formerly called Davies') Quarry, about a mile north of Kinglake West State School at the end of a track and on the west branch of Stony Creek, Parish of Kinglake, allotment 59 A, no section. The track runs from Mr. Middendorp's house northwards on the west side of the creek, stopping opposite the quarry which is on the east bank. (Military

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[5] Numbers so given are registered numbers in the paleontologic collections of the National Museum of Victoria, Australia.

Map, Kinglake Sheet, grid ref. 286,783.) Mr. R. B. Withers has kindly advised that he considers these two localities to be on the same or similar stratigraphic level.

Age.—Lower Devonian.

Description of holotype.—Pl. 1, figs. 1, 3. Theca flat, circular, about 4 cm. in diameter, consisting of a large number of plates which vary in diameter from a couple of millimetres to a centimetre, but usually are between a quarter and three-quarters of a centimetre. Perimeter entire. Smaller plates are more common round the perimeter of the theca. Most plates possess a spine normal to the plate surface. Over most of the theca, the spine is at the centre of the plate, but round the perimeter the spine is often towards the outer edge of the plate. There is thus a tendency to have a row of spines round the perimeter. On the right hand side of the holotype, as viewed in the matrix, there are two spines directed outwards in the plane of the theca, suggesting a row of marginal spines. The impressions of the spines show them to have been sharply conical in longitudinal outline, circular in cross-section, and 1.25 to 1.5 mm. long. *Stele* about 6.3 cm. long as preserved, *i.e.* over 1½ times as long as the theca. Stele inset into the theca about half a centimetre. Proximal stele about 1.2 cm. wide where inserted into theca; length about 1.7 cm.; tapering distally so that lateral borders of proximal stele continue without interruption as borders of distal stele. Proximal stele has well-marked median furrow, interpreted as a suture. There was apparently a suture also along each lateral border, making four sutures in all. The median suture is not quite straight, the irregularities perhaps reflecting development from original polygonal plates. Proximal stele composed of a series of segments, marked off by furrows (sutures) which are subparallel, and although transverse proximally, they become deflected distally, reminiscent of the arrangement of the pleurae in the pygidia of some trilobites. There are probably ten segments in the proximal stele, but the count is not without doubt. There is a suggestion of a weakness longitudinally through the plates halfway between the median and lateral furrows, hinting that the segments may originally have consisted of eight plates per annulus—four on each surface of the stele. However, the break could be artifactual, which interpretation is supported by the fact that no such break appears on the proximal stele of the hypotype.

Spines like those on the thecal plates appear on many of the segments of the proximal stele. It appears that the pattern is to have one spine on each segment on each side of the median furrow, set about one millimetre from it, but in actuality spines are not present in every case. The contact of the proximal stele with the theca is of a broad V-shape, almost sagittate, as also is the contact between the proximal stele and the distal stele. The hypotype demonstrates a similar contact between the brachiole and the theca.

Distal stele has subparallel sides except where it expands at the thecal end to fit the proximal stele. This triangular area can be distinguished from the rest of the distal stele and may be called the median stele. Bather made this distinction in *Dendrocystites.* The terminus of the stele as preserved is rounded and so evidently was not attached. The mold indicates that the distal stele of *Rutroclypeus junori* was a thin, flat structure, but this could in part be due to compression during fossilization. However, it certainly was not inflated. Faint transverse furrows provide evidence that the distal stele consists of a series of about two dozen fused segments.

Description of paratype.—Pl. 2, figs. 2, 3. Proximal stele about 2 cm. long and 1 cm. wide at the distal end. Wide V-shape of inset of proximal stele to theca well shown. Segments deflected distally, especially at the distal end. Triangular median stele is not so flat in the paratype as in the holotype. At the thecal end, a prosopon of fine transverse lines can be made out. On the side of the distal stele a few minute bosses are present—incipient spines perhaps.

Associated biota.—The holotype and paratype are from the Collins Quarry where the associated biota is as follows:

Plantae	Fragments of land plants
Anthozoa	Large colonial coral
	Lindstroemia ampla Chapman
	Pleurodictyum megastomum Dun
	Pleurodictyum, sp. nov.
Echinodermata	Blastoid
	Crinoids (numerous)
	Cystoids
	Machaeridian
	Crepidosoma kinglakensis Withers and Keble
	Crepidosoma sp.
	Eospondylus cf. *tenuis* Withers and Keble
	Lapworthura miltoni (Salter)
	Schuchertia junori Withers and Keble

Bryozoa	Undet.
Brachiopoda	*Atrypa* sp.
	Chonetes aff. *cresswelli* Chapman
	Eatonia sp.
	Lingula sp.
	Notanoplia autralis (Gill)
	Orbiculoidea?
	Strophonella?
Mollusca	*Coleolus?*
	Hyolithes sp.
Cephalopoda	Orthoceracones
Trilobita	Dalmanitid
Ostracoda	*Beyrichia* sp.

The specimens of *Rutroclypeus junori* other than the holotype and paratype come from Middendorp's Quarry, and these are now described.

Description of hypotype.—Plate 1, figure 2. This specimen is more or less a micromorph of the holotype, its thecal diameter being about 12 mm. The stele is about 25 mm. long, twice the length of the theca. The plates of the theca are much smaller than those of the adult specimens, being only 2-3 mm. in diameter as a rule, so growth of the theca must have been due in part to the enlargement of the plates. This applies also to *Rutroclypeus victoriae*. The brachiole consists of tetrameres—biserial plates on both anal and antianal surfaces. The insertion of the brachiole is shown clearly and reveals that it was introduced between the two thecal walls, similarly to the stele. The terminal plate at the proximal end has a broad V-shape, comparable with the corresponding plate of the stele. There is not so much deflection of the distal segments of the proximal stele as in the adult specimens. The proximal stele plates number at least as many as in the holotype. Several spines can be identified on the proximal stele, thus determining the species as *R. junori*. The distal stele tapers a little throughout its length. Its terminus is blunt and somewhat rounded, although this feature is not altogether clear. Casts of skeletal canals are present in the form of minute ferruginous columns. These are circular in cross-section. Plate 3, figure 3 shows similar structures in a specimen of *Rutroclypeus victoriae* (P16884). The canals are normal to the plate surface (commonest orientation), inclined or subhorizontal. Some of the columns (casts of the canals) are straight and some curved. They are minute in size, about 22 occurring per millimetre. Although contrasting somewhat in orientation, these canals appear to be homologous with those described by Caster and Eaton (1956) in the mitrate *Paranacystis*. The canals are generally more or less parallel to the plate surface in *Paranacystis* but usually more or less perpendicular in *Rutroclypeus*. Evidence for canals in both a mitrate (*Paranacystis*) and a solute (*Rutroclypeus*), the only two orders extant in Lower Devonian time, makes it pertinent to search for evidence of them in the other earlier orders of carpoids. The stereom canals were occupied by stroma strands in life, of course.

Description of P16447.—Imperfect stele of young specimen. Proximal stele about 4 mm. wide; some plates have spines. Distal stele about 1.5 cm. long and divided by transverse furrows taken to indicate the boundaries of the plates which by their fusion have formed the distal stele. Nearly 20 such plates can be distinguished. As far as can be made out on present evidence, growth in the stele is limited to enlargement of the plates, while in the theca there is the further factor of the addition of new plates (see description of *Rutroclypeus victoriae*).

Rutroclypeus victoriae Gill and Caster, new species

Pl. 2, fig. 1; Pl. 3, figs. 1-3; Pl. 4, figs. 1-3; Pl. 5, fig. 1

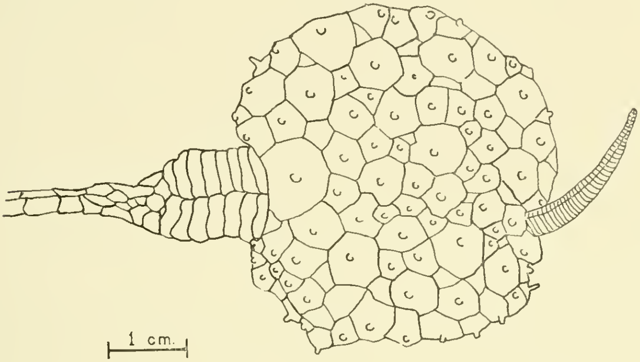
Diagnosis.—Rutroclypeus without spines on proximal stele. About seven or eight parallel plates in proximal stele.

Material.—1. Holotype. External molds (counterparts) of anal and antianal surfaces of a nearly complete skeleton. (P16441-2) ; 2. Paratype A. External molds (counterparts) of anal and antianal surfaces of a juvenile specimen. (P16443-4) ; 3. Paratype B. External molds (counterparts) of theca and proximal stele showing casts of canals. (P16883-4) ; 4. Specimens other than types: P16446 is a proximal stele and part of the theca; P16926 is a proximal stele only.

Locality.—All specimens are from Middendorp's Quarry, the location of which is described above.

Age.—Lower Devonian.

Description of holotype.—Theca flat, approximately circular in outline, 4 cm. in diameter, to which is attached a flattish stele, the proximal part of which is wider and consists of seven or eight annuli of four plates each, while the distal part consists of a series of comparatively narrow, fused plates. The stele is inset in the theca a distance of about 4 mm. which is the length of two segments of the proximal stele. The terminus of the stele is destroyed, but as preserved the fossil measures 7 cm. long. The theca consists of a large number of polygonal plates, 87 being counted on P16441, but some of these are small, and in many cases one cannot be sure whether a fracture or suture is present. Text-figure 8 provides our artist's interpretation of the plates. The largest plate is that contiguous with the proximal stele on the longitudinal axis of the animal and is distinctive enough to be given the name *basal plate*. It is the largest of the plates. There is a basal plate on both the anal and antianal surfaces. The proximal edge of the basal plate is shaped to accommodate the stele, a feature that can also be seen in the latex cast of specimen P16446. Overall, the largest plates are in the middle of the theca, and small plates more numerous round the periphery. Theca thin; originally probably slightly biconvex, but the only slight compressional displacement of the plates during fossilization shows that the theca was never distended, the body cavity was narrow. The plates geniculate at the thecal perimeter to form a narrow margin (see text-figure 6) as can be seen on the left edge of specimen P16442, and in P16449. The margin is between 1 mm. and 3 mm. high, and apparently possesses a zigzag suture where the various geniculated plates meet. Distance apart of the two molds shows that the plates were thin. In their growth, the plates have interfered with each other, so that the number of sides varies greatly. With all this variation, the overriding of the plates when squashed in the stratum containing them, and the accidents of preservation, it is difficult to count the number of sides on the plates. However, the sides on all the plates on P16441 were counted as



Text-fig. 8.—*Rutroclypeus victoriae* Gill and Caster, n. sp. Tracing from a photograph of the holotype. The brachiole is restored from the paratype. The lines shown in the median stele are fractures more than sutures. Drawing by Anneliese S. Caster.

accurately as possible, and the following figures obtained:

3 sides	4
4 sides	19
5 sides	38
6 sides	18
7 sides	7

In one case it was impossible to make an estimate. Total plates counted, 87. The above figures should not be taken literally but only as an indication that the commonest number of sides is five. A circular area cannot be covered with pentagons, so even if there were no growth interference, some accommodation of plates would be necessary if the entire theca were to be covered. The two sides of the theca are similar, but there is no precise correspondence of plates, except for the basal plates.

In the middle of nearly every plate there is a tapering spine with a rounded end in which no opening has been discovered. The spines are up to a millimetre in diameter at the base, and are generally 1 mm. to 1.5 mm. long. All spines project outwards normal to the surface on which they occur, whether it be one of the two main thecal faces or the margin. On the right side (as seen in the matrix) of P16442 there are three spines set closely together in a straight row, apparently on the one plate. On the marginal side of these spines is a small orifice which may be the *anus*. At the distal end of the theca, in the position occupied by the brachiole in other specimens, are some plates which may be a remnant of a brachiole; they are introduced between the thecal surfaces. This could be the locus of the *mouth*.

Stele.—Proximal stele consists of strongly imbricated plates, and the whole structure is considerably flattened. Width 11 mm. The contiguous part of the distal stele narrows rapidly to about 3 mm., whereafter the sides remain subparallel as far as the stele is preserved. The proximal part of the distal stele, *i.e.* the median stele, probably consists of fused plates, and what are interpreted by us as breaks rather than sutures are represented in text-figure 8. The distal stele, which consists of opposed dimeres, and the proximal stele are well organized, and it is, therefore, not expected that the plates of the median stele would be unorganized, as would be the case if the lines in the text-figure represented sutures.

Description of paratype A.—Juvenile specimen, like the holotype but much smaller, thecal diameter being 12 to 13 mm. and the stele of proportionate size. Thecal plates smaller than in adult. This specimen is notable for its possession of a brachiole which is situated a little eccentrically at the distal end of the theca, reminiscent of the arrangement in *Dendrocystites*. The arm appears in one only of the counterparts, viz. P16443, which shows that it is flattish, and consists on the face shown of about 20 pairs of opposing plates, thus contrasting with the proximal stele which has seven or eight. It is assumed that the opposite face of the brachiole had a similar constitution to the one shown, so that each annulus consisted of tetrameres as in the proximal stele. The more distal plates of the brachiole show no sign of imbrication, but those at the thecal end appear to have a slight imbrication; they have not the strong imbrication that characterizes the proximal stele. The brachiole is 11.5 mm. long and 1.5 mm. wide at the base; it gently tapers to a rounded end. The arm is longer than the proximal stele but narrower. As preserved the brachiole has a submedian furrow whereas the proximal stele has a median one (Pl. 4, figs. 2, 3).

Description of paratype B.—The counterparts are to a certain extent complementary, so that most of the theca, including part of the brachiole, the proximal stele, and most of the median stele are preserved. The specimen is a fully grown one, and provides evidence that the thecal plates were slightly convex, leading up to the spine in the middle. The brachiole is inserted between the two surfaces. The large strong proximal stele of this genus is well demonstrated. The pattern of fracture lines in the median stele is quite different from that shown in text-figure 8, and it is not yet known what plates made up the rigid middle part of the stele. The minute columns believed to be casts of skeletal canals are well preserved in this specimen and so are figured in Plate 3, figure 3. A description of this feature is given elsewhere.

4. *Notes on other specimens.*—Specimen P16446 shows well the insertion of the proximal stele into the theca. Like the brachiole, it was introduced between the anal and antianal shields. On the same piece of rock is a fragment of another *Rutroclypeus*; the genus appears to have been present in larger populations than is usual with carpoids. A fragment among the specimens collected by Mr. F. S. Colliver from Middendorp's Quarry demonstrates that there was a lumen in the proximal stele. A natural cross-section shows the plates on the anal and antianal surfaces with a space in between filled with sediment; as preserved the lumen is about half a millimetre high and almost the same width as the stele.

Preservation.—The specimens of *Rutroclypeus victoriae* are preserved in stratified siltstone which is bluish-grey where unoxidized and light grey where oxidized. The fossils are generally covered with a reddish-brown film of iron oxide. They have all had their skeletal material leached away, existing only as molds. By analogy it is concluded that the skeleton was calcareous; if it were not it would be siliceous or phosphatic and, therefore, preserved in this particular environment. In the denser part of the beds from which these fossils came, the calcic material of corals and brachiopods has been preserved, and it is hoped eventually to discover unleached *Rutroclypeus* material.

Paleobiology.—Counterparts being present in both the holotype and paratype of *R. victoriae* makes it possible to estimate the capacity of the body cavity. Counterparts when together are separated by only half a millimetre. As the displacement of plates by crushing during fossilization was not great, the body cavity must have been narrow. As no mud was found infilling the body cavity, it is inferred that on death the walls of the theca collapsed and were pressed together so that no sediment entered the body cavity. The smallness of mouth and anus would aid exclusion of sea floor mud. The plates of the theca are discrete, as shown by the sutures and by movement on them during fossilization, yet they held together remarkably well. Probably the skeleton was kept together by a strong integument, a feature well known in echinoderms, and one that links them with the vertebrates rather than the invertebrates.

Although the walls of the theca have been so closely adpressed, and there is no infilling matrix, nevertheless no impression of the gut could be recognized. This fact, plus the extreme narrowness of the body cavity suggests *Rutroclypeus* was a microphage and not a mud-eater. If the animal were a mud-feeder, the thecal lumen would have to be larger to accommodate the swollen gut, and there would be mud left inside the cavity when it died. It is imagined that minute plants and/or animals were swept into the alimentary canal by ciliary currents, probably from the brachiole. However, the possibility of a bellows-like action of the thecal walls has also to be considered.

The presence of spines on the thecal plates is an interesting feature which may well be related to the central bosses to be found on some of the plates of *Dendrocystites* (Barrande, 1887). Even the smallest and youngest plates of *Rutroclypeus* may have spines, and indeed the spine may be the nucleus from which the plate grew. In certain echinoderms the spines have been proved to appear early in development (*e.g.* Gordon, 1927).

Rutroclypeus presents three sympatric species. All occur at Middendorp's Quarry, and one species occurs at Collins Quarry in the same area and at the same or a similar stratigraphic horizon. Distribution of *Rutroclypeus* was apparently wide enough to allow separate populations to evolve their own characters (species differences), these species later coming together on the same sea floor. In spite of their rarity as fossils, therefore, rutroclypeids must have had a fairly wide distribution.

Paleoecology.—The fauna shows the environment was fully marine, while contemporary coral-stromatoporoid bioherms show that the seas were warm. There were currents present, as shown by current bedding, but these were not strong, as is proved by the fineness of the sediments and the small vertical thickness involved by current bedding. The rounded termini of the *Rutroclypeus* steles show that they were not attached by them to the substratum, while the flatness of these animals suggests they were benthonic. A free-living organism browsing on microzoa is envisaged; motile but not strongly so.

Associated Biota.—On the same slab as the holotype of *R. victoriae* there are two genera of trilobites, a number of brachiopods, and some other fossils. In a stratigraphical thickness of five feet at Middendorp's Quarry, the following fauna has been collected:

Plantae	Fragments of land plants (common in one layer)
Anthozoa	Favositid coral
	Lindstroemia ampla Chapman
	L. yeringae Chapman
	Pleurodictyum megastomum Dun
	Pleurodictyum, n. sp.
	Romingeria sp.
Bryozoa	Undet.
Brachiopoda	*Coelospira* cf. *australis* Chapman
	Eospirifer sp.
	Leptaena aff. *rhomboidalis* (Wilckens)
	Lingula sp.
	Notanoplia australis (Gill)
	N. withersi (Gill)
	Notoleptaena sp.
	"Nucleospira" australis McCoy
	Orbiculoidea sp.
	"Parmorthis" sp.

	Plectodonta bipartita (Chapman)
	"Spirifer" sp.
Lamellibranchiata	*Nuculites maccoyianus* Chapman
	Palaeoneilo sp.
Gasteropoda	*Loxonema* sp.
	Pleurotomaria sp.
Mollusca *Incertae Sedis*	*Hyolithes* sp.
Trilobita	*Cyphaspis* sp.
	Dicranurus kinglakensis Gill
	Leonaspis sp.
	Odontochile formosa Gill
	Phacops sp.
	Proetus euryceps (McCoy)
	Scutellum sp.
	Trimerus kinglakensis Gill
Ostracoda	*Beyrichia* sp.
Echinodermata	Asteroids including *Petraster* and *Sturtzura.*
	Blastoid
	Cystoids
	Ophiuroids including *Lapworthura* cf. *miltoni* (Salter)
	"Plumulites" sp.
	Victoriacystis aff. *wilkinsi*
Merostomata	Pieces of eurypterid integument P16878-9.

There is an horizon about a foot thick rich in Echinodermata (Gill 1947, pp. 17-18), and it is in this that *Rutroclypeus* occurs exclusively as far as is known. The above fauna and land plants indicate water of moderate depth not a great distance from land yet open to the ocean, allowing entry of pelagic forms such as *Dicranurus* and *Leonaspis.*

Rutroclypeus (?) withersi Gill and Caster, new species

Pl. 5, figs. 2-4; Pl. 6, fig. 1

Diagnosis of species.—Rutroclypeids with flat theca, lobate in outline, and with a characteristic arrangement of larger and smaller plates.

A new genus appears to be indicated but because the material is fragmental, it is referred temporarily to *Rutroclypeus.*

Material.—1. Holotype. External molds of portions of the anal and antianal surfaces of a theca. P16452-3; 2. Paratype. External molds of portions of the anal and antianal surfaces of a theca, with a fragment of the proximal stele. P16450-1.

Locality.—Middendorp's Quarry, Kinglake West, Victoria.

Age.—Lower Devonian.

Description of holotype.—The counterparts have only a median area in common. By making tracings and superimposing them so that the common part overlaps, the thecal outline was obtained. The theca is composed essentially of plates similar to those in *Rutroclypeus junori* but fused round them or intercalated between them are more numerous much smaller plates. Each plate possesses a spine of the same character as those found in *R. junori* and *R. victoriae*. In size the spines are relative to the dimensions of the plates on which they occur. The small plates are often distinct, but in some cases they are fused to the plate around which they form a circlet. The counterparts show that the theca was thin, with subparallel anal and antianal faces.

Description of paratype.—This specimen shows a few plates of the proximal stele. Round the large basal plate is a series of small spines which are interpreted as a circlet of small plates fused to the basal plate. The entire basal plate is not preserved, but 13 spines were counted on the perimeter of one-half of it. This fragment of a theca is approximately 28 mm. by 20 mm. revealing the theca to be of appreciable area in this species. A small part of the thecal margin on one side of the stele is preserved in this specimen, and it is rounded as in *R. victoriae* suggesting that the lobes shown in the holotype were at the distal end of the theca.

Comment.—We have pleasure in naming this species after Mr. R. B. Withers, who worked for many years on the geology and paleontology of the Kinglake District, and is the author of the genus *Rutroclypeus*. The present material is fragmental, but so characteristic is the plate pattern that the species is easily recognized.

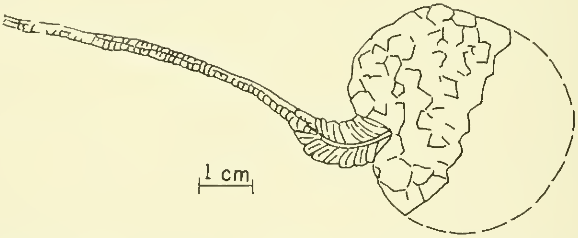
Some amphoridean cystoids possess large plates between which smaller ones are intercalated during growth. For instance, part of the theca of *Calix sedgwicki* (Chauvel, 1941, p. 38, figs. 6-7) possesses tuberculate larger plates between which smaller nontuberculate plates are added. The small plates form rows between the large ones in a regular fashion unlike the arrangement in "*R.*" *withersi*. The lobate outline of the new species is reminiscent of the Dendrocystitidae.

After the above was written, a further specimen (P16885-6) was found at Middendorp's Quarry. There is a proximal stele with about a dozen plates on each side of a median suture. A fracture passes through the median stele, but it can be seen that it narrows to a distal stele like that in other rutroclypeids. The theca is imperfect but compatible with the idea of an amphora-like outline. A brachiole like that in *R. victoriae* is present. Its position is enough to prove that the theca could not be a circular one as in *R. junori* and *R. victoriae*. Another specimen (P 16901-2) consists of a poorly preserved theca, but there is enough margin to prove that the theca was not circular.

"Rutroclypeus" globulus (Dehm) Pl. 6, fig. 2, 4; text-fig. 9

1934. *Dendrocystites* (*Dendrocystoides?*) *globulus* Dehm, Bayer. Akad. Wiss., Sitz., Math.-natur. Abt., 1934, pp. 20-21, pl. 1, fig. 1.

This enigmatic carpoid from the Rhenish Lower Devonian is known only from the imperfect holotype specimen. Like *Rutroclypeus,* of approximately the same age, it is circular in thecal outline, and was apparently likewise flattish in life. It is covered by numerous polygonal thecal plates and possesses an invagination of the proximal thecal edge to accommodate the proximal stele. The size and proportions are similar to the Australian *Rutroclypeus.*



Text-fig. 9—*"Rutroclypeus" globulus* (Dehm), (*Dendrocystites* (*Dendrocystoides?*) *globulus* Dehm, 1934) from the Rhenish Lower Devonian. Traced from a photograph of the holotype in the Senckenberg Museum.

Dr. Richard Dehm of Munich University and Dr. Wolfgang Struve of the Senckenberg Museum, Frankfurt a.M., assisted us by locating the holotype (Forschung-Institut Senckenberg, Katalog No. XXI 29a), provided the photographs here reproduced and advised us that they were unable to detect any evidence of spines on the thecal plates of the specimen when we failed to find them in the photographs or original illustration. This absence of the characteristic spines of *Rutroclypeus*, all other traits shared with it, would seem to be of generic importance. However, the unsatisfactory preservation of the holotype theca makes it prudent to await more information on Dehm's species before erecting the genus current information suggests. However, there can be no doubt of the close alliance between the Rhenish and Australian rutroclypeids for which a common family seems manifestly desirable.

Order **MITRATA** Jaekel, 1921

Diagnosis.—Moderately flattened heterosteles, having a convex carapace and a weakly concave or flat plastron: thecal plates relatively few and standardized, especially those of the plastron; marginal plates participate in both plastron and carapace surfaces. Styloid present. Distal exothecal appendages usually present and rigid[6].

For a fuller discussion of mitrate characters and habits, see Chauvel (1941) and Caster (1952; 1954; 1956). Suborders of the Mitrata were proposed and defined by Caster (1952; 1954). The Mitrata are among the oldest carpoid fossils, known from the Lower Ordovician (Bohemian fauna) through the Lower Devonian. When they first appear in the record, they are already distinctively mitrate, showing almost no features to be homologized with any other echinoderms; see discussion of *Mitrocystites* and *Mitrocystella* in Chauvel's (1941) epochmaking study of Armorican[7] carpoids. The presence of a styloid is peculiar to the Mitrata from their inception.

Suborder **PLACOCYSTIDA**[8] Haeckel, 1896

Diagnosis.—Mitrates in which the carapace is composed of fused[9], *nonimbricate plates; possessing a pair of rodlike brachia which articulate in sockets at the distal lateral extremities of the theca.*

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[6] In Caster's (1952) Anomalocystida, based on Schuchert's rendition (1904) of *Anomalocystites cornutus* Hall, flexible, segmented brachia are shown; however, doubts still remain that these brachia are genuine, and if so, whether the anomalocystids are mitrate carpoids. Among other anomalous features of this genus (and suborder) is a unique plate organization and no known styloid process. The latter, is, of course, possibly an oversight, or nonpreservational feature of the limited materials. See footnote 10, below.

[7] *Armorica* is the former name for Brittany, in France.

[8] The International Code of Zoological Nomenclature, Article 5, requires that "the name of a family or subfamily be changed when the name of its type genus is changed", but makes no such requirement for higher categories.

[9] The degree to which any or all mitrate thecal plates were ankylosed is open to reconsideration. The recent (1958-59) discovery of great quantities (many thousands) of free mitrate plates (*Enoploura*) in the Upper Ordovician rocks of the Cincinnati area of Ohio and Indiana, each with a characteristic muscle imprint on the inner surface, strongly suggests that the plates were discrete in life and had integumentary connections only, or in great part. This mode of organization would tend to explain the rarity of articulated specimens in the fossil record. Sieving and washing of carpoid-bearing strata may indicate a far greater abundance of the group than records so far reported in the literature would suggest. K. E. C.

Caster (1952; 1956) discussed Placocystida characters and relationships in some detail, and in the 1952 paper gave a diagnostic key for the recognition of major categories of the suborder. Placocystida are known from the Middle Ordovician (Canada) through the Lower Devonian (United States, Germany, South Africa, Brazil, and now Australia). They clearly stem from the Lower Ordovician Mitrocystida, from which they differ mainly in the possession of exothecal appendages, and a reduced number of nonimbricate carapace plates. From the exclusively Lower Devonian (United States) Anomalocystida, the Placocystida differ in the nature of the paired exothecal appendages (brachia). In the Placocystida they are rigid, while in the Anomalocystida they are segmented, if the reconstruction by Schuchert (1904) can be accepted[10].

In the Paranacystida (Brazil only), two (?) foliate and axially imbricating plates extend from the distal thecal margin. In this group there are also significant differences in the thecal plate organization; the "anomalocystid" plate, so characteristic of the Mitrocystida, Anomalocystida, and Placocystida, is absent or at least not identified.

Family **PLACOCYSTITIDAE**, new name

(Replaces *Placocystidae* Caster, 1952)

Diagnosis.—Typical Placocystida, having an asymmetrical plastron through the existence of an "anomalocystid" plate in the somatic series: carapace symmetrically arranged.

The genera of this family at present known are:

Boreal Province

- *Placocystites* de Koninck, 1869—Upper Silurian, Great Britain
- *Victoriacystis* Gill and Caster, new genus—Upper Silurian and Lower Devonian, Victoria, Australia
- *Victoriacystis* (?) Gill and Caster—Lower Silurian, Melbourne, Victoria

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[10] Caster (1952, p. 21) drew attention to the similarity between a distal stele and the unattached segmented structure alleged by Schuchert (1904, pl. 40) to be a brachium. The brachia illustrated by Barrande (1887, pl. 5, figs. IV, 1-4) for *Anomalocystites* show no segmentation, although he says that the preservation is poor. Wilson (1946) described and figured specimens of the closely related genus *Ateleocystites*, but found no brachia. If the brachia of *Anomalocystites* prove to be rigid, then the Anomalocystida will probably become synonymous with the Placocystida. J. K. Pope (pers. commun., 1959) has noted *Lepidocoleus* plates sheathing the brachial spines of Cincinnatian *Enoploura*. This suggests that the mitrate brachia were subvective, and that machaerideans are carpoid structures. K. E. C.

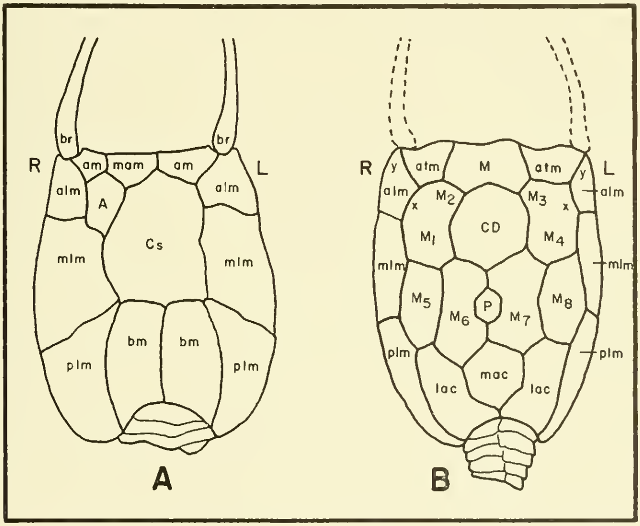
Rhenocystis Dehm, 1933—Lower Devonian, Germany

Austral Province

Placocystella Rennie, 1936—Lower Devonian, South Africa

Australocystis Caster, 1955—Lower Devonian, Brazil

The subfamily Placocystitinae (here emended from Placocystinae Caster, 1952) has been erected to receive *Placocystites* and the Australocystinae (Caster, 1955) to receive *Australocystis.* The other genera have not yet been referred to subfamilies. The three genera of the Boreal paleogeographic province have a "P" somatic plate in the middle of the carapace; the carapaces of the Austral genera have not yet been described. In the Boreal Placocystida there is an overall increase in the number of carapace plates from the Middle Ordovician *Ateleocystites* to the Lower Devonian genera, but this does not apply to the Austral genera, which apparently



Text-fig. 10.—*Placocystites forbesianus* de Koninck, Upper Silurian (Wenlock) of Great Britain, after Bather's (1900) restoration from the type material. A. Plastron view. B. Carapace view. Lettering after Caster, 1952, 1954, from analyses of *Enoploura* of the American Ordovician and *Rhenocystis* from the Rhenish Lower Devonian respectively. *M2* and *M3* indicate possible areas of the placocystitid *M1* and *M4* plates which were later differentiated into separate plates—or are here indistinguishably fused into the M1 and M4 plates; x—indicates the general positions in the M1 and M4 plates of the *lam* plates of *Enoploura* and *Rhenocystis,* (likewise either fused into or not differentiated from the M1 and M4 plates); y—indicates the general position of the *ax* plates in *Enoploura,* at the base of the brachia.

evolved along a different line. All the genera of the Placocystida have a conservative arrangement of plates in the plastron (the surface in contact with the substratum) ; new elements usually are introduced in the carapace (the surface in contact with the water environment). The plate organization of *Placocystites forbesianus* de Koninck as restored by Bather (1900) from the type material is shown in text-figure 10. An attempt has been made to employ the plate nomenclature used by Caster (1952; 1954) in his study of the Upper Ordovician *Enoploura* and of Dehm's (1934) *Rhenocystis* of the German Lower Devonian. The two austral genera are remarkable in deviating considerably both from the boreal norm for the plastron and from each other as well in this respect.

The increase in the number of carapace plates in the Boreal Placocystida, already referred to, takes place by an increase in the number of transverse rows of plates. In the Placocystitidae the increase is evidenced by the four rows of transverse plates in *Placocystites*, but five and six rows respectively in *Rhenocystis* and *Victoriacystis*. Evolutionally, the process of plate increase is of interest in that it is the reverse of the earlier reduction of plates which took place in the development of the comparatively oligomerous Carpoidea from the polymerous amphoridean-like ancestors.

Genus **VICTORIACYSTIS**, new genus

Diagnosis.—Placocystitids with elongate subquadrilateral theca, the proximal carapace plates of which overarch the proximal stele. Proximal stele with outer ends of plates distally deflected. Styloid consisting of a group of segments bladed on the inferior side, the blades being reduced in size distally. Stele approximates length of theca.

Type species.—Victoriacystis wilkinsi Gill and Caster, new species, Upper Silurian, Victoria, Australia.

Victoriacystis wilkinsi, new genus, new species

Pl. 7; Pl. 8, figs. 1, 2; Pl. 9, figs. 1, 2; Pl. 10, fig. 2; text-fig. 11

Diagnosis.—Same as genus for the time being, as only the type species is described.

Material.—1. *Holotype.* Counterparts P16787-8, are external molds in a fine-grained micaceous fawn sendstone with small diameter crinoid columnals and small fragments of brachiopods and other fossils.

2. *Paratype.* P16904, is a partial external mold in a matrix similar to

that of the holotype, showing part of the carapace and part of the plastron, plus the stele. On the same slab are some slender crinoids. This was the first known Australian mitrate specimen, and was found not *in situ* at the same locality as the holotype by Mr. R. W. T. Wilkins, after whom the species is named. Subsequent search led to the discovery of the holotype *in situ*.

3. P16905. Fragment of proximal end of theca, showing the characteristic prosopon, from the same locality. Not a type.

Locality.—Outcrop in eroded bed of gully, locality F41-42, geological map of Parish of Heathcote, Victoria, published by the Department of Mines, Victoria. These rocks belong to the "Graptolite Beds" division of the "Dargile Beds" of Thomas (1937). The associated fauna includes:

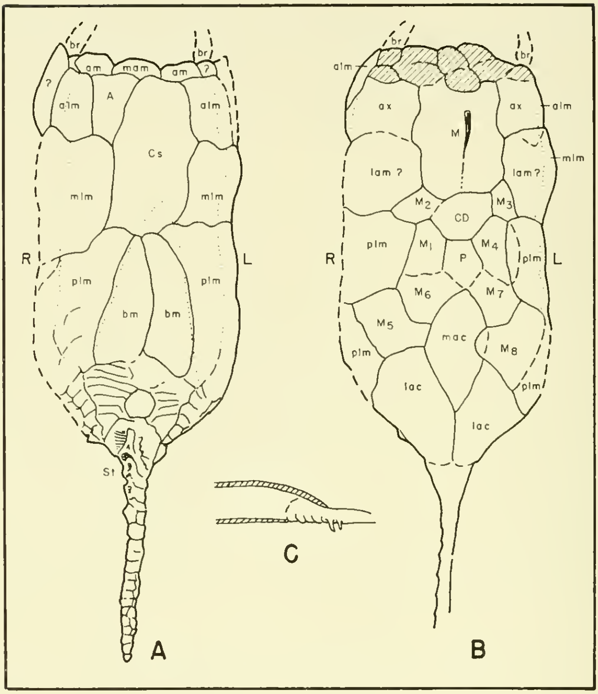
Monograptus aff. *nilssoni* (see Harris and Thomas, 1937)
Melbournopterus crossotus Caster and Kjellesvig-Waering, 1953
Lindstroemia
? Heliolites
Dalmanites
Starfish, cystid plate, and crinoid columnals of a number of kinds
Bryozoa

Age.—Upper Silurian, zone of *Monograptus nilssoni.*

Description of holotype.—Theca subquadrilateral, plano-convex, comparatively large, measuring about 20 mm. in length by 12 mm. in width. Brachia are not preserved on any of the specimens, but the distal corners of the theca seem to bear articulatory surfaces, hence text-figure 11 shows inferred bases of arms.

The carapace is highly vaulted; plastron flat or slightly concave. As indicated in the generic diagnosis, the proximal carapace (chiefly plates *lac*) is hooded over the proximal stele, and hence shows no proximal excavation of the margin. The plastron is considerably shorter than the carapace, and arcuately excavated on the proximal margin for the accommodation of the large proximal stele.

The plates of the two thecal surfaces are represented in text-figure 11. There has been some lateral imbrication of the plates after death, and only by closest comparison of the plates of the upper and lower surfaces, which were impressed upon one another internally and on the inner mold, has it been feasible to arrive at the reasonably certain plate determination shown. Both surfaces are shown in the figure as seen from above, *i.e.* the



Text-fig. 11.—Morphologic lineaments of *Victoriacystis wilkinsi* Gill and Caster, new genus. new species, based on photographs of the holotype. A. Plastron surface. B. Carapace surface. C. Diagrammatic representation of the proximal region, lateral view, showing the hooded overhang of the carapace above the proximal stele, and the corresponding excavation of the plastron to accommodate the exceptionally large and broad proximal stele. Solid lines represent definite margins and sutures. Broken lines are lineaments, in part sutural, in part fractures, and possibly in part representations of margins of plates of the opposite thecal surface. Lateral dotted lines indicate the lateral geniculation of mitrates. The mitrate "triangle" carina of the inner proximal plastron region is also shown in dotted lines. The plate nomenclature is that of Caster (1952; 1954) which has also been applied to *Placocystites* in the foregoing text-figure 10. The diagonally ruled proximal ("tegmenal") plates, first noted in these Australian specimens, are now known in great detail from American Ordovician *Enoploura* (1959). Drawing by Anneliese S. Caster.

carapace is as seen from above externally or on the inner mold; the plastron as seen on the outer mold. The plates are identified (with reservation as to homologies) in terms of the plate nomenclature of Caster (1952; 1954).

On a "tegmenal" surface, normal in orientation to the plastron, there appear to be five small plates[11]. These appear to be in series with the carapace plates but geniculate distally to form a cover-surface, beneath which, probably was located the anterior aperture (mouth-anus). The median of the five plates bears nine nodes and the laterally contiguous plates two nodes each.

The sides of the theca were nearly vertical, *i.e.*, normal to the general plastron surface, and composed of three plates which geniculate onto both the plastron and carapace surfaces to occupy considerable margin area of each; these marginal-lateral plates (*plm, mlm*, and *alm*) cover more than half the area of the plastron and also the largest area of the carapace of any known carpoid. The posterior marginal lateral (*plm*) is most unusual in reaching distally to about half the length of the theca. This may represent the fusion of the ancestral medial lateral plate (*mlm*) with the posterior one; however, here it is assumed that this is not the case. No sutures between the *M8* plate and the posterior lateral marginal has been noted.

There are definitely 12 somatic plates on the carapace; the *lam* and *ax* plates of *Enoploura* and *Rhenocystis* may be present as well, as indicated by the question marks on text-figure 11. The large area which is identified as the overlapping *plm* in front of *M8* may represent a separate plate, fused to the narrowly overlapping *plm* plate. No homologue of such a plate is, however, known in any mitrates.

The axial carapace plates of *Victoriacystis* are unique, *i.e.*, the *Mac*, *P, CD*, and *M* plates, the latter are extraordinarily large, and bear an axial carina which extends from the proximal margin of the plate to near the distal margin. The carina rises and broadens distally. The *Mac* plate is lozenge-shaped, but probably in life was a bit broader than here seen, for it is believed that a certain amount of imbrication between the margins of this plate and the *lac* plates has been brought about by compression, as is clearly the situation between *Mac* and the *M5* and *M8* plates. However, it seems quite certain that the *Mac* plate does not attain the proximal margin which is made by the contiguous and arched *lac* plates. The *M5, Mac, M8*, and *lac* plates bear the characteristic mitrate prosopon consisting of fine, slightly wavy raised lines which are spaced about .3 mm. apart.

The plastron plate organization is conservatively mitrate. The genus and species are unique, however, in having nearly half the plastron surface occupied by the *plm* and *bm* plates. The *Cs* plate is correspondingly reduced in size.

[11] A comparable, and probably homologous series of "tegmenal" plates, is now (1959) known to occur in the Cincinnatian Ordovician *Enoploura*. Hundreds of examples of these plates have been recovered by sieving operations. K. E. C.

The proximal stele shows marked flattening on the plastron side. It consists of a series of seven or more plates on each side of the midline, imbricated so that on each there is a free edge distally. The outer half of each plate is deflected distally in a marked manner. On the dorsal or superior surface the proximal stele is completely covered by extensions of the two most proximal thecal plates (*lac*). On the inferior side, in the middle of the proximal stele, there is a somewhat rounded structure to which the proximal stele plates appear to be related (see text-figure 11A). Neither the detailed structure of this organ nor its function are known.

The styloid is continuous with the distal stele, which is essentially a series of plates fused into a rod of triangular cross-section, tapering distally. The superior surface is flat, while the inferior surface is V-shaped in transverse outline. The styloid (*St*) is not an inserted element as in *Enoploura*, but a section of the axial skeleton; it comprises a succession of similar segments as seen in *Rhenocystis latipedunculata* Dehm, 1932, *Mitrocystis? styloidea* Dehm, 1934, and *Paranacystis petrii* Caster, 1954. The more proximal the segment of the styloid, the more fully it is developed. The first three segments from the proximal stele possess well-developed projections which become successively smaller distally, but thereafter descend to mere nodes, which are undoubtedly homologous with the styloid projections. Each projection consists of a transverse rounded flange, slightly hollowed on the distal face. The bar of the stele axis is thickened behind the flange so as to strengthen it. It is difficult to differentiate the styloid from the rest of the distal stele, for the segments with projections pass into segments with nodes which pass into a double row of plates as seen in many earlier carpoids. The terminus of the stele is blunt, and was apparently free; there is no evidence of attachment.

Description of paratype.—External mold with theca shown cornerwise, *i.e.* impression of thecal edge with most of the plastron and half of the carapace; also proximal stele, styloid, and part of the distal stele. Nodes on distal end of theca visible, and characteristic prosopon of proximal plates of the theca are visible. The distal deflection of the proximal stele plates is evident as is the nature of the styloid.

Comment.—The *P* plate and central region of the carapace (in fact pretty much all the somatic area) are somewhat obscure in the material at hand. Thus the plate nomenclature, as indicated both by the symbols and the broken lines in the text figure, is not definitive. Hence homologies are uncertain and comparisons only tentative. It is clear that the *mac* plate did not attain the proximal margin, as it does in all known Northern Hemisphere forms. In this respect the similarities, although quite probably homeomorphic, are with the Brazilian Lower Devonian *Australocystis*. Clearly, not all of the carapace plates of *Rhenocystis* (fig. 5 of Caster, 1954) or of *Placocystites* (text-fig. 10) are present in this Australian form. For example, is there a suture between the areas labelled *M6* and *M1* ?; *M7* and *M4* ? How about the *atm* plates of *Rhenocystis* —are they possibly incorporated into the exceptionally large *M* plate *sans* suture? There seems to be evidence of wholesale fusion of pre-existing plates in *Victoriacystis*, the while additional plates (as compared with *Enoploura*) have been developed. These two processes operating simultaneously and differentially in the mitrate carapace create serious problems in homologizing.

With respect to the plastron surface, far greater certainty as to plate components exists. The flat surface is more readily preserved undistorted than the vaulted carapace. Moreover. the plastron plates were in all likelihood more firmly ankylosed than were the carapace plates, some or most of which may have had integumentary suturing. All standard mitrate plastron plates are accounted for; only proportions among them vary from well-known boreal placocystitids.

In life the flat or slightly concave plastron surface would provide maximum friction with the substrate, while the deflected and slightly arched plates of the proximal stele would have less friction. Least friction of all would be caused by the V-shaped ventral edge of the distal stele. As the cupped flanges of the styloid are directed distally, they would act as anchors against a current into which the theca was heading, giving further reason for regarding the theca as the "business end" of the animal. It may well be that this was the attitude of *Victoriacystis* in life, the ingesting end of the animal facing the food-bearing currents, and the styloid holding it in position. The sharp edge of the distal stele could sink into the sea floor, thus allowing the styloid to be more effective as an anchor.

The flat plastron is interpreted as an adaptation to the flatness of the sea floor. Because of its simple function, little evolution has occurred in it, and so it is the conservative part of the theca. The rather flattened and rounded carapace accommodates the vitals, yet the smooth profile allows the easy flow of passing water currents. The fused stele would act as a telson, while the proximal stele would provide a zone of flexure. The animal might raise itself in the middle, *i.e.*, at the proximal plane, and then on the converse movement the stele would stick into the sea floor, and the plastron would glide forward over the substrate like a sledge. Alternatively, this movement may have been rapid, so that a flip would disengage it from the sea floor and allow it to drift a short distance with the current. In any case, the raising of the middle of the animal would disengage the styloid from the sea floor, and so facilitate movement.

Victoriacystis is nearest *Rhenocystis* Dehm (1933). Just as the Australian solute *Rutroclypeus* finds its correlative in *"Dendrocystis" globulus* from the Lower Devonian of Germany, so the Australian mitrate *Victoriacystis* finds its correlative in *Rhenocystis* from the Lower Devonian of Germany. *Victoriacystis* has been found in the Lower Silurian (?), Upper Silurian, and Lower Devonian (?), whereas *Rhenocystis* is known only from the Lower Devonian. These carpoids provide new evidence for a Middle Paleozoic seaway connecting the European and Australian areas (see Gill, 1953, for other evidence).

Victoriacystis aff. **wilkinsi** Gill and Caster Pl. 9, fig. 3; text-fig. 12

The collections of the Geology Department of the University of Melbourne yielded a unique specimen of Lower Silurian carpoid (No. 2876). It came from the City Brick Co. pit on Camberwell Road in the Melbourne suburb of Hawthorn, and was collected by Mr. Bruce Moore. The specimen[12] consists of the external imprint of the plastron surface, which is clearly a mitrate form, and for the nonce best referred to *V. wilkinsi,* although in all likelihood new and better material will prove the rightness of the surmise that this is a distinct species, if not a new genus as well.

Description.—The theca is 1 cm. wide and 2 cm. long. The plastron is approximately .25 cm. shorter than the carapace. Only the plastron surface details are known; these are characteristically mitrate, but differ somewhat in proportions from the typical *V. wilkinsi,* as can be seen on text-figure 12A. The proximal marginal excavation of the plastron margin is

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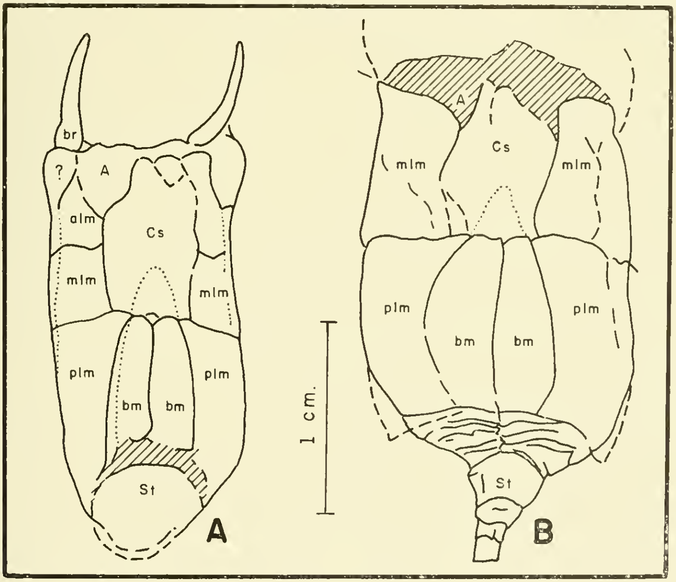
[12] While this paper was in press, five additional specimens of this species from the Melbourne Silurian were discovered in the collections of the Victoria National Museum. P18313 came from the Camberwell Road Quarry site; P18314-7 came from the same sequence as exposed in the excavations in 1952 for the Nurses' Home of the Children's Hospital, Gatehouse Street and Flemington Road, Parkville. Unfortunately, all specimens are poorly preserved and add little to understanding of this fossil, for again only the plastron surfaces are exposed, and these somewhat disarranged and badly leached. P18314 preserves the imprint of one of the spinelike brachial appendages which are so characteristic of the placocystids. The discovery of these additional examples raises hope that future close scrutiny of the Melbourne Silurian terrane may yield both substantial additional material and the data needed to resolve systematic problems.

considerably shallower than in *V. wilkinsi, s.s.,* and the carapace may be much less hooded over this area than in the Heathcote material. Characteristic undulatory prosopon lines are present on the posterior half of the plastron. The specimen is notable for the presence of both brachial spines, affixed (ball and socket articulation) at the distal lateral extremities of the theca. The better preserved exothecal appendage is 6 mm. long. The proximal stele itself is poorly preserved and the plates indistinguishable. Its area is proportionally less than in typical *V. wilkinsi.* The curious central plate or boss seems to be represented. Nature of styloid not shown.

Considering the generally conservate organization of mitrate plastrons, such deviations as here exist in proportions from typical *V. wilkinsi* suggest that a considerable deviation in carapace organization may well occur in this Melbourne form. Of course variation range in *V. wilkinsi* is unknown, hence the taxonomic import of the smaller size and plate deviations of this Lower Silurian form remain intangible.



Text-fig. 12.—Plate patterns in two Australian mitrate carpoids which show affinities with *Victoriacystis wilkinsi* Gill and Caster. A. Specimen from the Lower Silurian in the City of Melbourne, Victoria. (University of Melbourne No. 2876). B. Specimen from the Lower Devonian, Middendorp Quarry, Kinglake West, Victoria. This is the same horizon containing *Rutroclypeus junori* Withers and other species of this genus.

Fauna.—The matrix is fawn siltstone, and fossils are rare. Chapman (1925) described the solitary coral *Lindstroemia scalaris* in an identical matrix from "Hawthorn brick quarry, Camberwell", which is the same locality. The holotype of *Euomphalus holzeri* Pritchard (1944) came from the "Auburn brick pits", which, judging by the name of the collector, Mr. Holzer, came from the Fritsch Holzer and Co. pit. This pit is continuous with the City Brick Co. pit which yielded *Victoriacystis* (see Bain and Spencer-Jones, 1952).

Age.—In this area a thick series of strata forms an open fold called the Templestowe Anticline (Nicholls, 1930). Further north graptolites and illaenid trilobites (*Thomastus jutsoni*) prove a Lower Silurian age for the beds in this anticline. The beds yielding *Victoriacystis* are less than half a mile west of the axis of this anticline, while Upper Silurian (Lower Ludlow) graptolites occur at Studley Park over three miles west of the axis (Jones, 1927; Hills, 1941). The intermediate strata are notoriously paucifossiliferous. The site of the nearest illaenid to the *Victoriacystis* locality is 2½ miles north on the same anticline, so the possibility of pitch or faulting has to be taken into account. However, on present knowledge of the structure there is no reason to doubt that the age is Lower Silurian.

Victoriacystis aff. **wilkinsi** Gill and Caster Pl. 10, fig. 1, 3; text-fig. 13

This carpoid is the only mitrate known from the Devonian of Australia. It is a unique and poorly preserved internal mold of the plastron surface and proximal stele in a partly decomposed siltstone. It comes from the same site and faunal association as the abundant materials of *Rutroclypeus junori* in the abandoned Middendorp's Quarry at Kinglake West, Victoria.

The poor specimen has not photographed well. General plate relations are schematically shown in text-figure 12-B. The plastron surface is about 1.8 long and 1.2 cm. wide as preserved. The plate organization is typically mitrate, and, like typical *V. wilkinsi* and the placocystitid from Melbourne Lower Silurian, shows the unusually large expansion of the basal marginal and posterior lateral marginal plates, although here they seem to occupy somewhat smaller area than in the forementioned forms. It is of no doubt considerable taxonomic importance that in the Kinglake specimen the marginal excavation of the plastron for the accommodation of the proximal stele is of more nearly standard boreal proportions, and consequently no great discrepancy in length of plastron and carapace is to be expected and no hooded effect of the proximal carapace plates. Here the stele excavation seems to be restricted to the basal marginal plates. This difference in the more conservative surface of the organism no doubt bespeaks eventual generic distinction of the Lower Devonian mitrates from the Australian Silurian forms. The plastron plan here exhibited much more strongly bespeaks typical placocystitids of the Northern Hemisphere.

The proximal stele plates appear, on the other hand, to be organized around a roundish structure which is comparable to the organization of the holotype of *V. withersi.* Likewise there seem to be evanescent signs of distal flexure of the stele plates. However, the area of the proximal stele is markedly less in the Devonian form. Styloid details are not distinguishable.

The chief interest in this specimen is that it proves that the mitrates continued into the Lower Devonian in Australia, as they did elsewhere (Europe, North America, South America, Africa, and New Zealand[13]).

PALEOGEOGRAPHY

The Australian carpoid fauna as known at present consists of a new mitrate genus with one species and possibly other species, and one solute genus with three species. The mitrates belong to the Lower and Upper Silurian, and Lower Devonian, while the solutes are confined to the Lower Devonian. Their closest known congeners inhabited the Boreal seas of Europe, and this evidence strengthens that based on other forms for a seaway or seaways reaching from Europe to Australia in Middle Paleozoic times (Shirley, 1938; Gill, 1953). Although there are Lower Devonian carpoids in both South America and South Africa, these are well marked off from the Boreal forms (Rennie, 1936; Caster, 1954; 1956). The only known tangible link between the Austral and Boreal paleogeographic provinces is the brachiopod *Australocoelia* Boucot and Gill (1956).

The Australian carpoids belong to the end of the life span of the class. As the Paleozoic of Australia is rich in echinoderms, it may be that earlier carpoid forms existed, but have not yet been discovered because of their natural rarity and their unusual character.

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[13] During an excursion into the Reefton Lower Devonian terrane of South Island, New Zealand in 1956, a single specimen of mitrate carpoid was found. It is of the placocystitid organization. Fortunately the preservation is excellent, and all surfaces can be studied on the external and internal molds. A paper on this new form will soon appear under the authorship of the present writers.

ACKNOWLEDGMENTS

The authors are indebted to Anneliese S. Caster for her careful and independent drawings of the text-figures. The photographs are mostly the work of the late Mr. L. A. Baillôt, the remainder are by his successor, Mr. Frank Guy.

Mr. F. S. Colliver kindly made his collection available to us and generously donated to the National Museum of Victoria such specimens as were made types. Mr. R. B. Withers obliged us with information concerning the stratigraphy of the Kinglake District, while Mr. Middendorp gave us permission to work his quarry. A party of three men with a compressor from the Public Works Department spent a day bringing down rock to assist the search for *Rutroclypeus*. In this way the stratum yielding the specimens was discovered and further material collected.

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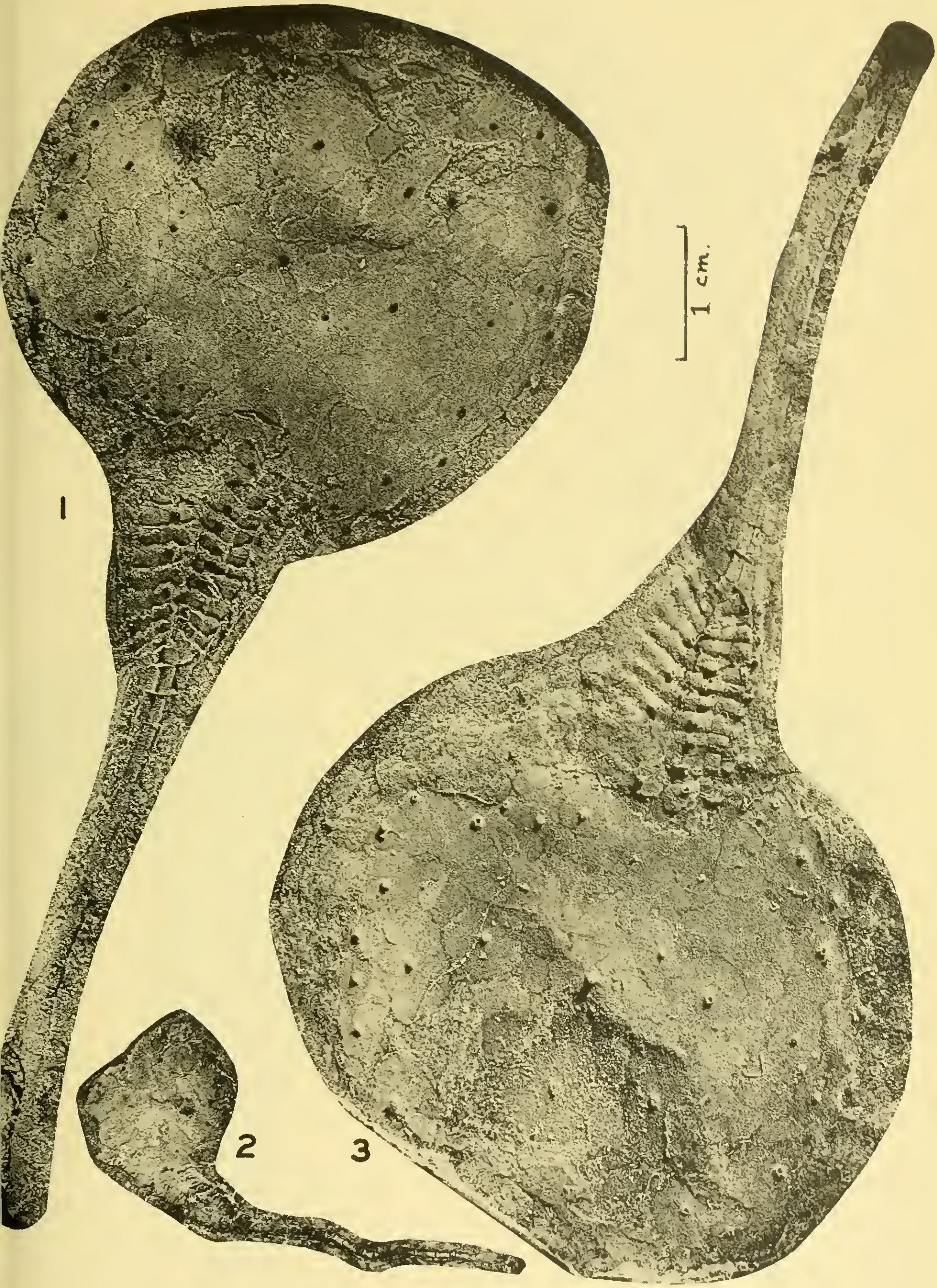
PLATES

The cost of plates and text-figures has been met in part from research funds of the Graduate School of Arts and Sciences of the University of Cincinnati.

EXPLANATION OF PLATE 1

Figure		Page
1.	**Rutroclypeus junori** Withers	30
	Holotype, P13681. Note spines on proximal stele.	
2.	Same. Holotype, P16792. Young specimen.	
3.	Same. Latex cast of holotype (fig. 1).	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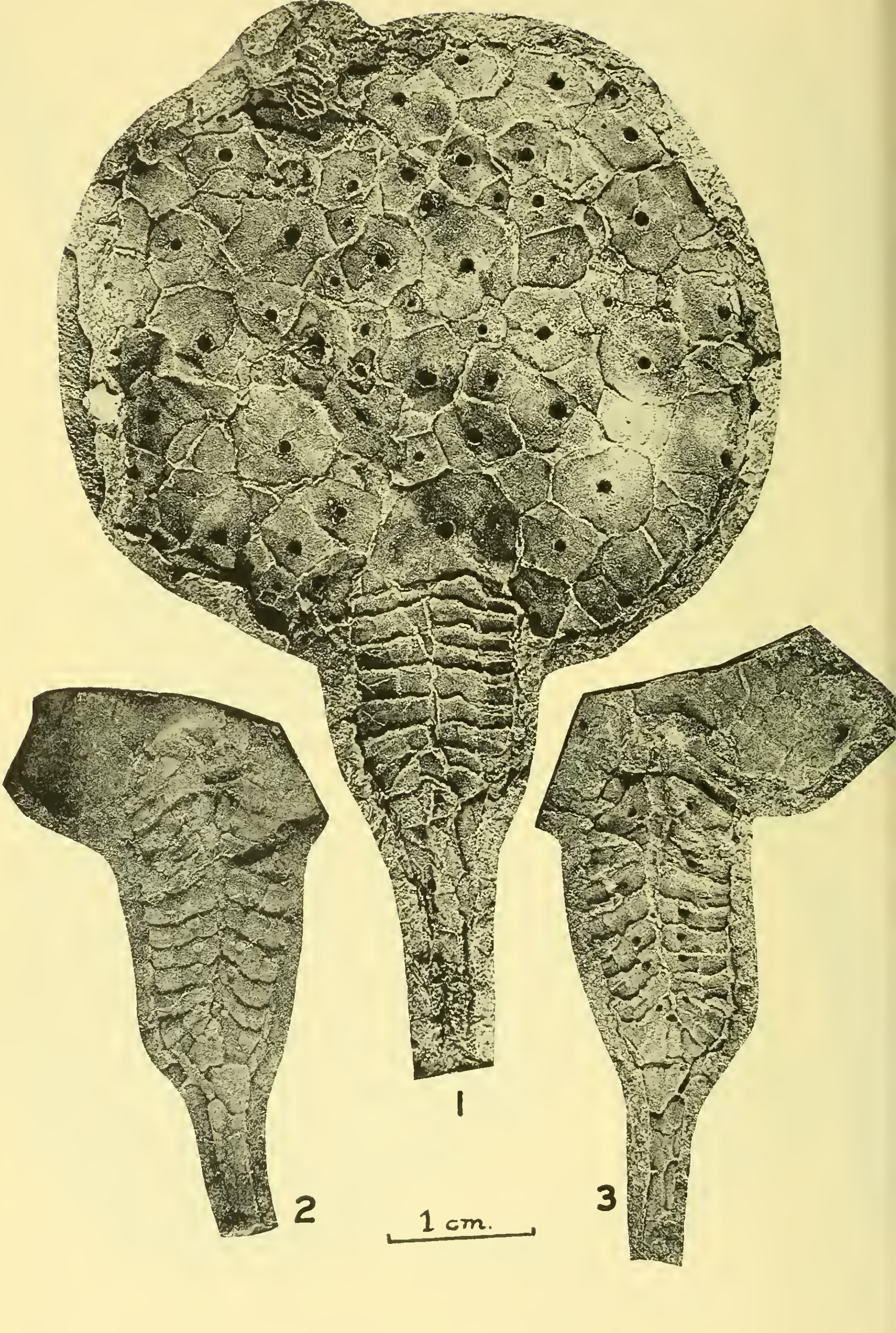
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EXPLANATION OF PLATE 2

Figure Page

1. **Rutroclypeus victoriae** Gill and Caster, n. sp. 34
Holotype, P16441. Antianal surface.

2. **R. junori** Withers 30
Latex cast of paratype (fig. 3).

3. Same. Paratype, P13682.

Explanation of Plate 3

Figure Page

1. **Rutroclypeus victoriae** Gill and Caster, n. sp. 34

   Specimen with lateral flexure, P16451. Natural section of proximal stele showing lumen. On same piece of rock as the paratype of *R. withersi.*

2. Same. Latex cast of antianal surface of holotype. Orifices in tips of some spines are due to air bubbles under latex in spite of vacuum injection.

3. Same. Paratype B. Enlarged to show casts of skeletal canals.


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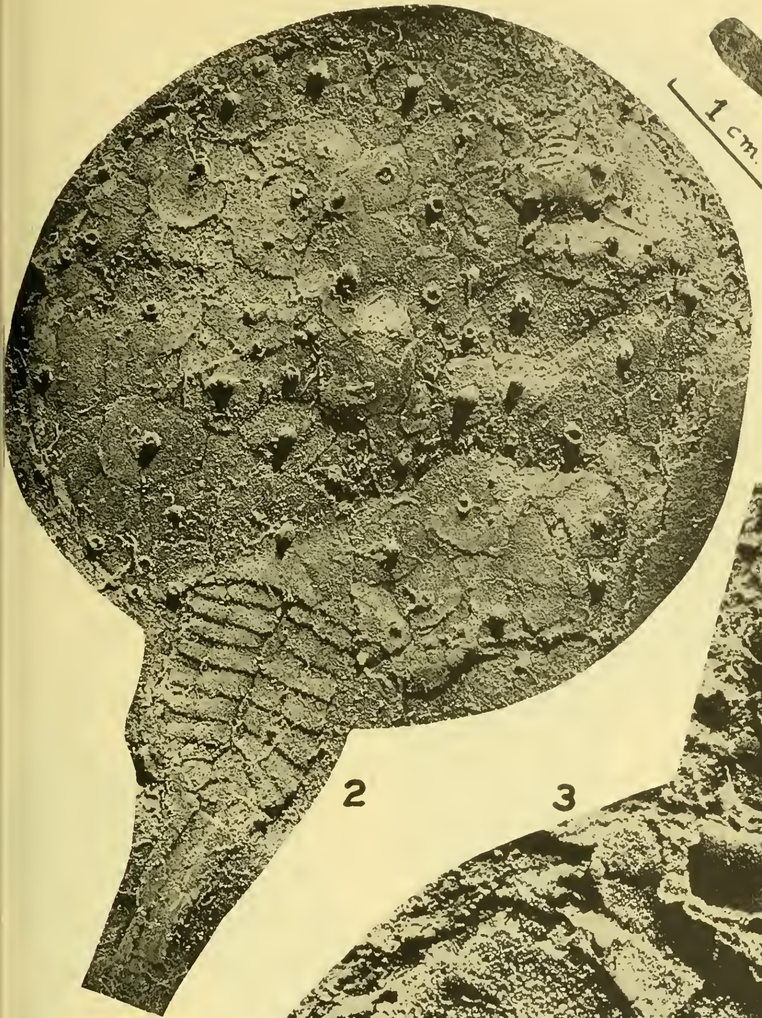
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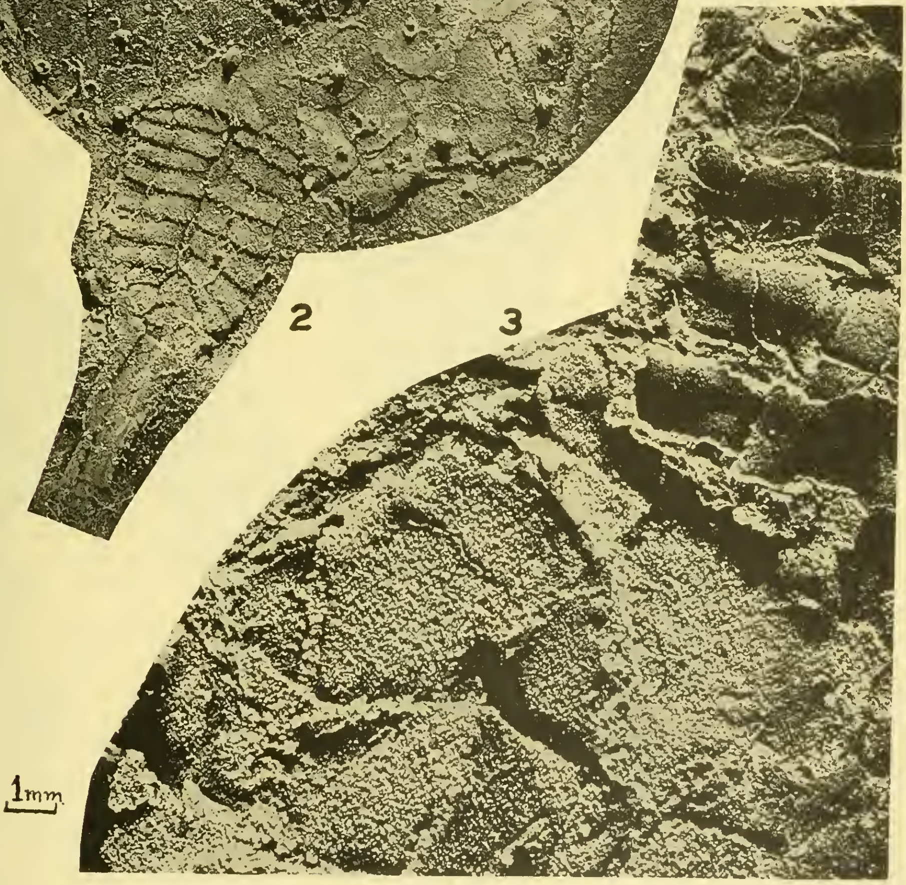
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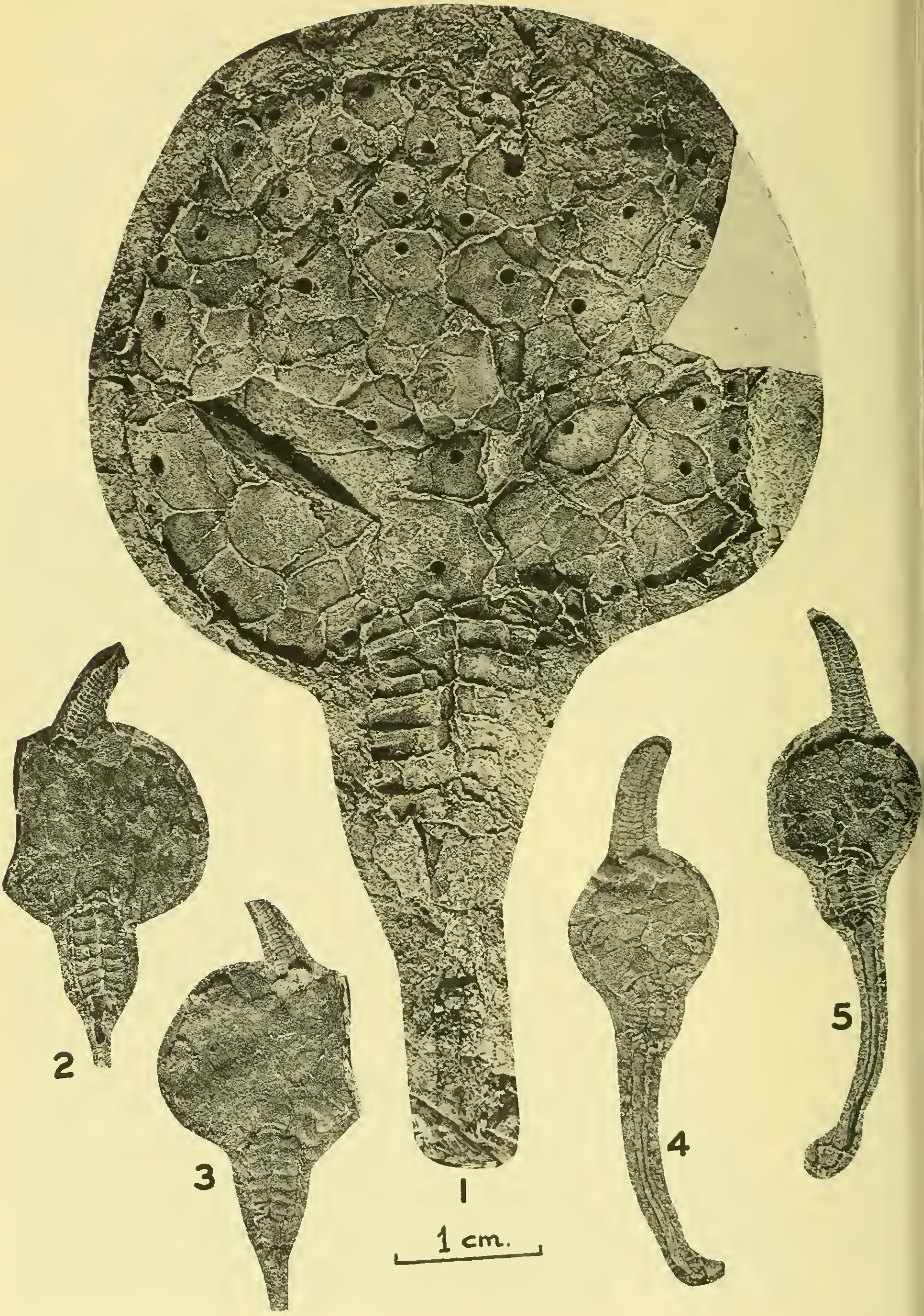
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	Latex cast of anal surface of holotype. A = probable anus. Note row of three closely spaced spines, with associated hollow interpreted as an orifice (the anus) in the animal.	
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3.	Same. Holotype, original specimen.	
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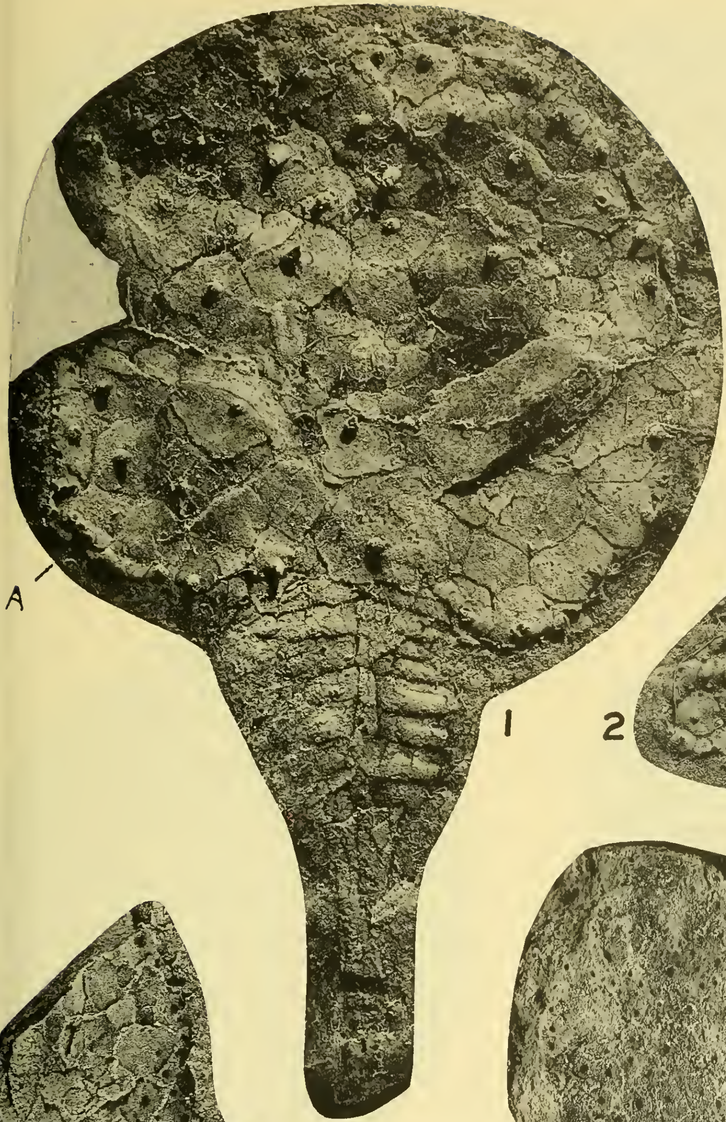

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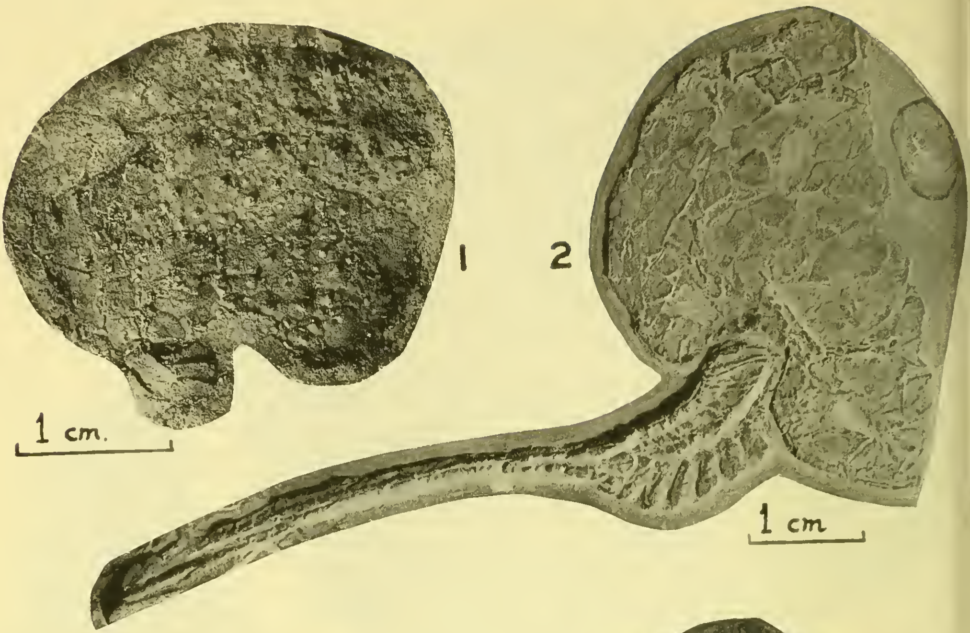

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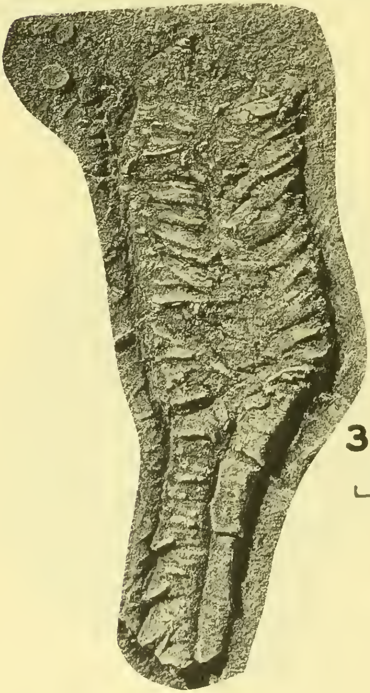

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1 cm.

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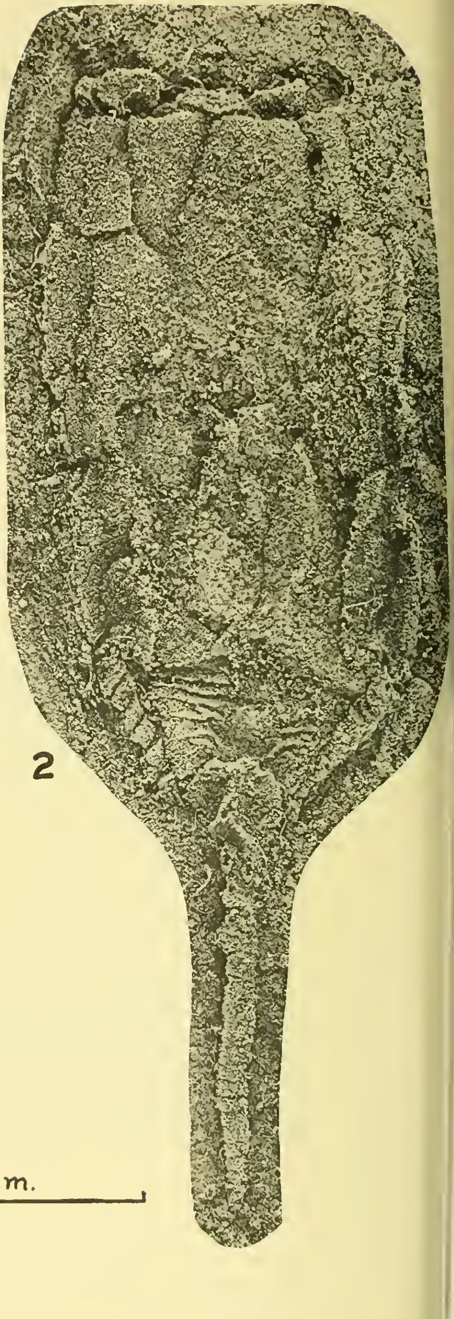
Victoriacystis wilkinsi Gill and Caster, n. g., n. sp. 46

Stereoscopic pair of photographs of the antianal surface of the holotype, P16787. The prominence of the spines, imbricated nature of the thecal plates and proximal stele are especially noteworthy.

1



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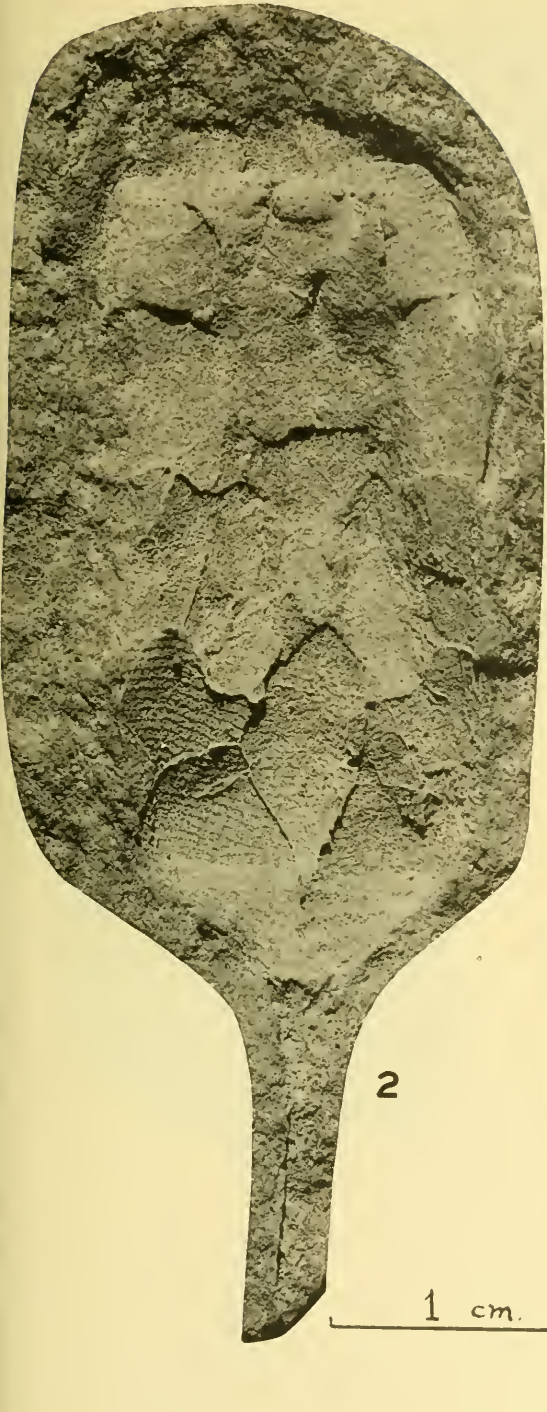
Latex cast of paratype, P16904.

2. Same. Holotype, carapace. Note proximal plates extended as a cover over the proximal stele.

3. **Victoriacystis** aff. **wilkinsi** 52
Dept. Geology, University of Melbourne, reg. No. 2876. City Brick Co. pit.

1



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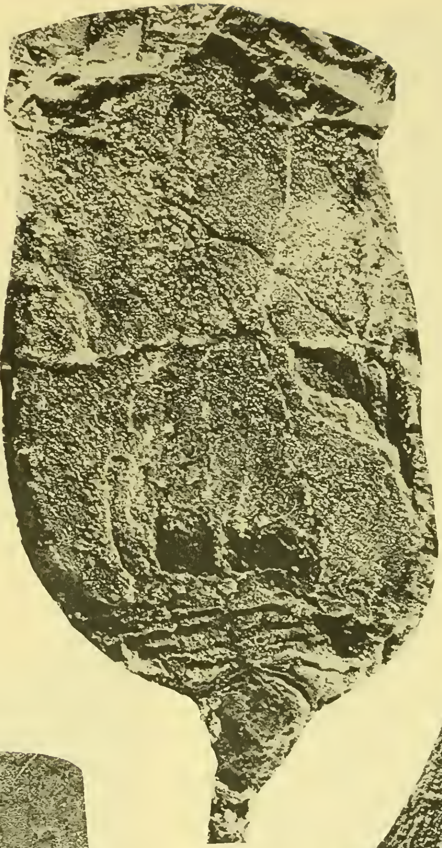

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CONFLICTING AGE DETERMINATIONS SUGGESTED BY FORAMINIFERA ON YAP, CAROLINE ISLANDS

By

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CONFLICTING AGE DETERMINATIONS SUGGESTED BY FORAMINIFERA ON YAP, CAROLINE ISLANDS[1]

W. Storrs Cole[2], Ruth Todd[3], and Charles G. Johnson[3]

ABSTRACT

The Map formation of Yap contains a good fauna of smaller planktonic and larger Foraminifera. This association of two kinds of Foraminifera, found in two samples, is the first such association observed by which comparison is possible between known and widely distributed zones of both larger and smaller Foraminifera in the Pacific.

The larger Foraminifera indicate correlation with formations on Guam and Fiji that are dated as Tertiary *f* (Miocene), and that overlie rocks of Tertiary *e* (early Miocene) age. The planktonic Foraminifera indicate correlation with a formation on Saipan that was provisionally dated as Tertiary *d* (late Oligocene) and that unconformably underlies rocks of Tertiary *e* age.

The Map formation is a variable, irregularly bedded, coarse and unsorted breccia and conglomerate with distorted lenses of finer material and channels filled with stratified sandstone. The conglomeratic nature of the Map formation makes reworking of the globigerinids seem a reasonable explanation of the conflicting age indicated by the two parts of the assemblage. However, that explanation is not wholly satisfactory as no source for the older Foraminifera has yet been found on Yap. Local expansion of ranges of index species or changes of sequence of zones that seem to apply consistently elsewhere in the Pacific are not acceptable explanations.

INTRODUCTION

In the many occurrences of Foraminifera that have been recorded from the Pacific Islands, good faunas of both smaller planktonic and larger Foraminifera have not hitherto been found associated in the same sample. Hence the discovery of both together on Yap is of unusual interest in that it seems to permit comparison between sequences that are based independently on larger Foraminifera on the one hand and on smaller Foraminifera on the other.

Although the association of smaller and larger Foraminifera is the rule rather than the exception, rarely is a good fauna of the floating type of smaller Foraminifera found in the same rock sample with a good fauna of the bottom-dwelling larger Foraminifera. Therefore this instance of association of these two kinds of Foraminifera that have proved most useful for age determinations elsewhere in the world is of special interest. However, the results of our comparison are perplexing, for the larger Foraminifera point to a younger stratigraphic age than do the smaller (Table 1).

We are indebted to many of our colleagues for suggestions, helpful advice, and discussions of the problem; in particular to Preston E. Cloud,

---

[1] Publication authorized by the Director, U. S. Geological Survey.

[2] Cornell University and U. S. Geological Survey.

[3] U. S. Geological Survey.

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GEOLOGIC SETTING

Yap is a compact group of four small high islands in the western Caroline Islands, latitude 9°35′ N., longitude 138°10′ E. It is situated near the southern end of the submarine ridge known as the West Caroline Geanticline and on the west side of the West Caroline Trench (Hess, 1948). In order of size and from south to north the islands are: Yap, Gagil-Tomil, Map, and Rumung. The geology of the islands was mapped in detail during 1947-48 by Charles G. Johnson. A later visit was made in 1956 during which additional samples of sandstones from the Map formation were collected, four of which are discussed in this paper. The stratigraphic names used here are slightly changed from those of Tayama's reconnaissances of 1933 and 1934; the chief differences are substitution of the term formation for beds and changing Tomil agglomerate to Tomil volcanics (Tayama, 1935).

The basement rocks, the Yap formation, are dominantly green schists, amphibolites, and phyllites intruded by dikes and masses of serpentinized ultramafic rocks. Overlying the basement rocks and derived from them is a mass of tectonic breccia and water-laid sandstone and siltstone, the Map formation. The paleontologic problem to be discussed is concerned only with this formation, specifically the upper sedimentary part. The Tomil volcanics, composed of andesitic tuffs, volcanic breccias, and lava flows almost completely weathered to red clay, unconformably overlie both the Map and Yap formations. Shallow alluvial deposits occupy the lower reaches of the short valleys, and narrow sandy beaches discontinuously line the seaward shores. A fringing coral reef up to a mile or more in width surrounds the entire group. Tiny Garim Island and two mushroom rocks on the reef flat off the east side of the southern tip of the Yap Island are the only remnants of formerly more widespread raised-reef limestone.

The dominantly amphibolitic tectonic breccia of the lowermost part of the Map formation grades through several feet into coarse, rubbly to blocky, unsorted conglomerate that contains distorted lenses of fine to coarse gravelly sand. Bedding in the conglomerate is irregular and rough where discernible. The entire aspect of the deposits where fully exposed

Table 1.—Comparison of correlations with Saipan and Guam based on smaller and larger Foraminifera.

Indonesian letter time scale	Saipan, Mariana Islands	Yap, Caroline Islands		Saipan, Mariana Islands	Guam,* Mariana Islands	Indonesian letter time scale
		Correlation by smaller Foraminifera	Correlation by larger Foraminifera			
Tertiary *f*	Not present		YM-306 —— [f11898] (younger than Tagpochau limestone)	correlated —→ Not present	Limestone of Tertiary *f* age (correlated with Futuna limestone of Fiji)	Tertiary *f*
Tertiary *e*	Tagpochau limestone			Tagpochau limestone	Limestone of Tertiary *e* age	Tertiary *e*
Tertiary *d* (possibly *e*)	Fina-sisu formation ←	— correlated-YM-306 [f11898] (older than Tagpochau limestone)		Fina-sisu formation	Not present	Tertiary *d*
Tertiary *c*	Not present			Not present		Tertiary *c*
Tertiary *b*	Matansa limestone Densinyama formation Hagman formation			Matansa limestone Densinyama formation Hagman formation	Sediments of Tertiary *c* and Tertiary *b* age	Tertiary *b*

* Section from Cloud (1956) and as modified by Cole (MS. in preparation).

in the sea cliffs along the eastern shore of Map is one of sporadic and sudden deposition accompanied by considerable slumping and sliding. Channels cut in the breccia and conglomerate are filled with stratified, green, friable, angular sandstone and siltstone.

The thickness of the Map formation is variable. It is greatest on Map where it may exceed 75 meters.

The sandstone in channel fillings generally is firm and only locally cemented by calcium carbonate. It is well bedded, with beds 2 to 12 inches thick, but with some massive beds 3 to 8 feet thick. In the well-bedded sandstone, small lenses of conglomerate are common; in the more massive sandstone, conglomerate lenses are rare but pebbles are scattered throughout the mass. The sand is dominantly grains of green hornblende with minor amounts of quartz, feldspar, serpentine, and needles of tremolite.

Masses of very coarse,* angular, green sandstone, cemented in part by calcium carbonate, crop out in several places on the upper slopes of the hills on northeastern Map Island. Such masses were not observed in the sea cliffs. They may be sheetlike deposits more continuous than the channel fillings. Other outcrops of sandstone are found in the interior of Map and Gagil-Tomil. Text-figure 1 shows the distribution of sedimentary rocks of the Map formation and the location of the five samples which contain the faunal assemblages with which this paper is concerned.

LOCALITY DESCRIPTIONS

Sample YM-304 [USGS loc. No. f11896]:

Location: In the path on the ridge top above Nlul, Map Island; 1,100 meters S. 29° W. of Thilimad Island; latitude 9°35′20″ N.; longitude 138°12′22″ E.

Altitude: About 55 meters.

Outcrop: Sandstone, gray, massive, very coarse,* angular, with clay and calcareous cement. No bedding is apparent. Stratigraphic relationships are obscure. About 250 meters southeast of the outcrop are two remnants of deeply weathered volcanic rock that apparently overlie the Map formation.

Sample YM-305 [USGS loc. No. f11897]:

Location: 5 meters up slope from sample YM-304 [f11896].

Altitude: About 56 meters.

Outcrop: Similar to that of YM-304 [f11896].

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* Wentworth classification of clastic particles on the basis of grain size.

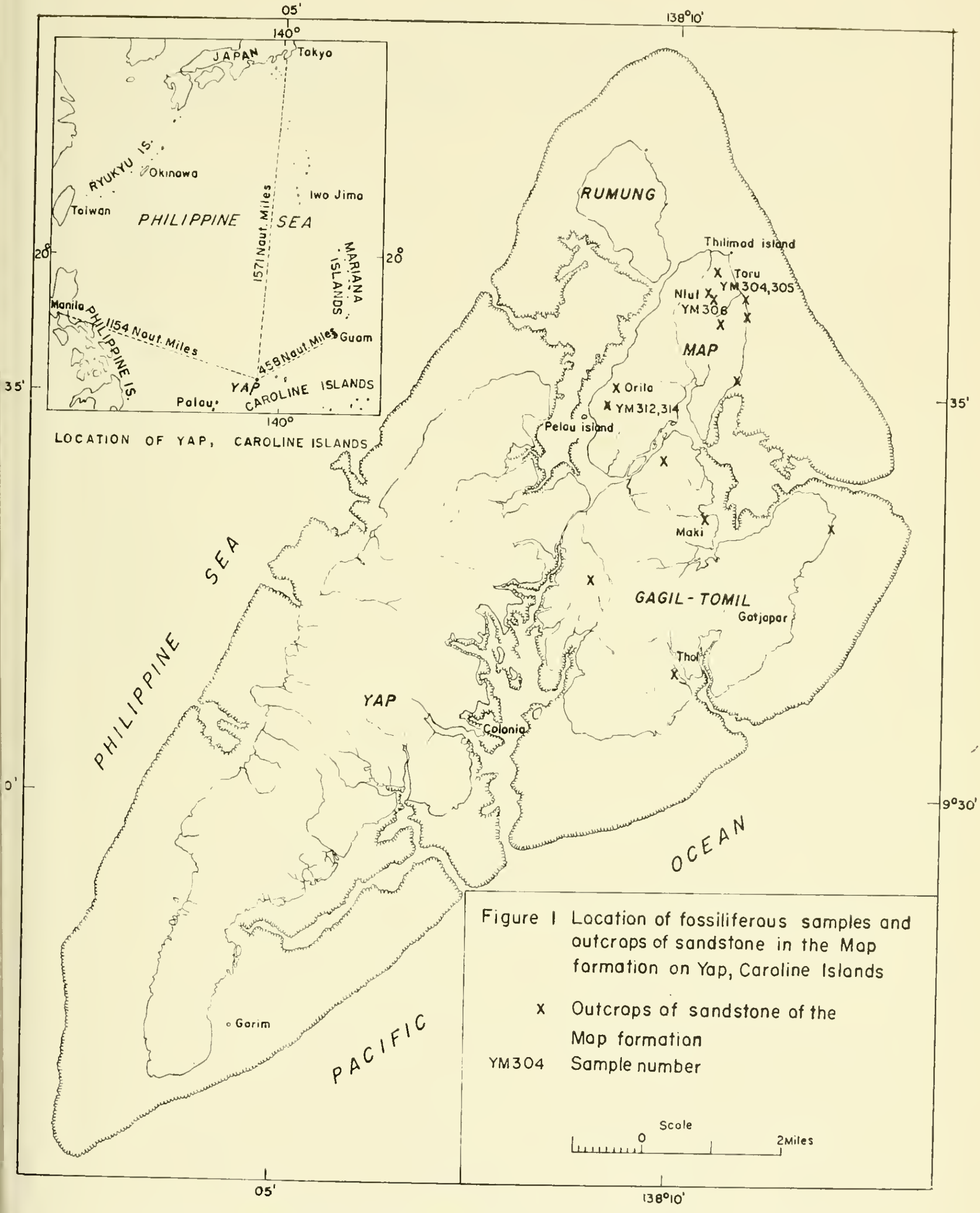

Figure 1 Location of fossiliferous samples and outcrops of sandstone in the Map formation on Yap, Caroline Islands

X	Outcrops of sandstone of the Map formation
YM304	Sample number

Text-fig. 1.—Location of fossiliferous samples and outcrops of sandstone in the Map formation on Yap, Caroline Islands.

Sample YM-306 [USGS loc. No. f11898]:

Location: In the path from Nlul to Woned, Map Island, about 125 meters south of YM-304 [f11896]; 1,200 meters S. 24.5° W. of Thilimad Island; latitude 9°35′16″ N., longitude 138°10′22″ E.

Altitude: About 45 meters.

Outcrop: Sandstone, greenish gray, with white speckles, massive, medium. No bedding is apparent. Stratigraphic relations are obscure. Two remnant masses of deeply weathered volcanic rock apparently overlie the Map formation 200 meters to the east and 100 meters to the southeast of the outcrop.

Sample YM-312 [USGS loc. No. f11899]:

Location: Sample was taken from the center and lowermost part of a ½- to 1-meter cut bank on the north side of the wide path on the hilltop east of Orila, Map Island; 625 meters N. 60° E. of Pelau Island; latitude 9°34′55″ N., longitude 138°9′3″ E.

Altitude: About 50 meters.

Outcrop: Three-fourths to 1½ meters of coarse green, angular sandstone exposed in a cut bank about 6 meters long. At the east end of the bank the coarse sandstone overlies light gray, very fine* siltstone. The contact dips west about 5 degrees. The Map formation is overlain by deeply weathered volcanic rock about 50 meters south of the outcrop.

Sample YM-314 [USGS loc. No. f11900]:

Location: Sample was taken from the middle of the path at same location as YM-312 [f11899]:

Outcrop: An area about 2½ x 3 meters of the coarse sandstone of sample YM-312 [f11899] is exposed in the path. At the east end of the outcrop the contact with underlying light gray, very fine* siltstone strikes N. 10° E. across the path.

PALEOECOLOGIC INTERPRETATION

The physical nature of the sediments that make up the Map formation, as discussed above, imply rather rapid deposition, probably into an area of irregular bottom and considerable slopes, and also probably during a period of concurrent disturbance of the sediments as they were laid down. In addition, the Foraminifera shed a little light on the local conditions of deposition. The discussion that follows refers specifically to sample YM-

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* Wentworth classification.

306 [f11898] and may be applied only questionably to the other samples of the Map formation.

Of the four species of larger Foraminifera recorded from YM-306 [f11898], only one belongs to a genus that is living and that one (*Cycloclypeus*) is known to be an inhabitant of relatively deep water. Cole (1957a, p. 750, table 5) discussed the probable living conditions of Recent examples of this genus and reported that its minimum depth is 24 fathoms and the average depth at which it occurs commonly or frequently is 180 fathoms. The other two genera of larger Foraminifera found in YM-306 [f11898], *Lepidocyclina* and *Miogypsina*, are both extinct. Even though other genera of larger Foraminifera having Recent representatives are probably indicative of shallow average depths (Cole, 1957a, table 5), little weight can be attached to the possibility that *Lepidocyclina* and *Miogypsina* suggest shallow rather than deep deposition.

Of the smaller Foraminifera, those having a floating habit during life provide no direct evidence as to depth of the bottom on which their shells accumulate. The only direct evidence is provided by the benthonic species of smaller Foraminifera. In YM-306 [f11898] a rather varied fauna was found (see Appendix B) of which most of the species were rare and about two-fifths of them are indicators of deep water (100 fathoms or more). Thus, the best estimate about depth of deposition that can be based on both larger and smaller Foraminifera is that the sediments were laid down in moderately deep water, probably of 100 fathoms or more.

CORRELATION BY LARGER FORAMINIFERA

There are five species of larger Foraminifera in the samples from the Map formation, of which four occurred in sample YM-306 [f11898] from which the best fauna of smaller Foraminifera was recovered. These species of larger Foraminifera with their stratigraphic range elsewhere are listed (Table 2) with those from sample YM-306 [f11898] starred.

Inasmuch as three of the species are restricted to Tertiary *f* and inasmuch as the two other species are known to range into Tertiary *f*, the age of the Map formation as indicated by the larger Foraminifera is Tertiary *f*.

CORRELATION BY SMALLER FORAMINIFERA

The fauna of smaller Foraminifera, as listed and illustrated in Appendix B, indicates correlation of the Map formation (at least that

Table 2.—Species of larger Foraminifera and their stratigraphic range

Species	Stratigraphic range	Authority
*_Cycloclypeus_ (_Cycloclypeus_) _indopacificus_ Tan	Tertiary _f_	M. G. Rutten _in_ Bemmelen, 1949, table 13
Lepidocyclina (_Eulepidina_) _japonica_ Yabe	Tertiary _f_	Caudri, 1939, p. 150; Van der Vlerk, 1928, p. 199
*_Lepidocyclina_ (_Eulepidina_) _martini_ Schlumberger	Tertiary _e_ and _f_	Caudri, 1939, p. 150; Van der Vlerk, 1928, p. 200
*_Lepidocyclina_ (_Eulepidina_) _sumatrensis_ (Brady)	Tertiary _e_ and _f_	Caudri, 1939, p. 150; Van der Vlerk, 1928, p. 204
*_Miogypsina_ (_Miogypsina_) _polymorpha_ (L. Rutten)	Tertiary _f_	M. G. Rutten _in_ Bemmelen, 1949, table 12; Mohler, 1949, p. 526

part of it represented by sample YM-306 [f11898]) with the Fina-sisu formation of Saipan (Todd, *et al.*, 1954) and also with a recently reported occurrence (Hamilton and Rex, 1959, p. 789) of a fossil *Globigerina* ooze from a pocket within altered basalt from the edge of Sylvania Guyot in the Marshall Islands.

These three occurrences (Saipan, Sylvania Guyot, and Yap) seem to be the first records in the western Pacific of the *Globigerinatella insueta* zone, a zone set up in Trinidad (Cushman and Stainforth, 1945, p. 12) and originally regarded as of middle to late Oligocene age. Without following the change in concept of the age of this zone, and without discussing the current disagreement about its age in terms of the European time scale, it is sufficient to state here that the *Globigerinatella insueta* zone is now regarded as belonging in the Miocene, probably lower to middle part. A recent zonation of the Miocene (Blow, 1959, chart 1) set up in Venezuela on the basis of planktonic Foraminifera includes this zone with others above and below it. Occurrences of many of the planktonic species upon which Blow's West Indian zonation is based have been reported, having the same relative positions, in both the Mediterranean and the western Pacific regions, thus giving support to the theory of worldwide extension of planktonic Foraminifera zones.

Globigerinatella insueta Cushman and Stainforth, itself, for which the zone was named, seems to be nowhere abundant. In Trinidad and elsewhere in the West Indian region the much commoner species, *Globigerinoides bisphericus* Todd, serves as substitute zone marker for it, and in Venezuela as a means of setting off the upper part of it as a subzone (Blow, 1959, p. 75, 77). *Globigerinoides bisphericus* is present in the Map formation on Yap as well as in the Fina-sisu formation on Saipan and in the *Globigerina* ooze from Sylvania Guyot. In addition, both on Saipan and Yap, rare specimens of *Globigerinatella insueta* were also found, confirming that in the western Pacific, as well as the West Indies, the two species are associated.

EVIDENCE REGARDING AGE

It is generally agreed that over long distances a better correlation theoretically can be made by planktonic species of any group of organisms than by benthonic ones. This concept is based on the assumption that planktonic species have virtually instantaneous world-wide dispersal, at least in the equatorial belt, provided the oceanic areas are connected. Although this concept is widely accepted for the planktonic as compared with the benthonic small Foraminifera, it may be questioned for the planktonic as compared with the larger Foraminifera because most species of larger Foraminifera have shorter recorded stratigraphic ranges than most of the benthonic smaller Foraminifera; possibly a result of more rapid evolution in the more complex larger Foraminifera.

The benthonic Foraminifera, larger as well as smaller, are probably dispersed as adults entangled in masses of drifting seaweed or similar materials (Myers and Cole, 1957, p. 1075), but this means of dispersal could be effective only in shallow-dwelling benthonic Foraminifera. Geographic ranges of the benthonic species that inhabit the deep sea bottom are extended by some other means. Myers' (1936, p. 133) statement " . . . gametes are at the best only a transition stage of brief duration to which the great oceans would constitute a barrier difficult if not impossible to traverse" suggests that probably little dispersion of Foraminifera species takes place during their larval stages. Within a faunal province the migration of the benthonic Foraminifera seems, on distributional evidence, to be as rapid and as efficient as that of the planktonic Foraminifera. However, the migration of benthonic Foraminifera from province to province may be slower and more fortuitous than that of the planktonic Foraminifera.

A problem arises when an attempt is made to reconcile the Yap faunas of smaller and larger Foraminifera with the Indonesian letter time scale.

EVIDENCE OF THE LARGER FORAMINIFERA

It has been well established that faunas of larger Foraminifera similar to that of the Map formation are stratigraphically younger than the faunas of the Tagpochau limestone (Cole, 1957b, p. 324) of Saipan. The Tagpochau limestone contains species, such as *Heterostegina borneensis* van der Vlerk, *Spiroclypeus tidoenganensis* van der Vlerk, *Lepidocyclina* (*Eulepidina*) *ephippioides* Jones and Chapman, and *Miogypsinoides dehaartii* (van der Vlerk), which are widespread throughout the Indo-Pacific region and are restricted to and diagnostic of Tertiary *e*. Moreover, the Viti limestone of Vitilevu, Fiji (Whipple, 1934, p. 146), containing *Lepidocyclina* (*Eulepidina*) *formosa* Schlumberger (= *L.* (*E.*) *ephippioides* Jones and Chapman) is also Tertiary *e* in age, whereas the fauna of the younger Suva limestone is similar to that of the Map formation.

Although a Tertiary *f* fauna was not found on Saipan (Cole, 1957b), such a fauna was found in limestone on Guam (Cole, MS. in preparation). This fauna is similar to that of the Map formation of Yap, and, moreover, it has been proved to be stratigraphically younger than other faunas found on Guam which have typical Tertiary *e* associations of larger Foraminifera and which are correlated with the Tagpochau limestone. Thus, the larger Foraminifera indicate that the Map formation is younger than the Tagpochau limestone of Saipan.

Larger foraminiferal sequences were established as early as 1927 by van der Vlerk and Umbgrove and have been widely accepted (Glaessner, 1942; Cloud, 1956). All the evidence available to date demonstrates that the various faunas of larger Foraminifera are not only widespread within the Indo-Pacific region (Cole, 1957a, p. 748), but also that sequences are similar (Cole, 1957a, p. 744). The age of the Map formation may be reasonably given as Tertiary *f* so far as the evidence from the larger Foraminifera may be considered proof.

EVIDENCE OF THE SMALLER FORAMINIFERA

Correlation of the fauna from the Map formation with that of the Fina-sisu formation of Saipan seems to be the only presently available means by which the planktonic Foraminifera can shed any light on the placement of the Map material in the Indonesian letter time scale.

The Fina-sisu formation, with which the correlation is made, is unconformably overlain by the Tagpochau limestone. The latter is dated by means of larger Foraminifera as Tertiary *e*, and also includes, in its Donni sandstone member, a rich planktonic assemb'age characterized by the following species:

Globigerinoides sacculifer (Brady)
Globigerinella aequilateralis (Brady)
Orbulina bilobata (d'Orbigny)
O. universa d'Orbigny
Pulleniatina obliquiloculata (Parker and Jones)
Sphaeroidinella dehiscens (Parker and Jones)
S. kochi (Caudri)
S. seminula (Schwager)
Candeina nitida d'Orbigny
Globorotalia menardii (d'Orbigny)
G. tumida (Brady)

The above species, recorded as common to abundant in predominantly planktonic Miocene assemblages in the western Pacific (Todd, 1957, table 3 and p. 281; Chang, 1959) are not found in the planktonic assemblage from Yap.

The possibility was considered that the Donni sandstone might not be a member of the Tagpochau limestone but a separate formation overlying it, and that the Donni planktonic assemblage might be younger than the Tertiary *e* assemblages of the Tagpochau limestone. Cloud, Schmidt, and Burke (1956, p. 70) stated that the Donni sandstone member was observed to wedge out into and beneath lower Tertiary *e* limestones of the Tagpochau. Todd (1957, table 3 on p. 279) found several of the same planktonic species in other facies of the Tagpochau that were characteristic of the Donni sandstone member. In view of these two lines of evidence it is not thought likely that the Donni assemblage could be younger than that of the bulk of the Tagpochau limestone. But even if it were, the comparison may be restricted to the Tagpochau limestone which contains a Donni-type assemblage of planktonic Foraminifera and is dated as Tertiary *e* by its larger Foraminifera.

Even without the confirming stratigraphic relationships between these two formations: Tagpochau (including Donni) above and Fina-sisu below, their planktonic assemblages imply separate age; the Donni assemblage being younger than that of the Fina-sisu (Todd, 1957, p. 274-280). Furthermore, regardless of where these assemblages occur, there is an easily recognizable age distinction between the older *Globigerinatella insueta* zone and a younger assemblage containing the species listed above, in particular *Globorotalia menardii* and species of *Sphaeroidinella* (compare Blow, 1959, chart 1). It seems unlikely that the relative age of these two faunas—dissimilar in species composition but identical in facies—are reversed in the Pacific, or that the stratigraphic ranges of their species are much extended in the Pacific, in view of their restriction elsewhere.

Finally, two trial assumptions about the age of the Yap fauna of smaller planktonic Foraminifera will be made, as follows: first, that the Yap fauna is either Tertiary *e* or Tertiary *d*. If we accept the assumption that the Yap fauna is older than that of the Tagpochau limestone, then there is no conflict with already presented evidence on Saipan. Whether the Fina-sisu formation (with which the correlation of the Yap material is made) proves to be Tertiary *e* or Tertiary *d* is an open question. However, as the overlying Tagpochau limestone appears from the evidence of the larger Foraminifera to be no younger than Tertiary *e*, the fauna from Yap is presumably also no younger than Tertiary *e*. The possibility should be left open that it might prove to belong in Tertiary *d*, should the Tertiary *d* (late Oligocene?) age of the Fina-sisu formation eventually be established.

Second, the trial assumption will be made that the Yap fauna is Tertiary *f*. Then both the Fina-sisu (with which the correlation is made) and its unconformably overlying Tagpochau limestone must be no older than Tertiary *f* which is not consistent with the evidence of the larger Foraminifera concerning Saipan.

The evidence of the smaller Foraminifera favors Tertiary *e* or Tertiary *d* as the age of the Map formation, rather than Tertiary *f* as indicated by the larger Foraminifera. It is, therefore, necessary to seek a logical explanation which will satisfy these conflicting age indications.

CONCLUSIONS

One possible explanation which might account for the difference in age determinations between the smaller and the larger Foraminifera is that the larger Foraminifera represent the indigenous fauna, whereas the smaller Foraminifera were reworked from an older deposit on Yap. The nature of the deposit, as described in a previous section, is thoroughly consistent with reworking. However, no earlier sedimentary formation which could have been the source of reworked fossils has been recognized on Yap.

Search for additional evidence of reworking has not been fruitful. M. N. Bramlette, Scripps Institution of Oceanography, to whom material was sent in the hope that the coccoliths and discoasters from inside the individual chambers of the globigerinids might be significantly different from those in the matrix, reported (written communication Oct. 8, 1959): ". . . neither the raw sample nor the picked specimens of globigerinids from YM-306 were much good for my studies. The few coccoliths and discoasters in both were much the same, but both had only sparse specimens and these were corroded or with secondary growth."

In sample YM-306 [f11898] there is no strong indication of mixture of deep-living and shallow-living forms. Moreover, as discussed in an earlier section, the weight of evidence suggests moderately deep deposition for both parts of the Map fauna. The abundance of the planktonic specimens makes it seem unlikely that such a predominant part of the population would have had its origin in reworking of a previous deposit.

Therefore, lacking evidence of the existence of an earlier deposit and lacking conclusive evidence of reworking, other possible explanations of the age discrepancy between larger and smaller Foraminifera must be sought.

One such explanation is that in the Pacific area the zone of an index species might be locally expanded so that particular species here used for restricted age indicators are not narrowly limited stratigraphically on Yap. Such an expanded stratigraphic range of species of various organisms in the Indo-Pacific region has been long recognized (Vaughan, 1924, p. 685). Examples of this phenomenon are *Tubulogenerina tubulifera* (Parker and Jones) and *Valvulammina globularis* (d'Orbigny), both Eocene markers in the Paris Basin and known from the Miocene of the Marshall Islands drill holes; and the genus *Bolivinella* extinct in post-Oligocene rocks of North America but living in the Indo-Pacific. We know of no such examples, however, among planktonic Foraminifera. Introduced species, even planktonics, may have different ranges within the region into which they are introduced than in their areas of origin, and it is not always possible to determine which of these regions is the area of origin.

Although the possibility was considered that the ranges of the Foraminifera within wide areas of the Pacific basin might vary from place to place, the evidence of essentially similar sequences of larger Foraminifera has been reported from so many different localities that this possibility is rejected.

For the smaller Foraminifera similar evidence in the Pacific is, so far as known at present, less complete and not widespread. But the evidence is not lacking; Saipan (see Table 1) provides the best sequence of good planktonic faunas (Eocene, Oligocene? and Miocene, separated on stratigraphic grounds) known at the present time in the Pacific, and here the succession is the same as that known elsewhere in America and Europe. Furthermore, four of the West Indian planktonic zones are known in Japan (Shoshiro Hanzawa, written communications, Sept. 26 and Oct. 9, 1959) having the same relationships to each other in Japan as they do in the West Indian region where they were originally established. That these four planktonic zones are placed higher in the Indonesian letter time scale in Japan than they are on Saipan on the basis of their relationships to larger Foraminifera zones is not so important as their occurrence in Japan with their order as expected and not reversed. Therefore, although we recognize the probability of Foraminifera zones having different absolute ages from place to place, we do not, on the basis of present knowledge, consider it likely that the major zones of planktonic Foraminifera have different relative positions in the Pacific than they have elsewhere, or that they are recurrent.

These rejected possibilities leave us with scarcely anything more than the conclusion that we cannot explain the conflicting evidence of age from the larger and smaller Foraminifera on Yap.

More data correlating the ranges of smaller Foraminifera with those of the larger Foraminifera are needed. In fact, correlation between the ranges of all species, regardless of group, are a pressing need in stratigraphic paleontology. Until such studies are made, extreme caution is indicated in long distance correlation, particularly when only one or another group of specialized organisms are used.

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APPENDIX

A. LARGER FORAMINIFERA FROM YAP

W. Storrs Cole

INTRODUCTION

Larger Foraminifera have been reported from Yap by Tayama (1935; 1936). He recorded the presence of *Miogypsina* in the Map formation and of *Cycloclypeus* in the Garim formation. Asano (1939, p. 546, 549) correlated the beds with *Miogypsina* of Yap with the Miocene limestones of Saipan and other islands and those with *Cycloclypeus* with Pliocene and Pleistocene limestones found elsewhere in the mid-Pacific. Recently, Hanzawa (1957, p. 32, 93) recorded the presence of *Nephrolepidina* sp. and *Miogypsina* sp. in the Map formation and illustrated three specimens.

Charles G. Johnson collected numerous samples from Yap of which several yielded larger Foraminifera. Their presence was noted first in certain thin sections made from the Map formation. Later, samples from this formation were disintegrated and matrix-free specimens were obtained for oriented thin sections. It was not possible to obtain matrix-free specimens from the Garim limestone, therefore, its fauna is known only from thin sections.

The species and the localities from which they came from the Map formation are shown in the table on the following page.

Although the fauna is small, this part of the Map formation is assigned definitely to Tertiary *f*. (Miocene). The fauna is a younger one than that of the Tagpochau limestone (Cole, 1957 b, p. 324) of Saipan which was assigned to Tertiary *e*. The Map formation correlates approximately with a Tertiary *f* limestone of Guam (Cole, MS.,), the Suva and Futuna formations (Ladd and Hoffmeister, 1945, p. 26) of Fiji and the Mentawir beds or lower Balikpapan layers (Marks, 1957, p. 9) of eastern Borneo.

Certain samples (as YM-311) from the Map formation contain thin seams of lignitic material. These samples seemingly are without Foraminifera.

During this investigation John T. Stark submitted for examination thin sections of xenoliths from a volcanic breccia on Truk (locs. Eo-102 and Ud-170). Although matrix-free specimens were not studied from this

Species from the Map formation

Species	Locality				
	YM-304 [f11896]	YM-305 [f11897]	YM-306 [f11898]	YM-312 [f11899]	YM-314 [f11900]
Cycloclypeus (*Cycloclypeus*) *indopacificus* Tan	x		x		
Lepidocyclina (*Eulepidina*) *japonica* Yabe	x				
martini Schlumberger	x		x		
sumatrensis (Brady)	x		x		
Miogypsina (*Miogypsina*) *polymorpha* (L. Rutten)	x	x	x	x	x

material, the species are similar to those found in the Map formation of Yap.

Numerous thin sections from two localities (YY 89 and 90) representing the Garim limestone were available. This limestone apparently has a sparse population of larger Foraminifera. There were, however, a sufficient number of accidental sections of *Cycloclypeus* (*C.*) *carpenteri* Brady in the thin sections from locality YY 89 to identify this species. In addition from this same locality one undoubted specimen of *Baculogypsina sphaerulata* (Parker and Jones) was found. The only other Foraminifera in the thin sections were a few *Amphistegina* sp. (YY 89) and one peneroplid (YY 90).

Although the fauna is small, the Garim limestone apparently represents a reef limestone of Pleistocene age.

The specimens are deposited in the U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

Family **Camerinidae**

Genus **Cycloclypeus** W. B. Carpenter, 1856

Subgenus **Cycloclypeus** W. B. Carpenter, 1856

Tan (1932) erected numerous specific and subspecific names in an intensive study of specimens of this subgenus from abundant material from the Malay Archipelago. He based his classification on the external appearance of the test, on a statistical analysis of the number of periembryonic chambers between the embryonic chambers and the annular chambers, and on the size of the embryonic chambers. Although Tan established without question that the number of periembryonic chambers do decrease and that the size of the embryonic chambers does increase from stratigraphically older to younger populations, this progression can not be used for the precise stratigraphic determinations implied by Tan. Moreover, it is impossible to recognize the numerous subspecies which he proposed because in a given population there is within limits complete gradation between specimens with varying number of periembryonic chambers, size of embryonic chambers, and external appearance.

Although it is impossible to revise Tan's classification completely without studying his material, it is possible to suggest that most of his species and all of his subspecies can not be distinguished. It is doubtful if there are more than four recognizable species in the subgenus *Cycloclypeus,* namely, *C.* (*C.*) *koolhoveni* Tan (Tertiary *c* and *d*), *C.* (*C.*) *eidae* Tan (Tertiary *e* and Tertiary *f*), *C.* (*C.*) *indopacificus* Tan (upper Tertiary *e*, Tertiary *f* and probably Tertiary *g*), and *C.* (*C.*) *carpenteri* H. B. Brady (probably Tertiary *g* to Recent).

As Tan did not recognize certain earlier proposed specific names for *Cycloclypeus* for he thought they could not be applied because of inadequate original descriptions, it will be necessary to restudy the types of these older disregarded species. It will be possible after this is done to determine which of the specific names used by Tan are synonyms.

The suggested reduction in species of *Cycloclypeus* conforms more nearly to Caudri's (1932, p. 180) early classification of the subgenus. Hanzawa (1957, p. 48) recently considered that her classification was better than that proposed by Tan. Other references expressing doubt concerning Tan's classification are Cole (1945, p. 278) and Drooger (1955, p. 415).

Cycloclypeus (Cycloclypeus) indopacificus Tan Pl. 11, figs. 1, 3, 4, 9

1930. *Cycloclypeus neglectus* var. *indopacificus* Tan, Mijningenieur, Jaarg. 11, p. 235, 236.

1932. *Cycloclypeus indopacificus indopacifica* Tan, Nederdandsche Akad. Wetensch. Meded., no. 19, p. 66-67, pl. 19, fig. 1; pl. 22, fig. 10; pl. 23, fig. 2.

1932. *Cycloclypeus postindopacificus postindopacifica* Tan, *idem*, p. 66-67, pl. 15, fig. 7; pl. 18, fig. 3; pl. 23, fig. 1.

Four specimens only were found. As the surface of these specimens was weathered, they could be identified only by the internal features of the median sections. The measurements made from these specimens are shown on the following page.

Discussion.—Specimens from Guam Island (Cole, MS.) assigned to this species have five nepionic chambers and specimens from Lau, Fiji, (Cole, 1945, p. 280, 281) had four to six nepionic chambers. The specimens from Yap have four to eight chambers.

In the study of *Cycloclypeus* found on Guam, Cole (MS.) expressed the opinion that, "The variety which Tan named *C.* (*C.*) *posteidae hexaseptus* is sufficiently distinct to be a separate species." He separated *C.* (*C.*) *hexaseptus* from *C.* (*C.*) *indopacificus* by the fact that the nepionic chambers "make slightly more than one complete volution around the embryonic chambers in *C. hexaseptus* and somewhat less than a complete volution in *C. indopacificus.*"

Dimensions	Specimen from locality—			
	YM-304 [f11896], shown on Pl. 11—			YM-306 [f11898], shown on Pl. 11—
	Fig. 4	Fig. 1	Fig. 9	Fig. 3
Diameter mm.	1.6	2.2	2.6	1.2
Diameters of initial chamber μ	230x240	110x120	150x170	190x190
Diameters of second chamber μ	120x340	70x180	100x260	140x290
Distance across both chambers μ	360	200	260	330
First nepionic chamber	Large, undivided	Small, undivided	Small, divided	Large, undivided
Number of nepionic chambers	5	7	8	4
Nepionic coils	1—	1	1+	⅞

As the specimens from Yap are intermediate between specimens from Lau, Fiji, which were referred to *C. hexaseptus* and those from Guam Island which were assigned to *C. indopocificus* in the length of the nepionic coil, they are assigned to *C. indopacificus*, and *C. hexaseptus* is considered to be a synonym of this species.

Occurrence elsewhere.—Java; Lau, Fiji; Guam Island.

Family **Miogypsinidae**

Genus **Miogypsina** Sacco, 1893

Miogypsina (Miogypsina) polymorpha (L. Rutten)

Pl. 11, figs. 2, 6-8; Pl. 12, figs. 4, 5, 8

1911. *Lepidosemicyclina polymorpha* L. Rutten, K. Akad. Wetensch. Amsterdam Verh., p. 1137-1139.

1912. *Miogypsina polymorpha* (L. Rutten), L. Rutten, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 9, p. 207-209, pl. 12, figs. 6-9.

1912. *Miogypsina bifida* L. Rutten, *idem*, p. 209, 210, pl. 12, figs. 10, 11.

1926. *Miogypsina polymorpha spiralis* L. Rutten, Geol.-mijnb. genootsch. Nederland. en Kolonien, Verh., Geol. ser., v. 7, p. 321, 322, pl. 2, figs. 27, 28, 30-34.
1953. *Miogypsina polymorpha* (L. Rutten), Drooger, K. Akad. Wetensch. Amsterdam, ser. B, v. 56, No. 1, p. 106-108, pl. 1, figs. 1-4, 31.
1953. *Miogypsina bifida* L. Rutten, Drooger, *idem*, p. 108, 109, pl. 1, figs. 5-9.
1953. *Miogypsina polymorpha spiralis* L. Rutten, Drooger, *idem*, p. 109.

Numerous specimens of this species were found in several of the samples. Although the exterior of these specimens was weathered so that the details of the surface were obscured the specimens could be recognized as miogypsinids by the fan-shaped outline of the test. Numerous equatorial and vertical thin sections were prepared of which one vertical section and parts of four equatorial sections are illustrated.

The distinctive features of the equatorial sections are the large initial periembryonic chamber which may be larger than either of the embryonic chambers and the numerous, normally elongate hexagonal equatorial chambers. Although the hexagonal chambers are more numerous toward the distal margin of the test, they occur also in the area adjacent to the embryonic chambers. These chambers are interspersed with the diamond to arcuate chambers which are found in most of the other species of *Miogypsina*.

Although the periembryonic coil is developed seemingly only on the distal side of the embryonic chambers, certain specimens have small periembryonic chambers on the proximal side of these chambers. Thus, the periembryonic coil may surround the embryonic chambers except for the proximal edge of the second embryonic chamber which is in direct contact with the marginal fringe.

Measurements of the four equatorial sections are shown on the following page.

Discussion.—L. Rutten (1911) from the vicinity of Balik—Papan bay on the east coast of Borneo described two species of miogypsinids assigning them to a new subgenus *Lepidosemicyclina* which he considered to be a new subdivision of the genus *Orbitoides*. He stated (p. 1139) that *O.* (*L.*) *thecideaeformis* was obtained from "Pulu Balang-strata" and *O.* (*L.*) *polymorpha* came from "Mentawir strata." Later, Rutten (1912) enlarged the description of these species, gave illustrations, and transferred them to the genus *Miogypsina*. At the same time he described a third species under the name *M. bifida*.

Drooger (1953) reëxamined the part of Rutten's original material which was retained in the Mineralogisch-Geologisch Instituut of Utrecht, Measurements of equatorial sections of *Miogypsina* (*Miogypsina*) *polymorpha*

Dimensions	Specimen from—			
	YM-304 [f11896], shown on Pl. 11—		on pl. 12—	M-314 [f11900] shown on pl. 11—
	Fig. 7	Fig. 6	Fig. 8	Fig. 8
Length mm.	2.57	1.77	1.65	2.0
Width mm.	2.0	1.8	1.3	1.6
Embryonic chambers:				
Diameters of initial chamber μ	110x140	90x70	80x90	80x80
Diameters of second chamber μ	90x170	90x120	80x110	70x130
Distance across both chambers μ	215	210	190	170
Diameters of initial periembryonic chamber .... μ	110x80	120x100	140x110	110x80
Equatorial chambers:*				
Radial diameter ... . μ	130	90	80	110
Tangential diameter μ	100	60	70	80

*Hexagonal chambers near distal edge.

thereby adding significant details concerning the three species described by Rutten. Recently, Cole (1957*b*, p. 340; 1957*a*, p. 771) identified specimens from Saipan Island and from samples from drill holes on Eniwetok Atoll with *M.* (*M.*) *thecideaeformis* and discussed this species in detail.

There appears to be agreement that *M. bifida* is a synonym of *M. polymorpha.* Umbgrove (1931, p. 71) placed it in the synonmy of *M. polymorpha*, and Drooger (1953, p. 108) stated "The internal features of *M. bifida* appeared to be practically identical with those of *M. polymorpha.*"

M. (*M.*) *thecideaeformis* has been recorded from Saipan Island (Cole, 1957*b*, p. 324) and the drill holes on Bikini and Eniwetok Atolls (Cole 1957*a*, p. 746) in strata which were assigned to upper Tertiary *e*. In the Malay Archipelago *M. thecideaeformis* has been reported from Tertiary *e* and Tertiary *f*, whereas *M. polymorpha* has been considered to be confined to Tertiary *f*.

In part the extension of the range of *M.* (*M.*) *thecideaeformis* into Tertiary *f* may be the result of misidentification. Drooger (1953, p. 110) stated "Evidently *M. thecidaeformis* mainly differs from *M. polymorpha* in the regular development of the nepionic chambers, and in the development of elongate-hexagonal equatorial chambers at a much later ontogenetic stage, if at all."

Two other species of *Miogypsina* from the Malay Archipelago which develop hexagonal equatorial chambers in the proximal part of the equatorial layer that should be mentioned are: *M.* (*M.*) *polymorpha spiralis* L. Rutten and *M.* (*M.*) *indonesiensis* Tan. Drooger (1953, p. 109) restudied *M.* (*M.*) *polymorpha spiralis* and stated "No definite conclusions about the exact systematic place of this variety can be given, though it is likely that it belongs to *M. polymorpha*," a conclusion with which the writer agrees.

Specimens identified by Cole (1954, p. 599) from the Bikini Atoll drill holes as *M.* (*M.*) *indonesiensis* Tan are not only identical with the illustrations given by Tan of this species but also are similar to the specimens named by L. Rutten *M.* (*M.*) *polymorpha spiralis*. Therefore, it is probable that *M.* (*M.*) *indonensiensis* is another synonym of *M.* (*M.*) *polymorpha*.

Family **Orbitoididae**

Genus **Lepidocyclina** Gümbel, 1870

Subgenus **Eulepidina** H. Douvillé, 1911

1911. *Nephrolepidina* H. Douvillé.

Inasmuch as embryonic chambers of the nephrolepidine and eulepidine shape intergrade and both shapes are found in specimens assigned to a single species, these two subgenera are combined. This change in the subgeneric classification is discussed in detail in an article in press which will be published in "Micropaleontology", volume 6, No. 2 [1960].

Lepidocyclina (Eulepidina) japonica Yabe Pl. 12, figs. 6, 7, 9-11

1906. *Lepidocyclina japonica* Yabe, Geol. Soc. Tokyo, Journ., v. 13, p. 317, 2 text-figs.

1909. *Lepidocyclina tournoueri* var. *angulosa* Provale, Riv. Ital. Paleont., v. 15, p. 90, 91, pl. 2, figs. 13-15.

Typical specimens with few heavy pillars (fig. 7, Pl. 12) were found. Associated with these are specimens with small pillars (fig. 10, Pl. 12). Moreover, certain vertical sections of specimens with heavy pillars do not show the pillars as the section may pass between the pillars (fig. 6, Pl. 12). All of the specimens are similar in every other internal feature.

Although the presence or absence of pillars has been used in the past by authors, either as a specific or a varietal distinction, Cole (1957*c*, p. 42) expressed the opinion that this criterion is not valid, inasmuch as there is normally complete gradation in a given population from individuals without pillars to those with well-developed, heavy pillars. As *L.* (*N.*) *angulosa* represents one end of a series, the other end of which is *L.* (*N.*) *japonica*, these two species are combined.

Occurrence elsewhere.—Vanua Mbalavu, Lau, Fiji; Bobor Zone, West Java; Koetei, east Borneo; Guam Island.

Lepidocyclina (Eulepidina) martini Schlumberger Pl. 12, figs. 1-3

1900. *Lepidocyclina martini* Schlumberger, Geol. Reichs-Mus. Leiden Samml., ser. 1, v. 6, p. 131-133, pl. 6, figs. 5-8.

1945. *Lepidocyclina* (*Nephrolepidina*) *martini* Schlumberger, Cole, Bernice P. Bishop Mus., Bul. 181, p. 288, 289, pl. 25, figs. A-M.

1957. *Lepidocyclina* (*Nephrolepidina*) sp. Hanzawa, Geol. Soc. America, Mem. 66, p. 32, pl. 34, fig. 7.

This species which occurred in the Tertiary *f* limestone of Guam has been redescribed and discussed in a manuscript (Cole, MS.) which should be published soon. As the specimens from Yap are identical with those from Guam additional comments are not necessary.

Occurrence elsewhere.—Madoera; Rembang, Java; Vanua Mbalavu, Lau, Fiji; Guam Island.

Lepidocyclina (Eulepidina) sumatrensis Brady Pl. 11, fig. 5

1958. *Lepidocyclina* (*Nephrolepidina*) *sumatrensis* (Brady), Cole, U. S. Geol. Sur., Prof. Paper 260-V, p. 773-775, pl. 239, figs. 1-4; pl. 241, figs. 1-30; pl. 242, figs. 3-20 [imprint date, 1957] (reference and synonyms).

Occurrence elsewhere.—Under various names this species has been recorded from numerous Tertiary *e* and Tertiary *f* localities in the Malay Archipelago, Saipan and Guam Islands, and from the drill holes on Bikini and Eniwetok Atolls.

B. SMALLER FORAMINIFERA FROM YAP

RUTH TODD

Numerous species of smaller Foraminifera found in the Map formation on the island of Yap are recorded; the planktonic ones illustrated and the benthonic ones merely listed. Although most of the specimens are filled, recrystallized, or covered with a fine crystalline coating, the specimens may be studied as free individuals, and good identifications are possible for most of them. The planktonic fraction of the population of smaller Foraminifera is predominant over the benthonic.

This Map fauna appears to be approximately equivalent in age to the Fina-sisu fauna of Saipan, and both may be attributed to the *Globigerinatella insueta* zone of Trinidad. Age and correlation with other Pacific occurrences are discussed in the main body of the paper.

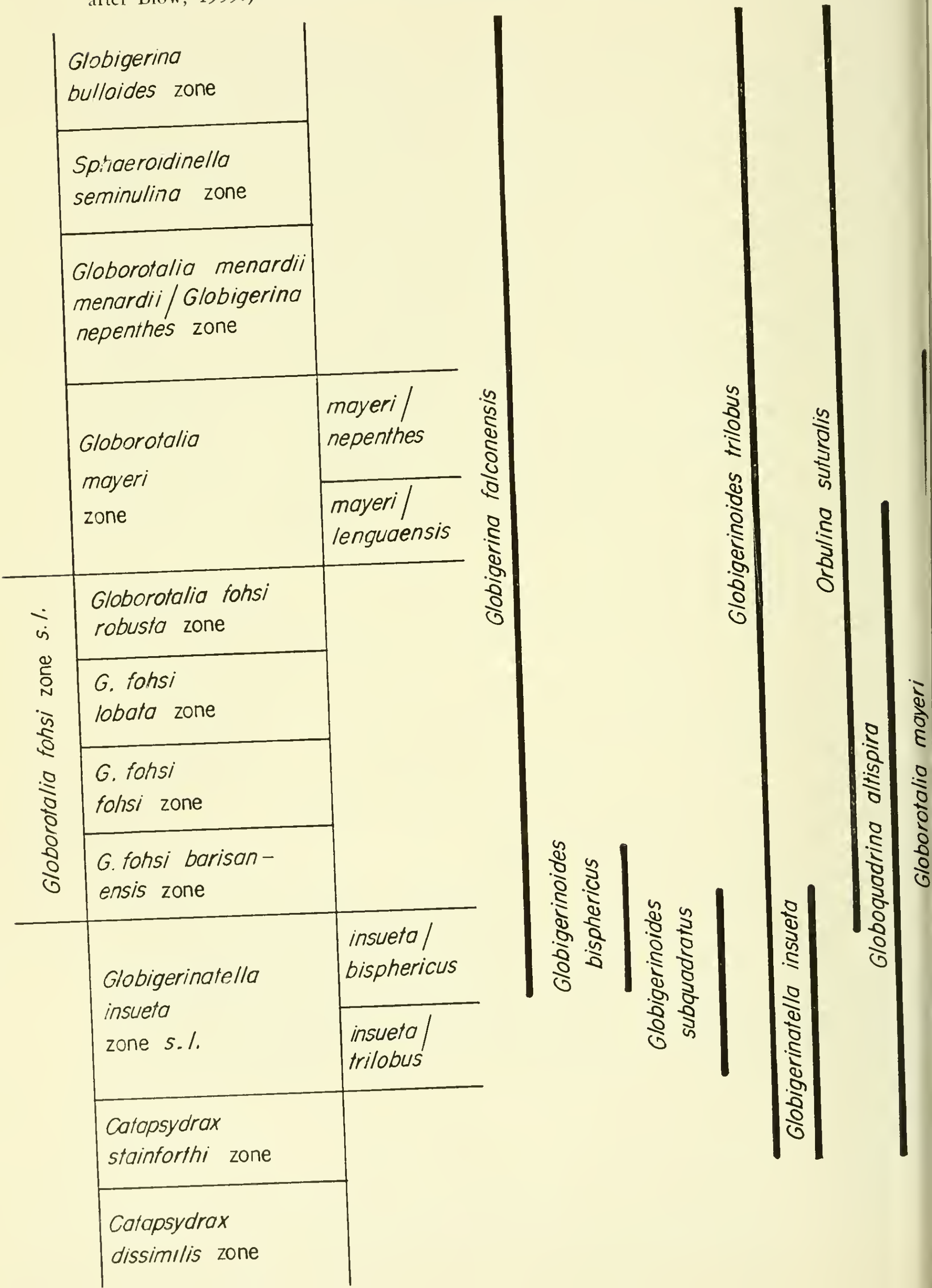
Though two samples (YM-304 [f11896] and YM-306 [f11898]) were studied and appear to contain essentially the same fauna, the specimens from YM-306 [f11898] are much better preserved. Hence the lists that follow pertain solely to YM-306 [f11898]. The following species were found and are listed in approximate order of abundance under each group.

Planktonic species:

**Globigerinoides bisphericus* Todd
Globoquadrina altispira (Cushman and Jarvis)
Globigerinoides trilobus (Reuss)
Globorotalia mayeri Cushman and Ellisor
**Globigerinoides subquadratus* Bronnimann
Globigerinoides aff. *G. ruber* (d'Orbigny)
Globigerina falconensis Blow
**Globigerinatella insueta* Cushman and Stainforth
Orbulina suturalis Bronnimann

The restricted age determination is based on the starred species as shown in Table 3. All the others include the restricted range within their longer ranges. The absence of *Orbulina universa* d'Orbigny in the Yap assemblage, which is the kind of assemblage in which *O. universa* would be expected, is further confirmation of the placement of the Yap material in the *Globigerinatella insueta* zone, which records so far indicate is everywhere older than *O. universa*.

Table 3.—Species of smaller planktonic Foraminifera and their stratigraphic range. (Zonation after Blow, 1959, p. 75, chart 1. Ranges of species in the West Indies after Blow, 1959.)



Benthonic species:
Amphistegina sp.
Anomalinella rostrata (Brady)
Asterigerina sp.
Cassidulina aff. *C. subglobosa* Brady
Gyroidina aff. *G. soldanii* (d'Orbigny)
Pseudoeponides umbonatus (Reuss)
Reussella sp.
Anomalina? sp.
Planulina cf. *P. wuellerstorfi* (Schwager)
Neoconorbina sp.
Eponides sp.
Nonion sp. aff. *N. pompilioides* (Fichtel and Moll)
Bulimina cf. *B. tuxpamensis* Cole
Elphidium sp.
Rosalina sp.
Robulus vortex (Fichtel and Moll)
Bolivina sp.
Rectoglandulina sp.
Epistominella sp.
Cibicides sp. aff. *C. cicatricosus* (Schwager)
Osangularia? sp.

These benthonic species, having longer ranges than the planktonic, do not permit any refinement of the age which is based exclusively on the planktonic species.

SYSTEMATIC DESCRIPTIONS

Family **Globigerinidae**

Genus **Globigerina** d'Orbigny, 1826

Globigerina falconensis Blow — Pl. 13, figs. 1a-b

1959. *Globigerina falconensis* Blow, Bull. Amer. Paleont., v. 39, No. 178, p. 177, pl. 9, figs. 40a-c, 41.

Rare specimens seem identical with the types of this species that was described from the Miocene of Venezuela. There it ranges from the *Globigerinatella insueta/Globigerinoides bisphericus* subzone upward to the *Globigerina bulloides* zone of uppermost Miocene to Pliocene? age.

Genus **Globigerinoides** Cushman, 1927

Globigerinoides bisphericus Todd — Pl. 13, figs. 11a-b

1954. *Globigerinoides bispherica* Todd, *in* Todd, Cloud, Low, and Schmidt, Amer. Jour. Sci., v. 252, p. 681, pl. 1, figs. 1, 4.

This most abundant form among the Yap planktonics has been recorded widely (from Saipan and Sylvania Guyot in the central Pacific; from Trinidad, Ecuador, Venezuela, and Barbados in the West Indian and South American region; and from Algeria, Morocco, Angola, and Sicily in the Mediterranean region). It serves as a means of subdividing the upper part of the *Globigerinatella insueta* zone. In eastern Venezuela its range is rather restricted, as it is found only in the *Globigerinatella insueta/Globigerinoides bisphericus* subzone and the lower part of the overlying *Globorotalia fohsi barisanensis* zone.

Globigerinoides aff. **G. ruber** (d'Orbigny) Pl. 13, figs. 10a-c

A few specimens, having a small spire and three chambers of about equal size comprising the final whorl, may be closely related to *Globigerinoides ruber* (d'Orbigny) but cannot be identified with certainty.

Globigerinoides subquadratus Bronnimann Pl. 13, figs. 9a-b

1954. *Globigerinoides subquadrata* Bronnimann, *in* Todd, Cloud, Low, and Schmidt, Amer Jour. Sci., v. 252, p. 680, pl. 1, figs. 5, 8a-c.

Rare, but not entirely typical, specimens of this species described from the *Globigerinatella insueta* zone in Trinidad and Saipan occur in the Yap assemblage. They are characterized by high arched apertures which distinguish the species from *Globigerinoides trilobus* (Reuss).

Globigerinoides trilobus (Reuss) Pl. 13, figs. 8a-b

1850. *Globigerina triloba* Reuss, K. Akad. Wiss. Wien, Math.-Nat. Cl., Denkschr., v. 1, p. 374, pl. 47, figs. 11a-d.

This species appears to have a relatively long range in the Miocene and probably extends upward into the Pliocene or higher. It is characterized by broad, curved, low-arched apertures. Specimens are fairly common in the Yap assemblage, but preservation is not good enough to verify that they have the wall texture typical of this species.

Genus **Globigerinatella** Cushman and Stainforth, 1945

Globigerinatella insueta Cushman and Stainforth Pl. 13, fig. 12

1945. *Globigerinatella insueta* Cushman and Stainforth, Cushman Lab. Foram. Res., Sp. Pub. 14, p. 69, pl. 13, figs. 7-9.

Only one specimen of this distinctive species was found.

Genus **Orbulina** d'Orbigny, 1839

Orbulina suturalis Bronnimann Pl. 13, fig. 13

1951. *Orbulina suturalis* Bronnimann, Contrib., Cushman Found. Foram. Res., v. 2, pt. 4, p. 135, text-fig. 2, figs. 1-15; text-fig. 3, figs. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, figs. 2-4, 7-12, 15, 16, 19-22.

A single specimen was found. Preservation is not good enough to allow determination of whether the apertural pores are restricted to the sutural areas or are scattered over the final chamber. If the apertural pores are restricted, the specimen belongs in the form described as *Globigerinoides glomerosa* Blow (Blow, 1956, p. 64), the stratigraphic range of which is restricted to approximately the same degree as *Globigerinoides bisphericus* Todd (Blow, 1956, text-fig. 4). If the apertural pores are scattered over the final chamber, the specimen belongs in *Orbulina suturalis*, the stratigraphic range of which extends upward into the upper Miocene or basal Pliocene. Lacking a firm basis for identification as the more restricted species, the specimen is identified as the more wide-ranging one. The lower limits of the ranges of both these species include the upper part of the *Globigerinatella insueta* zone.

Genus **Globoquadrina** Finlay, 1947

Globoquadrina altispira (Cushman and Jarvis) Pl. 13, figs. 3-7

1936. *Globigerina altispira* Cushman and Jarvis, Contrib., Cushman Lab. Foram. Res., v. 12, p. 5, pl. 1, figs. 13a-c, 14.

This species is nearly as abundant in the Yap material as *Globigerinoides bisphericus*. It was described from the Miocene of Jamaica, W. I., and has been widely recorded from the Miocene in various parts of the world (Louisiana, Haiti, Cuba, Dominican Republic, Aruba, Trinidad, Venezuela, Colombia, and Peru in the West Indian and South American regions; in Spain, Italy, and Sicily in the Mediterranean; and in Saipan, Sylvania Guyot, and mid-Pacific seamounts in the Pacific). In the Venezuelan section its range is from the *Catapsydrax stainforthi* zone to the lower subzone of the *Globorotalia mayeri* zone.

Several variations in shape are illustrated.

Family **Globorotaliidae**

Genus **Globorotalia** Cushman, 1927

Globorotalia mayeri Cushman and Ellisor Pl. 13, figs. 2a-c

1939. *Globorotalia mayeri* Cushman and Ellisor, Contrib., Cushman Lab. Foram. Res., v. 15, p. 11, pl. 2, figs. 4a-c.

A few typical specimens were found in the Yap material. This species was described from subsurface Miocene material in Louisiana. It serves as a zone marker in the West Indian region. It has been recorded from various parts of the world, as follows: Cuba, Dominican Republic, Trinidad, Venezuela, Peru, Italy, Sicily, and Algeria. In the Venezuelan section *Globorotalia mayeri* ranges from the *Catapsydrax stainforthi* zone to the top of the *Globorotalia mayeri* zone, including the *Globigerinatella insueta* zone in the lower part of its range.

PLATES

EXPLANATION OF PLATE 11

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1, 3, 4, 9.	**Cycloclypeus (Cycloclypeus) indopacificus** Tan	97
	Parts of median sections, x 40, illustrating embryonic and periembryonic chambers; 1, 4, 9, USNM 626410 a, b, c, from locality YM-304 [f11896]; 3, USNM 626411, from locality YM-306 [f11898].	
2, 6-8.	**Miogypsina (Miogypsina) polymorpha** (L. Rutten)	98
	2. Vertical section, x 20; USNM 626415b, from locality YM-312 [f11899].	
	6-8. Parts of equatorial sections, x 40, illustrating embryonic, periembryonic and equatorial chambers; 6, 7, USNM 626414a, c, from locality YM-304 [f11896]; 8, USNM 626415a, from locality YM-314 [f11900].	
5.	**Lepidocyclina (Eulepidina) sumatrensis** (Brady)	102
	Vertical section, x 20, USNM 626416, from locality YM-304 [f11896].	

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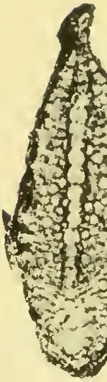

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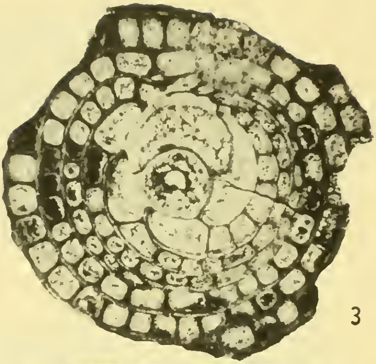

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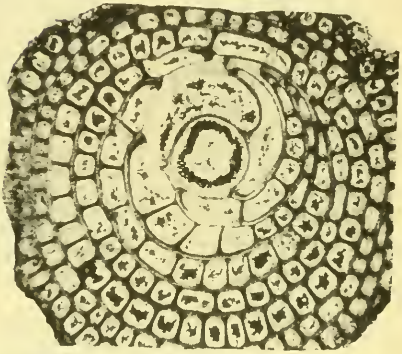

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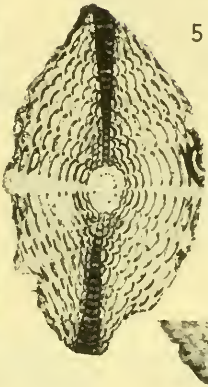

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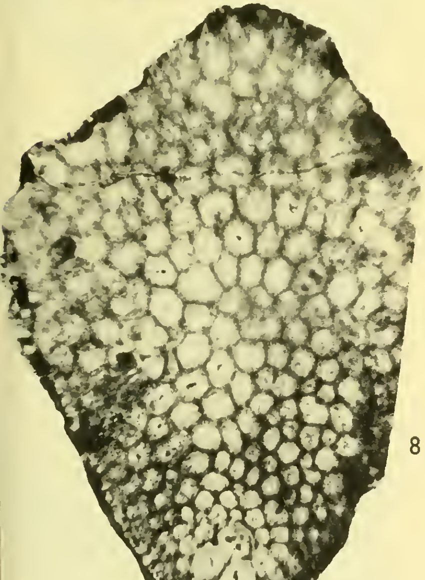

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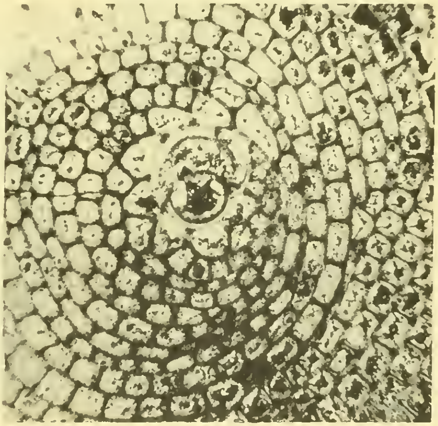

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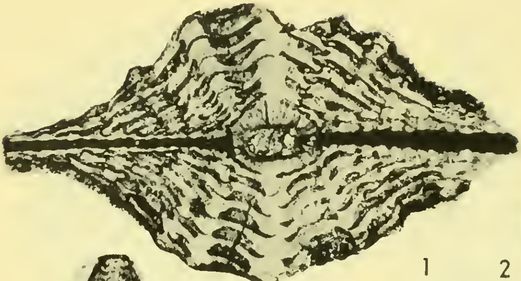
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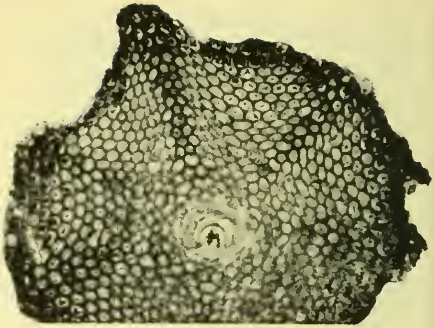
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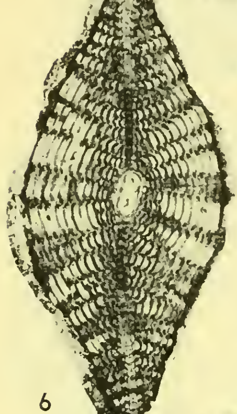
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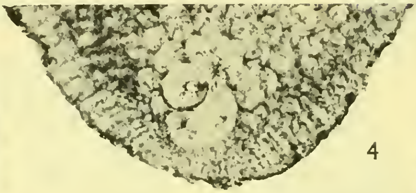
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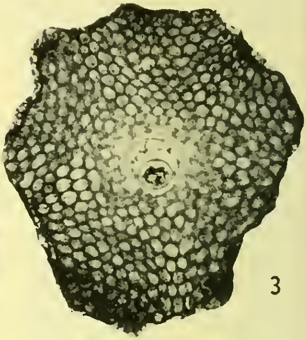
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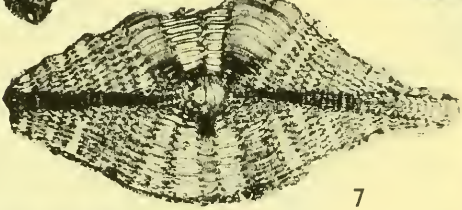
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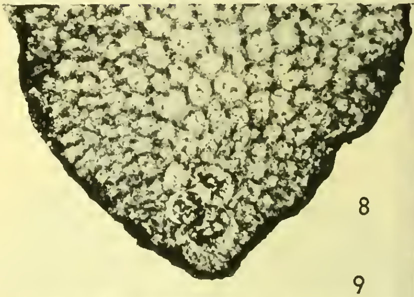
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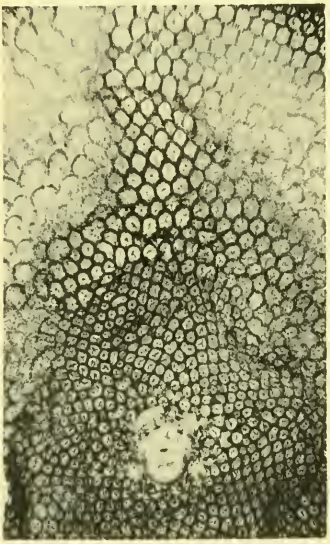
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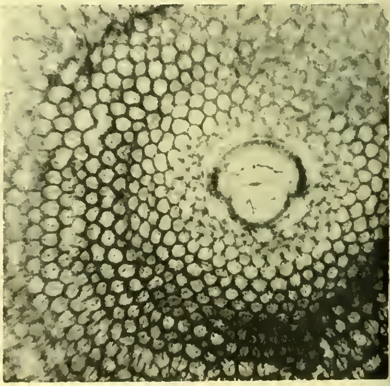
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EXPLANATION OF PLATE 12

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1-3. **Lepidocyclina (Eulepidina) martini** Schlumberger.................. 102

1. Vertical section, x 40, USNM 626409a, from locality YM-304 [11896].

2, 3. Equatorial sections, x 40; 2, specimen with "tryblio-lepidine" embryonic chambers, USNM 626409b; 3, specimen with "nephrolepidine" embryonic chambers, USNM 626409c; from locality YM-304 [f11896].

4, 5, 8. **Miogypsina (Miogypsina) polymorpha** (L. Rutten)............. 98

4, 8. Parts of equatorial sections, x 40, illustrating embryonic, periembryonic and equatorial chambers; USNM 626414b, d, from locality YM-304 [f11896].

5. Vertical section, x 40, USNM 626414e, from locality YM-304 [f11896].

6, 7, 9-11. **Lepidocyclina (Eulepidina) japonica** Yabe.............................. 102

6, 7, 10. Vertical sections, x 20, USNM 626412a, b, c, from locality YM-304 [f11896].

9, 11. Parts of equatorial sections, x 40, illustrating embryonic, periembryonic and equatorial chambers; USNM 626413a, b, from locality YM-304 [f11896].

EXPLANATION OF PLATE 13

(Magnifications all x 68 except figures 3, 4, and 8, x 45.

a, Dorsal view; *b*, ventral view; *c*, side view unless otherwise stated.)

Figure Page

1. **Globigerina falconensis** Blow 105
USNM 627031.

2. **Globorotalia mayeri** Cushman and Ellisor 107
USNM 627038.

3-7. **Globoquadrina altispira** (Cushman and Jarvis) 107
3. USNM 627033. *b*, Side view.
4. USNM 627035. *b*, Side view.
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USNM 627030.

9. **Globigerinoides subquadratus** Bronnimann 106
USNM 627029.

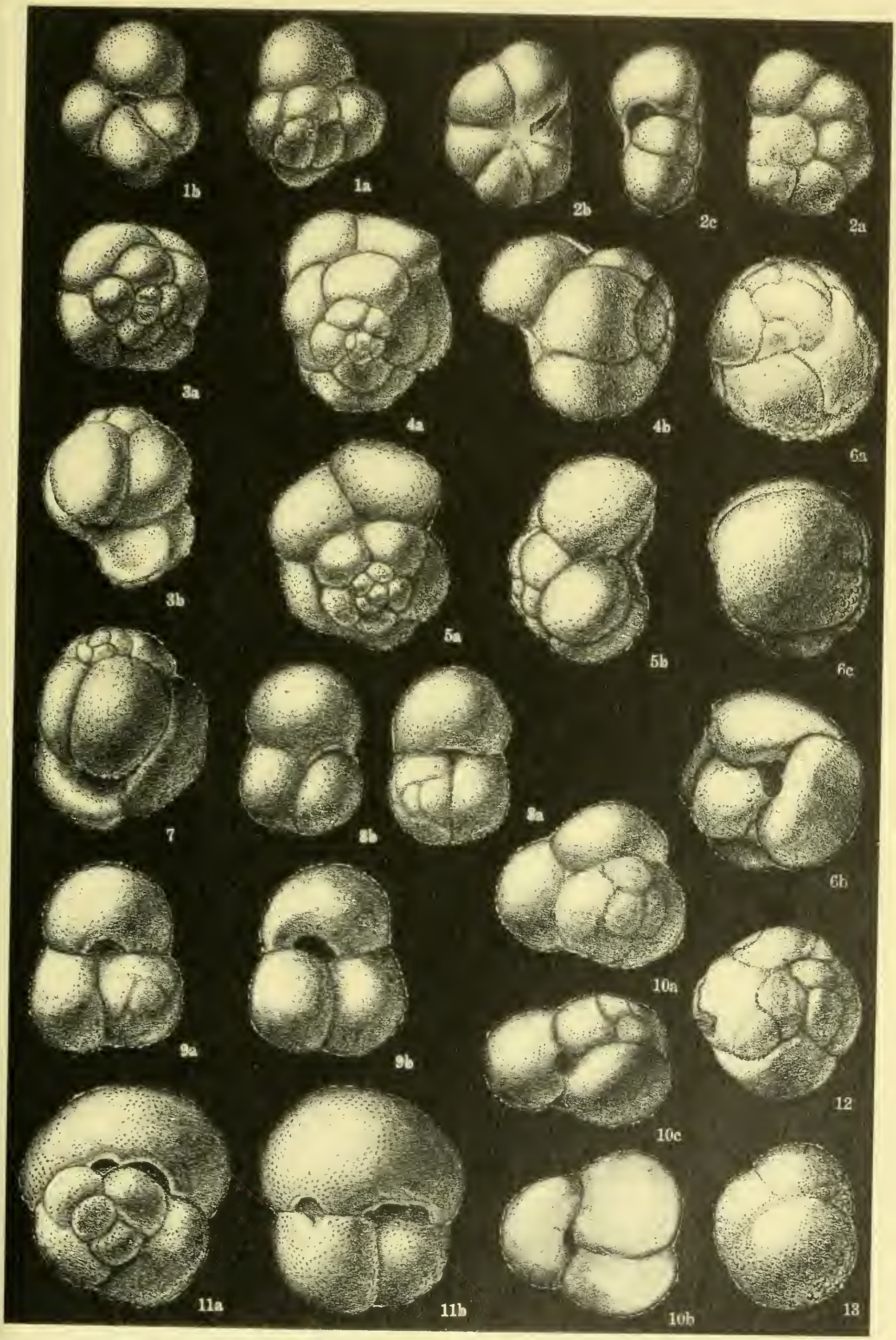
10. **Globigerinoides** aff. **G. ruber** (d'Orbigny) 106
USNM 627037.

11. **Globigerinoides bisphericus** Todd 105
USNM 627028.

12. **Globigerinatella insueta** Cushman and Stainforth 106
USNM 627026.

13. **Orbulina suturalis** Bronnimann 106
USNM 627027.

All specimens from YM-306 [f11898].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CORRECTIONS

Page 68—explanation of Plate 7—read
Rutroclypeus victoriae Gill and Caster, p. 34
Change specimen No. P16787 to P16441

Page 46—under *Victoriacystis wilkinsi*
delete Pl. 7

Page 34—under *Rutroclypeus victoriae*
read Pl. 7

Please insert the included correction in Bulletin American Paleontology, vol. 41, No. 185, 1960.

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SOME SMALL FORAMINIFERA FROM SHELL BLUFF, GEORGIA

By

S. M. Herrick

May 6, 1960

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

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CONTENTS

SOME SMALL FORAMINIFERA FROM SHELL BLUFF, GEORGIA[1]

S. M. HERRICK[2]

ABSTRACT

Microfossiliferous material was collected from the uppermost part of the large oyster bed (Cooke's Unit 6, 1943 description) exposed at Shell Bluff, Burke County, Georgia, in February, 1955. From the material a total of 20 species was identified, 19 of which are illustrated. No new species were found. The age of these fossils is considered to be no older than uppermost Eocene and possibly younger. This famous locality, together with the type locality of the McBean formation, is described and shown on the map.

INTRODUCTION

The foraminiferal fauna at Shell Bluff, Burke County, Georgia, has not previously been described.

During a field conference in February 1955, the writer, accompanied by R. L. Wait, C. Wythe Cooke, and George E. Siple, collected material at the Shell Bluff locality, and the Foraminifera contained in those rocks are described in this paper. The specimens described have been deposited at the U. S. National Museum.

This study is a part of the writer's current subsurface and ground-water studies of the Coastal Plain of Georgia. The investigations were made under the supervision of P. E. LaMoreaux, Chief, Ground Water Branch, U. S. Geological Survey, in cooperation with the Georgia Department of Mines, Mining and Geology, Captain Garland Peyton, Director. Drawings of fossils were made by Mrs. Doryand J. Drake.

Location of exposure.—Shell Bluff is on the Georgia side of the Savannah River approximately 40 miles below Augusta and 8 miles southeast of the town of McBean, Burke County (fig. 1).

Description of section.—According to Cooke (1943),[3] Shell Bluff is composed of approximately 65 feet of sediments of the Barnwell formation of late Eocene age lying conformably upon strata of the McBean formation

---

[1] Publication authorized by the Director, U. S. Geological Survey.

[2] Geologist, U. S. Geological Survey, Atlanta, Georgia; prepared in cooperation with the Georgia Department of Mines, Mining and Geology.

[3] Cooke, C. Wythe, *Geology of the Coastal Plain of Georgia.* U. S. Geol. Sur., Bull. 941, 1943, p. 57.

of middle Eocene age estimated to be 81 feet thick. The Foraminifera were derived from the uppermost part of unit 6, as described in Cook's published section listed below.

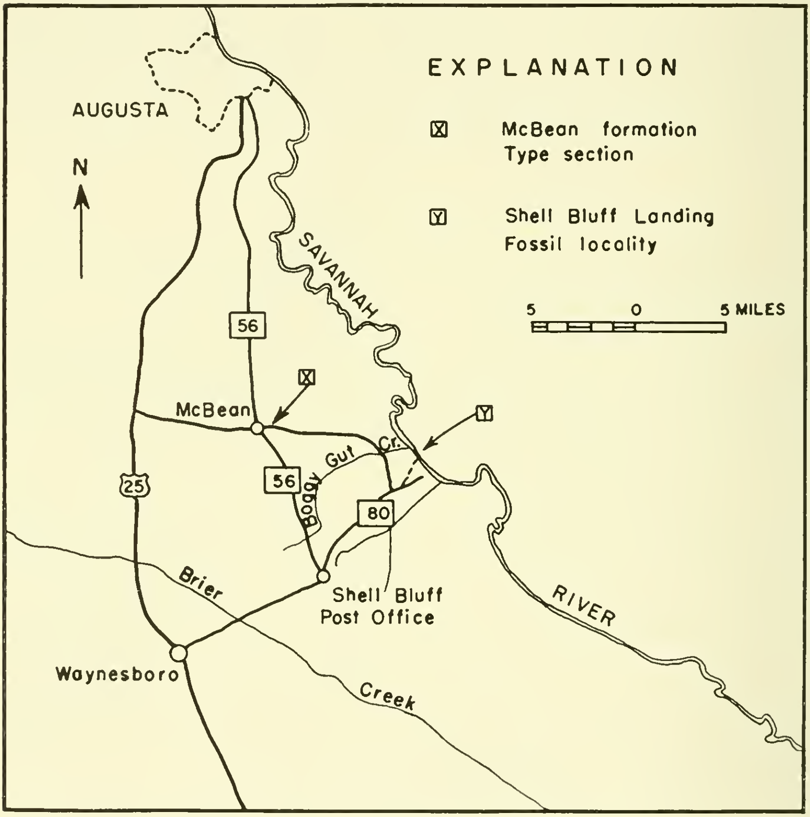

Figure 1.—Index map of Shell Bluff area, Georgia

GENERALIZED SECTION AT SHELL BLUFF

	Feet
Barnwell formation:	
7. Red argillaceous sand to level of upland plain	35
6. Oyster bed (*Ostrea gigantissima* Finch); base 80 feet above zero water level	30
McBean formation:	
5. Concealed interval between the upper and lower bluffs. Covered by talus from the oyster bed and other overlying beds but probably a bed of sand	10
4. Moderately hard to hard light-colored marl, with few fossils	9
3. Ledge of hard brown coquina-like rock, with numerous hollow casts of fossils	6
2. White to purplish sandy limestone made up largely of fossils. Vaughan collected 35 species from it. It is characterized by large specimens of *Ostrea sellaeformis* Conrad	6
1. Sandy and argillaceous marl, not abundantly fossiliferous; in layers differing considerably in color, hardness, and chemical composition. Content of calcium carbonate ranges from less than 50 percent to more than 90 percent. The color as a whole appears light gray, but individual beds have various shades of white, yellow, buff, gray, and greenish yellow, exposed as an almost vertical cliff, rising from water level, in which the harder layers form projecting ledges	50

Lithology of fossiliferous strata.—The rock containing the fossils here described (unit 6) consists of a dense (much calcitized), indurated, fine to medium-grained sandstone (or sandy limestone). The calcium carbonate content of this sandstone appears to be of secondary origin.

Preservation of fossils.—The foraminiferal fauna contained in the uppermost part of unit 6 is apparently preserved by secondary replacement. Hence all the foraminiferal tests observed have a granular appearance which eliminates many of the details necessary for specific determinations. However, it is felt that this difficulty was overcome through the examination of relatively large numbers of specimens representative of the various species.

Age of fauna.—No single species described from Shell Bluff can be regarded as diagnostic of the geologic age of these rocks. The reported occurrences and geologic ranges of the majority of these species suggest an age not older than late Eocene and might possibly be younger.

DISCUSSION OF SPECIES

The following list includes the various species found in unit 6 at Shell Bluff. No attempt is made to describe each species, as adequate descriptions already exist in the literature. Moreover, no attempt is made to include under each species its complete synonomy. Only the references to the original descriptions with several of the subsequent citations—those containing adequate specific descriptions and good illustrations—are included under each species. The stratigraphic ranges of the species are given wherever possible.

Family **LAGENIDAE**

Genus **MARGINULINA** d'Orbigny, 1826

Marginulina triangularis d'Orbigny, variation Pl. 14, fig. 1

Marginulina triangularis d'Orbigny, 1846, Foraminifères fossils du bassin tertiaire de Viènne, p. 71, pl. 3, figs. 22, 23.

The Shell Bluff fossil appears to be a variation of D'Orbigny's species. However, it does not agree with any of the subspecies referred to this species, such as *Marginulina triangularis danvillensis* Howe and Wallace, and *Marginulina triangularis panamensis* Coryell and Embich, both of which were described from strata of late Eocene age. This fossil occurs rarely in the Shell Bluff material but is recorded here for future reference.

Family **POLYMORPHINIDAE**

Genus **GUTTULINA** d'Orbigny, 1839

Guttulina irregularis (d'Orbigny) Pl. 16, fig. 21

Globulina irregularis d'Orbigny, 1846. Foraminifères fossiles du bassin tertiaire de Vienne, p. 226, pl. 13, figs. 9, 10; Cushman and Thomas, 1929, Jour. Paleont., v. 3, p. 177, pl. 23, figs. 2a-c.

Guttulina irregularis Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., v. 77, art. 6, p. 25, pl. 3, figs. 4, 5; pl. 7, figs. 1, 2; Howe and Wallace, 1932, Louisiana Dept. Conserv. Geol., Bull. 2, p. 48, pl. 8, fig. 8.

Polymorphina byramensis Cushman, 1922, U. S. Geol. Sur., Prof. Paper 129, p. 94, pl. 17, figs. 2a-b; 1923, U. S. Geol. Sur., Prof. Paper 133, p. 31, pl. 5, figs. 1-5; Cushman and Schenck, 1928, California Univ. Dept. Geol. Sci., Bull., v. 17, p. 309, pl. 43, figs. 6-8.

Guttulina irregularis Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 24, pl. 9, figs. 13-16; Cushman and Herrick, 1945, Cushman Lab. Foram. Research, Contr., v. 21, pt. 3, p. 59, pl. 9, fig. 22.

This is a widely ranging species and hence is not important as a stratigraphic marker. It occurs rarely in the Shell Bluff material.

Genus GLOBULINA d'Orbigny, 1826

Globulina gibba d'Orbigny, variation Pl. 14, fig. 2

Globulina gibba d'Orbigny, 1826, Annales sci. nat., v. 7, p. 266, No. 10, Models, No. 63; Terquem, 1875, Essai sur le classement des animaux de Dunkerque, p. 38, pl. 5, fig. 15,1878, Soc. geol. France Mem., ser. 3, v. 1, p. 43, pl. 4 (9), figs. 1-5, v. 2, p. 130, pl. 13 (21), figs. 22-27, 1882; Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., v. 77, art. 6, p. 60, pl. 16, figs. 1-4; Howe and Wallace, 1932, Louisiana Dept. Conserv. Geol. Bull. 2, p. 46, pl. 8, figs. 11a, b; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 25, pl. 9, fig. 18.

This is a variation of *Globulina gibba* d'Orbigny and occurs rarely in the Shell Bluff material. Until such time as a sufficient number of specimens are available it does not seem feasible to refer this fossil to a particular subspecies of the species. The species has wide geologic and geographic distribution and hence is of relatively little value as an indicator of geologic age.

Genus SIGMOMORPHINA Cushman and Ozawa, 1928

Sigmomorphina semitecta terquemiana (Fornasini) Pl. 14, fig. 3

Polymorphina amygdaloides (Reuss) var. *terquemiana* (Fornasini), 1902, Accad. Sci. Ist. Bologna, Mem., ser. 5, v. 9, p. 72, fig. 25 (in text).

Sigmomorphina semitecta (Reuss) var. *terquemiana* Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., v. 77, art. 6, p. 129, pl. 33, figs. 4, 5; pl. 34, figs. 2, 3; pl. 35, fig. 1; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 28; Cushman and Herrick, 1945, Cushman Lab. Foram. Research Contr., v. 21, pt. 3, p. 61, pl. 10, fig. 4.

Though this species occurs commonly in the American Eocene, it has a long vertical range and hence is not stratigraphically significant.

Sigmomorphina cf. **williamsoni** (Terquem) Cushman and Ozawa Pl. 14, fig. 4

Polymorphina lactea var. *oblonga* Williamson, 1858, Recent Foram. Great Britain, Roy. Soc. London, p. 71, pl. 6, figs. 149-149a.

Sigmomorphina williamsoni Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., v. 77, art. 6, p. 139, pl. 38, figs. 3a-b.

Sigmomorphina cf. *williamsoni* (Terquem), Cushman, Cushman Lab. Foram Research Contr., v. 20, p. 41, p. 7, fig. 5, 1944; 1951 (1952), U. S. Geol. Sur., Prof. Paper 232, p. 35, pl. 10, fig. 5.

Sigmomorphina williamsoni McLean, 1956, Bull. Amer. Paleont., v. 36, No. 160, p. 338, pl. 42, figs. 1-4.

Specimens referable to this species occur commonly in the Shell Bluff material. This species ranges from the Paleocene to the Recent and hence is of little stratigraphic significance.

Family NONIONIDAE

Genus NONION Montfort, 1808

Nonion advena (Cushman) Pl. 15, fig. 16

Nonionina advena Cushman, 1922, U. S. Geol. Sur., Prof. Paper 129-F, p. 139, pl. 32, fig. 8; Cushman and Applin, 1926, Amer. Assoc. Petroleum Geol., Bull., v. 10, p. 181, pl. 10, figs. 16, 17.

Nonion advena Howe, 1928, Jour. Paleont., v. 2, p. 175 (list).

Nonion advenum Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 30, pl. 11, figs. 1-4; Cushman and Herrick, 1945, Cushman Lab. Foram. Research, Contr., v. 21, pt. 3, p. 61, pl. 10, fig. 9.

Nonion advena Bandy, 1949, Bull. Amer. Paleont., v. 32, No. 131, p. 71, pl. 10, figs. 8a-b.

This species, though originally described from the Oligocene, is common in the late Eocene as well as the Oligocene of the Atlantic and Gulf Coasts.

Nonion inexcavatus (Cushman and Applin) Pl. 15, fig. 17; Pl. 15, fig. 23

Nonionina advena Cushman var. *inexcavata* Cushman and Applin, 1926, Amer. Assoc. Petroleum Geol., Bull., v. 10, p. 182, pl. 10, figs. 18, 19.

Nonion inexcavatum Ellisor, 1933, Amer. Assoc. Petroleum Geol., Bull., v. 17, No. 11, pl. 2, fig. 7; Cushman, 1939, U. S. Geol. Sur., Prof. Paper 181, p. 30, pl. 11, figs. 5-8, 1935; Prof. Paper 191, p. 7, pl. 2, fig. 4; Cushman and Herrick, 1945, Cushman Lab. Foram. Research. Contr., v. 21, pt. 3, p. 62, pl. 10, fig. 10.

This species, originally described from the late Eocene (Jackson) of Texas, is prominent in the middle and late Eocene of the Atlantic and Gulf Coasts. It occurs abundantly and typically in the Shell Bluff material.

Genus ELPHIDIUM Montfort, 1808

Elphidium texanum (Cushman and Applin) Pl. 14, fig. 5; Pl. 15, fig. 14

Polystomella texana Cushman and Applin, 1926, Am. Assoc. Petroleum Geol., Bull., v. 10, p. 184, pl. 10, fig. 7-9.

Elphidium texanum Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 32, pl. 12, figs. 5a-c. Cushman and Herrick, 1945, Cushman Lab. Foram. Research Contr., v. 21, pt. 3, p. 63, pl. 10, fig. 13.

Until recorded by Cushman and Herrick from the middle Eocene of Georgia, this species had not been observed east of Texas, where it has been recorded from the late Eocene (Jackson). It occurs commonly and typically in the Shell Bluff material.

Family **ROTALIIDAE**

Genus **DISCORBIS** Lamarck, 1804

Discorbis hemisphaerica Cushman Pl. 14, fig. 6

Discorbis hemisphaerica Cushman, 1931, Cushman Lab. Foram. Research Contr., v. 7, p. 59, pl. 7, figs. 14a-c; Ellisor, 1933, Amer. Assoc. Petroleum Geol. Bull., v. 17, No. 11, pl. 3, figs. 17, 18; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 43, pl. 16, fig. 13; Howe, 1939, Louisiana Geol. Sur., Geol. Bull. 14, p. 73, pl. 10, fig. 16-19; Cushman and Herrick, 1945, Cushman Lab. Foram. Research Contr., v. 21, pt. 3, p. 67, pl. 11, fig. 3.

This species occurs commonly in the late Eocene (Jackson) of North America and has been reported also from beds of middle Eocene age. It occurs rarely in the Shell Bluff material.

Discorbis assulata Cushman Pl. 15, fig. 13

Discorbis assulata Cushman, 1933, Cushman Lab. Foram. Research Contr., v. 9, p. 15, pl. 2, fig. 2; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 44, pl. 17, figs. 1, 2; Cushman and Herrick, 1945, Cushman Lab. Foram. Research Contr., v. 21, pt. 3, p. 68, pl. 11, fig. 2.

This species was originally described from the Ocala limestone of Georgia and is characteristic of the Atlantic and Gulf Coasts. It has been recorded also from the middle Eocene of Georgia. It occurs commonly in the Sheil Bluff material.

Discorbis cocoaensis Cushman and Garrett Pl. 16, fig. 18

Discorbis subaraucana Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 43, pl. 18, figs. 1a-c.

Discorbis cocoaensis Cushman and Garrett, 1938, Cushman Lab. Foram. Research Contr., v. 14, pt. 3, p. 63, pl. 11, fig. 1.

This species is different from *Valvulineria jacksonensis* Cushman because of its circular outline and large final chamber. The Shell Bluff specimens show eight chambers in the adult coil and hence are different from *Discorbis subaraucana* Cushman.

This species, according to Cushman[4] is diagnostic of uppermost Eocene (Jackson) in the American Gulf Coast. It occurs somewhat rarely in the Shell Bluff material.

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[4] Cushman, J. A., and Garrett, J. B., 1938, Cushman Lab. Foram. Research Contr., v. 14, pt. 3, p. 63.

Genus **VALVULINERIA** Cushman, 1926

Valvulineria jacksonensis Cushman Pl. 14, fig. 7

Valvulineria jacksonensis Cushman, 1933, Cushman Lab. Foram. Research Contr., v. 9, p. 18, pl. 2, figs. 9a-c; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 44, pl. 18, figs. 2a-c.

This species is characteristic of the late Eocene (Jackson) of the American Gulf Coast, and it has been recorded as common in the Ocala limestone of Georgia. It occurs abundantly in the Shell Bluff material.

Family **ANOMALINIDAE**

Genus **ANOMALINA** d'Orbigny, 1826

Anomalina jacksonensis texana (Cushman and Applin) Pl. 15, fig. 12

Discorbina jacksonensis Cushman and Applin, var. *texana* Cushman and Applin, 1926, Amer. Assoc. Petroleum Geol., Bull., v. 10, p. 178, pl. 9, fig. 11; Howe and Wallace, 1932, Louisiana Dept. Conserv., Geol. Bull. 2, p. 77, pl. 14, figs. 3a-c; Ellisor, 1933, Amer. Assoc. Petroleum Geol., Bull., v. 17, No. 11, pl. 4, fig. 8.

Anomalina jacksonensis (Cushman and Applin) var. *texana* (Cushman and Applin), Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 51, pl. 21, fig. 10.

The Shell Bluff specimens are small but show open, somewhat evolute coiling, and hence are tentatively placed under this subspecies.

This form has been recorded from the late Eocene (Jackson). It occurs commonly in the Shell Bluff material.

Anomalina granosa dibollensis Cushman and Applin Pl. 16, fig. 22

Anomalina granosa (Hantken) var. dibollensis Cushman and Applin, 1926, Amer. Assoc. Petroleum Geol., Bull., v. 10, p. 179, pl. 9, fig. 15; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 50, pl. 21, figs. 6, 7.

This subspecies has been reported from the late Eocene (Jackson) of Texas. It occurs rarely in the Shell Bluff material.

Genus **PLANULINA** d'Orbigny, 1826

Planulina cocoaensis Cushman Pl. 14, fig. 8; Pl. 15, fig. 11

Planulina cocoaensis Cushman, 1928, Cushman Lab. Foram. Research Contr., v. 4, p. 76, pl. 10, figs. 1a-c; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 52, pl. 22, figs. 7a-c.

Planulina cocoaensis Cushman has been reported from the late Eocene (Jackson) of Alabama. It occurs rarely in the Shell Bluff material. Figure 11 illustrates what probably is a young form belonging to this species.

Cibicides cf. lobatulus (Walker and Jacob) Cushman
Pl. 14, fig. 9; Pl. 16, fig. 19

Nautilus lobatula Walker and Jacob, 1798, Adam's Essays on the microscope, Kanmacher's ed., p. 642, pl. 14, fig. 36.

Cibicides lobatulus Cushman, 1927, Jour. Paleont., v. 1, p. 170, pl. 27, figs. 12, 13; Hanna and Church, 1928, Jour. Paleont., v. 1, p. 201.

Truncatulina lobatula (Walker and Jacob), d'Orbigny, 1839, in Barker-Webb and Berthelot, Histoire naturelle des iles Canaries, v. 2, pt. 2, Foraminiferes, p. 134, pl. 2, figs. 22-24; d'Orbigny, 1846, Foraminiferes fossiles du bassin de Vienne, p. 168, pl. 9, figs. 18-23; Brady, H. B., 1884, *Challenger* Report, Zoology, v. 9, p. 660, pl. 92, fig. 10; pl. 93, fig. 1; Cushman, 1918, U. S. Geol. Sur., Bull. 676, p. 16, pl. 1, fig. 10; pl. 17, figs. 1-3; Cushman, 1922, U. C. Geol. Sur., Prof. Paper 129, p. 96, 135, pl. 20, figs. 1-3; Cushman, 1923, U. S. Geol. Sur., Prof. Paper 133, p. 40.

Cibicides lobatulus Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 52, pl. 22, figs. 4-6.

Cibicides cf. *lobatulus* (Walker and Jacob), Cushman, 1945, Cushman Lab. Foram. Research Contr., v. 21, pt. 3, p. 72.

This species is widely distributed through the Tertiary and Recent. It is abundant in the Shell Bluff material.

Cibicides pseudoungerianus (Cushman) Cole and Gillespie

Truncatulina ungeriana Brady, H. B., 1884, Challenger Report, Zoology, v. 9, pl. 94, figs. 9a-c (not *Rotalina ungeriana* d'Orbigny); Cushman, 1918, U. S. Nat. Mus., Bull. 103, p. 69, pl. 24, fig. 1.

Truncatulina pseudoungeriana Cushman, 1922, U. S. Geol. Sur., Prof. Paper 129, E, F, p. 97, 136, pl. 20, fig. 9; Cushman, 1923, U. S. Geol. Sur., Prof. Paper 133, p. 40.

Cibicides pseudoungerianus Cole and Gillespie, 1930, Bull. Am. Paleont., v. 15, No. 57b, p.15, pl. 3, figs. 10, 11; Ellisor, 1933, Am. Assoc. Petroleum Geol., Bull., v. 17, No. 11, pl. 5, figs. 3, 4; Cushman, 1935, U. S. Geol. Sur., Prof. Paper 181, p. 52, pl. 23, figs. 1a-c.

This species occurs commonly in the late Cenozoic (Oligocene-Recent). Rare specimens referable to this species were found in the Shell Bluff material.

Cibicides americanus (Cushman) Pl. 16, fig. 20

Truncatulina americana Cushman, 1918, U. S. Geol. Sur., Bull. 676, p. 63, pl. 20, figs. 2, 3; pl. 21, fig. 1.

Cibicides americanus Cole and Gillespie, 1930, Bull. Am. Paleont., v. 15, No. 57b, p. 14, pl. 4, fig. 4; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 61, pl. 12, figs. 5a-c; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175, p. 34, pl. 13, figs. 2a-c; Nuttall, 1932, Jour. Paleont., v. 6, p. 32, pl. 7, figs. 10, 11; Cushman and McGlamery, 1942, U. S. Geol. Sur., Prof. Paper 197-B, p. 75, pl. 7, figs. 8-10.

This species occurs commonly in the American Oligocene and Miocene. Many specimens referable to this species were observed in the Shell Bluff material.

Cibicides americanus antiquus (Cushman and Applin) Pl. 14, fig. 10

Truncatulina americana (Cushman) var. *antiqua* Cushman and Applin, 1926, Am. Assoc. Petroleum Geol., Bull., v. 10, p. 179, pl. 9, figs. 12, 13.

Cibicides americanus (Cushman) var. *antiquus* (Cushman and Applin), 1935, U. S. Geol. Sur., Prof. Paper 181, p. 53, pl. 22, figs. 1, 2.

This subspecies has fewer chambers and more curved sutures than the typical species with which it is associated at Shell Bluff.

Cibicides americanus antiquus (Cushman and Applin) has been reported from the late Eocene (Jackson) of South Carolina and Alabama. It is common in the Shell Bluff material.

Cibicides cf. refulgens Montfort Pl. 15, fig. 15

"Hammonia *Balanus* seu *Balanoidea,*" Soldani, 1789, Testaceographia, v. 1, pt. 1, p. 58, pl. 46, figs. nn. oo.

Cibicides refulgens Montfort, 1808, Conch. Syst., v. 1, p. 122; Cushman, 1928, Cushman Lab. Foram. Research, Spec. Pub. No. 1, pl. 50, figs. 2a-c.

Truncatulina refulgens d'Orbigny, 1826, Am. Sci. Nat., v. 7, p. 279, pl. 13, figs. 8-11; d'Orbigny, 1826, Modeles, No. 77; Brady, H. B., 1884, *Challenger* Report, Zoology, v. 9, p. 659, pl. 92, figs. 7-9; Egger, 1893, Abhandl. kon. bay. Akad. Wiss., Munchen, Cl. II, v. 18, p. 401, pl. 16, figs. 31-33; Goës, 1894, Kongl. Svensk. Vet. Akad. Handl., v. 25, No. 9, p. 89, pl. 15, figs. 775, 776; Bagg, 1912, U. S. Geol. Sur., Bull. 513, p. 83; Cushman, 1915, U. S. Nat. Mus., Bull. 71, pt. 5, p. 30, pl. 12, fig. 2; figs. 33a-c (text); Cushman, 1918, U. S. Geol. Sur., Bull. 676, p. 61, pl. 18, figs. 3a-c; Cushman, 1921, U. S. Nat. Mus., Bull. 100, v. 4, p. 312, pl. 63, figs. 1a-c; Heron-Allen and Earland, 1922, British Antarctic Exped. Zoology, v. 6, p. 207, pl. 7, figs. 23, 28.

Cibicides refulgens Cushman, 1931, U. S. Nat. Mus., Bull. 104, p. 116, pl. 21, figs. 2a-c.

The Shell Bluff specimens are not so flat, dorsally, nor so convex, ventrally, as the typical species. For similar reasons these specimens cannot be referred to *Cibicides planoconvexus* Cushman and Todd. Nevertheless, these specimens are sufficiently convex ventrally as to belong clearly in the *refulgens-westi* group; hence they are tentatively assigned to this species.

Cibicides refulgens Montfort has wide geographic and geologic distribution, particularly in the Tertiary. It is common in the Shell Bluff material.

PLATES

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1. **Marginulina triangularis** d'Orbigny, variation Side view; x 120.	120
2. **Globulina gibba** d'Orbigny, variation Side view; x 120.	121
3. **Sigmomorphina semitecta terquemiana** (Fornasini) Side view; x 120.	121
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5. **Elphidium texanum** (Cushman and Applin) a, Ventral view; b, Peripheral view; x 120.	122
6. **Discorbis hemisphaerica** Cushman a, Ventral view; b, Dorsal view; x 120.	123
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9. **Cibicides** cf. **lobatulus** (Walker and Jacob) Cushman a, Ventral view; b, Dorsal view; x 120.	125
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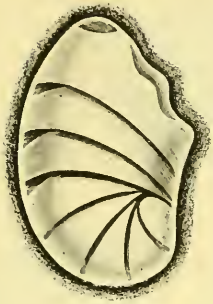
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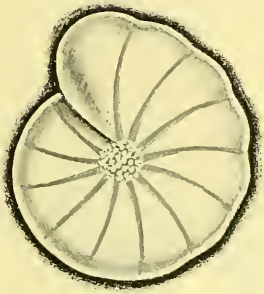
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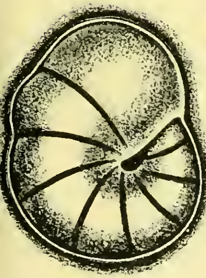
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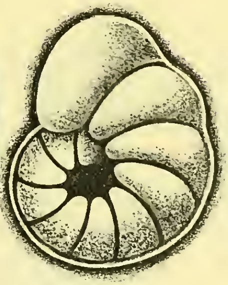
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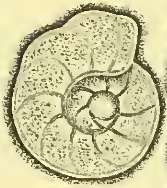
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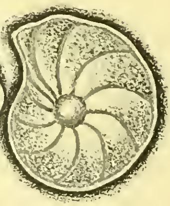
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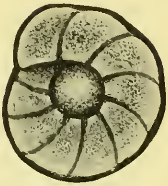
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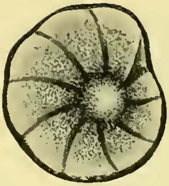
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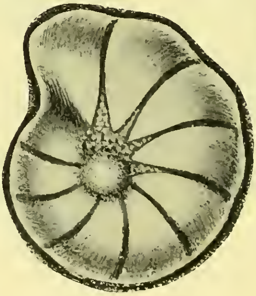
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17b

EXPLANATION OF PLATE 15

Figure Page

11. **Planulina cocoaensis** Cushman 124
a, Dorsal view; b, Ventral view; c, Peripheral view; x 120.

12. **Anomalina jacksonensis texana** (Cushman and Applin) 124
a, Side view; b, Peripheral view; x 120.

13. **Discorbis assulata** Cushman 123
a, Dorsal view; b, Ventral view; x 120.

14. **Elphidium texanum** (Cushman and Applin) 122
a, Side view; b, Peripheral view; x 120.

15. **Cibicides** cf. **refulgens** Montfort 126
a, Dorsal view; b, Ventral view; c, Peripheral view; x 120.

16. **Nonion advena** (Cushman) 122
a, Side view; b, Peripheral view; x 120.

17. **Nonion inexcavatus** (Cushman and Applin) 122
a, Side view; b, Peripheral view; x 120.

EXPLANATION OF PLATE 16

Figure Page

18. **Discorbis cocoaensis** Cushman and Garrett 123
    a, Dorsal view; b. Ventral view; c, Peripheral view; x 120.

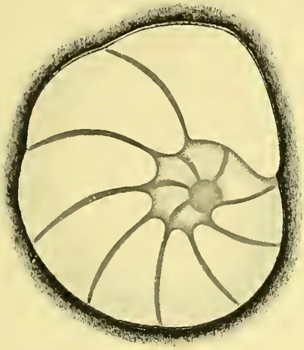
19. **Cibicides** cf. **lobatulus** (Walker and Jacob) Cushman 125
    a, Dorsal view; b. Ventral view; c, Peripheral view; x 120.

20. **Cibicides americanus** (Cushman) 125
    a, Ventral view; b, Dorsal view; c, Peripheral view; x 120.

21. **Guttulina irregularis** (d'Orbigny) 120
    a, Side view; x 120.

22. **Anomalina granosa dibollensis** Cushman and Applin 124
    a, Dorsal view; b. Ventral view; c, Peripheral view; x 120.

23. **Nonion inexcavatus** (Cushman and Applin) 122
    a. Peripheral view; b, Side view; x 120.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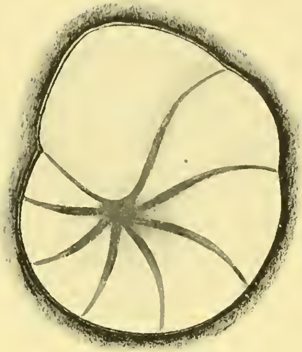
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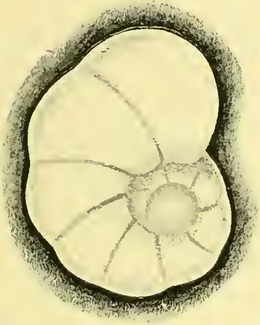
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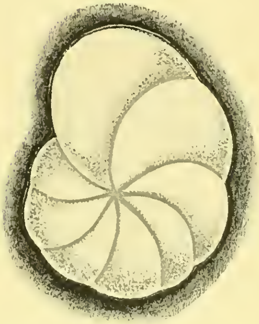
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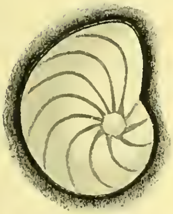
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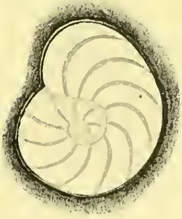
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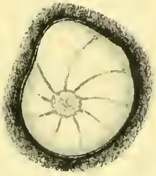
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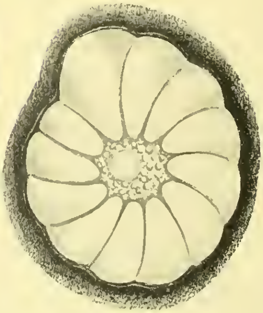
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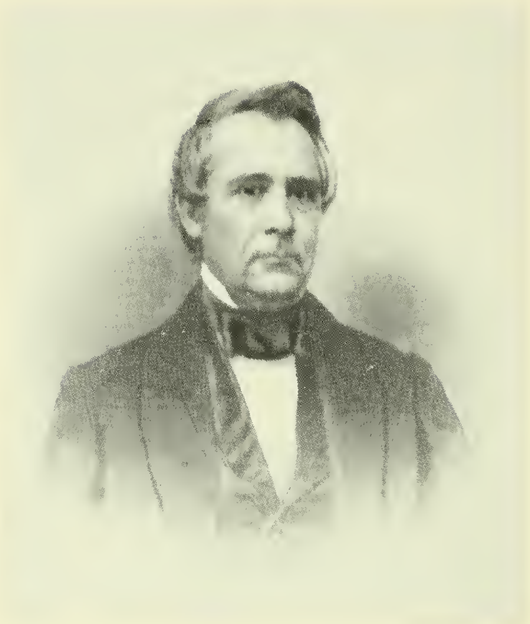

W. Newcomb

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CATALOGUE AND ILLUSTRATIONS OF MOLLUSKS DESCRIBED BY WESLEY NEWCOMB, WITH A BIOGRAPHICAL RESUME

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Ottawa, Ontario

June 30, 1960

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CATALOGUE AND ILLUSTRATIONS OF MOLLUSKS DESCRIBED BY WESLEY NEWCOMB, WITH A BIOGRAPHICAL RESUMÉ

Arthur H. Clarke, Jr.*

ABSTRACT

Wesley Newcomb, M.D. (1808-1892), conchologist and traveller, described 126 species of mollusks (mostly species of *Achatinella* and *Helix*) in 21 papers published between 1853 and 1874. In 1868 his large private collection, containing most of his types, was purchased for Cornell University where it remains today. Although most of Newcomb's species are still considered good, several, which are here figured for the first time, have not been clearly understood.

INTRODUCTION

Wesley Newcomb (1808-1892) has often been called the last of the old school of American conchologists. Socially prominent and highly regarded as a scientist, Newcomb was a friend of Augustus A. Gould, Isaac Lea, Thomas Bland, and many other well-known conchologists active during the third quarter of the nineteenth century. He is probably best known for his work with Hawaiian Achatinellidae of which he described nearly 100 species, but he will also be remembered as the author of many Californian species of "*Helix*" and other mollusks.

Except for an affectionate but brief memorial by R. E. C. Stearns written in 1892, little information regarding Newcomb has been published. The Newcomb Collection of shells, once one of the largest and most complete in America, has remained nearly unnoticed for over 60 years. Fortunately, this collection has been preserved intact and is now at Cornell University.

Information for the following biographical resumé of Wesley Newcomb has been gathered from scattered published reports and from a number of unpublished letters. Notations written by Newcomb in books and on labels have also been of value, and such data have been included in the catalogue of his species. The task of uncovering types in the Newcomb Collection is probably complete with respect to species described by Newcomb or formerly attributed to him, but no finalized list of types received by Newcomb from other authors can be given at this time.

BIOGRAPHICAL RESUMÉ

Wesley Newcomb was born at Pittstown in Rensselaer County, New York, on October 20, 1808, the third son of Dr. Simon Newcomb and Sarah (Follett) Newcomb. His father was of the fifth generation of the family in America. The first was Andrew, also a physician, who came to

*National Museum of Canada, Ottawa, Ontario.

this country in 1635. Young Newcomb undertook the study of medicine and matriculated at White Plains Academy, Rensselaer Institute, and Jefferson Medical College. He received his M.D. degree from Castleton Medical College in Vermont, where he was valedictorian of his class.

While at Rensselaer Institute, Wesley Newcomb came under the influence of Professor Amos Eaton who directed him into the study of shells preliminary to studying paleontology. To quote Dr. Newcomb, "I fancied recent shells would furnish a key to paleontology and I expected in a few weeks of study to master the science of conchology". (Stearns, 1892). Newcomb was so intrigued with conchology that it became a dominating influence, and paleontology was virtually forgotten.

After graduation from Castleton, Newcomb visited Paris for further study of medicine. Upon his return, he began medical practice in Albany in partnership with Dr. Henry Van Antwerp. Later he moved to Troy and was engaged in the wholesale drug business. In February, 1838 he married Mrs. Helen H. Wells Post, the sister of his business partner, and on May 10, 1842 a son Thomas was born.

Details of Newcomb's efforts in conchology are lacking for this period. It is known that he was accumulating a collection and was corresponding with other workers as early as 1845, the date given by C. B. Adams (1851: 203) for *Cyclostoma swiftianum* Newc. MS. According to Stearns, Newcomb visited 21 of the West Indian Islands in 1846 and 1847, and also collected in South America. Some of Newcomb's manuscript names for species collected during this period were published by others, viz.: *Tomigerus cumingi* "Newcomb" Pfeiffer, 1849; *Helix cassiquiensis* "Newcomb" Reeve, 1852; and *Pupa conoidea* "Newcomb" Pfeiffer, 1854.

In the Gold Rush Year 1849 Dr. Newcomb and his family moved to California. Living was especially difficult in that unsettled territory for Mrs. Newcomb whose health was poor. Accordingly, in January 1850 the family sailed for the Hawaiian Islands and settled in Honolulu.

It was in the islands that Newcomb did his most important work. During the next five years he collected extensively and accumulated his famous collection of beautiful Hawaiian tree snails, the Achatinellidae, species of which were common in those early days. According to Hartman (1888), "He collected and reared large numbers of the different species and observed the numerous varieties from a common ancestor." Nearly 40 years later the Newcomb Collection of Achatinellidae was regarded as still the finest in existence (Stearns, 1892).

In May, 1853 Newcomb's first paper was published, a description of 21 new species of *Achatinella*. In 1854 a second paper entitled, "Descriptions of Seventy-Nine New Species of *Achatinella* (Swains.)" appeared, in which 58 additional species were described and the original 21 were redescribed. This paper was first published separately sometime before June 4, 1854, and on November 14 of the same year it was republished, with changes in orthography and pagination, as part of volume 21 of Proceedings of the Zoological Society of London. L. Pfeiffer (June 4, 1854) gave many page references to the first issue of Newcomb's paper and included additional evidence indicating that the 58 new names involved should date from that issue which should be considered a first edition. A more complete discussion of this problem has been published (Clarke, 1958b).

In 1856 Newcomb returned to New York and settled in Albany, where he devoted most of his time to his collection. A second visit to Europe was made in 1857, this time primarily for the purpose of studying the types of *Achatinella* of Ferrusac, Swainson, Pfeiffer, and others. For a portion of this sojourn Newcomb had Augustus A. Gould for a companion. He met Cuming, Reeve, Gray, Sowerby, Adams, Hanley, Owen, and others in London, and Deshayes, Kiener, Bernardi, and Hupé in Paris. After returning to the United States he completed his, "Synopsis of the Genus *Achatinella*" which appeared the next year.

In 1858, Newcomb returned to California and established medical practice in Oakland. Here he continued active field work and research, and although opportunities were less numerous he continued to describe new species. During this period and subsequently, Newcomb collected extensively and travelled as far south as Ecuador. He maintained a lively series of exchanges with most of the well-known conchologists over the world. Many additional species and much type material were obtained in this manner. Many specimens collected by Newcomb were described by other authors, especially Ancey, Gould, Lea, Tryon, and Pfeiffer.

According to Tryon (1865), the Newcomb Collection contained approximately 10,000 species and was then the third most complete in North America, exceeded only by the collections of the Academy of Natural Sciences at Philadelphia and of John C. Jay with 13,000 and 12,000 species respectively. Ezra Cornell, who founded Cornell University three years earlier, purchased the Newcomb Collection in 1868 for $15,000. It was soon transported to Ithaca and set up in the museum in McGraw Hall.

Newcomb supervised the installation of the collection and continued to devote his time to its increase and enrichment until his death.

Numerous letters from Newcomb to Ezra Cornell add much information that is of interest here. After making arrangements for the purchase of the collection and before moving to Ithaca, Newcomb revisited the Hawaiian Islands for the purpose of collecting additional specimens. In a letter to Ezra Cornell dated September 1, 1868, Newcomb wrote, "I arrived in this place [Honolulu] last Monday and have been engaged in gathering shells, all thus far duplicates which will be useful only in exchanges. . . . After using my dredge in the harbor I expect to sail for Kauai, one of the islands to the leeward which I have never visited. My son in law Dr. Hillebrand will accompany me, and we expect to penetrate a district not often visited even by the natives, and may hope to find some novelties in the way of Botanical and Conchological specimens. . . . I shall be on the look out in every *department* of Nat. Science for the Museum of the Cornell University. On the 5th. of Oct. shall leave on the steamer for San Francisco, and as soon as possible *after 4th. Nov.* sail for New York, reaching there about the 1st of Dec. in time for the arrival of the "Cremorne" [a ship carrying the main part of the Newcomb Collection]. Since reaching here I have been successful in obtaining several specimens of *Cypraea tessellata* and *C. sulcidentata* both rare species, also quite a number of South Sea Island and especially *Marquesan* shells of some value."

Again on October 20, 1868, Newcomb wrote, "I arrived from my expedition to the Sandwich Isl. in this place [San Francisco] on the 18th. and make the following general report.

"By dredging *outside* the Harbor of Honolulu in from 10 to 30 fathoms of water I obtained a species of *Modiola* entirely *new* to Science and incomparably the most beautiful of the Genus [*M. Peasei* Newcomb]. Also some 10 species of *Terebra* some of them in quantity for exchange. Several (30 to 50 species) other shells quite rare in Collections were also obtained in perfect condition.

"In the Harbor of Hanele [Hanalei] on the Island of Kauai I dredged only 2 or 3 species of *Terebra*; but I obtained many desirable shells by collecting some 12 miles westward and from the Collection of Mrs. Johnson by purchase. A vessel arriving from Enderbury Isl. enabled me to purchase some fine Cones of great rarity at my own price. Upon the whole my success exceeded my expectations the result being a trunk of large size well filled (no. 46). [He described acquisition of botanical specimens and purchase of "The Friend", "The Hawaiian Spectator" and other rare publications on Hawaiian history.]

"I propose to remain here until after election as my friends in Oakland insist upon my aid in the Canvas for Grant and Colfax. . . . On the steamer of the 6th of Nov. I expect to leave and spend a week or two dredging in the Bay of Panama & thence to New York."

Newcomb spent 10 days in Panama, but the rainy weather made collecting difficult and only a few species new to his collection were obtained. On December 9, in a letter written from New York, Newcomb announced the arrival of the ships Cremorne and Valparaiso bearing the collection, and inquired about working conditions in the new McGraw Hall.

In response to a request for information, G. W. Tryon wrote to Newcomb on January 4, 1869,

". . . I think that you will have great difficulty in preserving your specimens if they are to be handled by students in the manner you describe. My opinion is, decidedly, that such a course should not be permitted by *any* institution. Duplicate specimens only, should be handled—a type series should be arranged in glass cases, locked up, and the key *mislaid.* Small specimens might be protected by enclosing them, *with the labels* in glass tubes closed at the open end by cork dipped in hot sealing wax. Mounting on glass *will not answer.* We propose to mount our large specimens on Card board printed to order—and made to fit the trays exactly. . . ."

Tryon's advice was sound and Newcomb followed it, spending much of his time during the following years preparing tablets for exhibition.

While waiting for the arrival of cardboard trays and other supplies, Newcomb spent the time "in examining the public and private Collections in Boston, Cambridge, Salem, and New Bedford" and in visiting the Academy of Natural Sciences and the Smithsonian Institution. In two letters written from his father's home in Lansingburgh (now Troy), New York, dated February 6 and 26, 1869, Newcomb expressed disappointment at the contents and manner of arrangements of these museums. He wrote, "I noticed the same species repeated 8 to 10 times and under 3 or 4 different names, usuing synonyms as designating species. This in a Scientific Collection is unpardonable." This feeling probably accounts for the present absence from the Newcomb Collection of some of the types of Newcomb's Achatinellas which he had synonymized in his "Synopsis" (1858). Types of only a few of these synonymized species were retained under their original names, perhaps indicating that Newcomb later considered them distinct.

During the winter of 1869 and 1870, Dr. Newcomb and his wife collected again in Central America. Newcomb described his experiences in a series of letters to Ezra Cornell. As in former letters, Newcomb's social inclinations and manifest ability to make friends are plainly indicated. He was given much assistance in his expeditions by the Governor of Panama, and was invited by new-found acquaintances to visit Nicaragua and the interior of Ecuador. According to one of his letters, he also collected on Navassa Island. In addition, collections were made also at Taboga and Flamenco Islands in Panama Bay, and in Costa Rica, Nicaragua, and San *sic* [El] Salvador. Several days were spent collecting in the Gulf of Fonseca after which Newcomb wrote, "I have pretty thoroughly scraped at the bottom for specimens in Natural History. . . . My collection of shells is so full that I doubt if I can thus far add a single species to the Collection."

Although details are lacking we know that in 1870, at President Grant's request, Dr. Newcomb accompanied a government expedition to Santo Domingo as "Sanitary Expert" and, according to Lamb's Biographical Dictionary, succeeded in rediscovering the rare *Helicina viridis* Lamarck. The next year he was appointed one of the commissioners to examine and report on the Sutro Tunnel near Virginia City, Nevada.

In addition to preparing shells for exhibition, much time was spent in enlarging the collection through exchanges of duplicates with other workers. In an undated report to Professor Burt Wilder, Newcomb wrote that he had recently added 402 species and many varieties to the collection from specimens sent by Thomas Bland, H. H. Smith, James Lewis, Mrs. George Andrews, Henry Hemphill, Mrs. Hillebrand, and many others. The collection was already particularly rich in types received from Ancey, Anthony, Cuming, Hemphill, Nevill, Lea, Pease, Pfeiffer, and Reeve, and contained some lots, including types, from nearly every worker in mollusks active during that period.

In a report to the Trustees of Cornell University dated July 1, 1885, Newcomb estimated the commercial value of the collection at nearly double the original purchase price. He also quoted Isaac Lea as stating that the Newcomb Collection was the most beautiful and best arranged of any in Europe or America.

Although Newcomb made several collecting expeditions in his later years, no published contributions appeared after 1874 when his description of *Mya hemphilli* marked the first appearance of *Mya arenaria* Linné on the Pacific Coast in recent time. From 1886 to 1888, he was instructor in conchology at Cornell. On January 27, 1892, at the age of 83, Dr. Newcomb died of the "grippe" at his home in Ithaca. He was survived by his wife and son.

About 1906, under the direction of Professor G. D. Harris, the Collection was catalogued as part of the Paleontological Museum collections and a card file of species was made. The Newcomb Collection then numbered approximately 16,600 lots, and with the subsequent addition of the excellent Carlotta J. Maury Collection of New York fresh water shells and miscellaneous donations, the total increased to about 17,000 lots. Approximately 25 years later the Collection was partially dismantled and put in storage to make room for expansion of teaching facilities. In 1953 the Newcomb Collection was removed from storage for renovation. At that time the shells were removed from their cardboard placques, retaining Newcomb's original label with each lot. This renovation was partially completed by Mr. Arthur W. Soper and continued from September 1955 to September 1956 by the author. After the reduction of the number of species resulting from the application of modern taxonomic concepts, the collection will still contain well in excess of 10,000 species and subspecies.

A prominent characteristic of most of the material in the Newcomb collection is the lack of precise data, a common fault with early collections. Many of his published localities are similarly vague, and a few of them have been shown to be incorrect (Cooper, 1868; Pilsbry, 1914, 1939). Such errors have been attributed in most cases to incorrect locality data given to Newcomb by other collectors. Mixture of labels came about also by movement of the collection after Newcomb's death.

Newcomb was a meticulous and conscientious worker and described species only after careful study. He was deceived by ambitious artists, however, to the extent that he unwittingly described four "manufactured" species: *Achatinella aplustre, A. hybrida, A. johnsoni,* and *A. venulata.* In addition, a small number of species were based on the mistaken but widely accepted philosophy that no molluscan species could be so widespread as to occur on both the Atlantic and Pacific coasts.

In 1956, Dr. Henry A. Pilsbry, the best qualified malacologist to judge all of Newcomb's work, wrote as follows:

"Newcomb was an excellent conchologist of the old school. Most of the forms defined by him are still held to be valid species or subspecies. His work was done at the time when one of the chief tasks of naturalists was the discovery and definition of species. Until this was well advanced, little sound work on the classification, zoogeography or ecology of mollusks could be accomplished. Newcomb was one of the small group of pioneers of whom Say, Gould, Lea, Conrad, and A. Binney were illustrious examples. Their work cleared the way for later malacologists."

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1855, May 8. *Abstract of descriptions of some animals of Achatinella, and other remarks. Ibid.*, 22, pp. 310-311.

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1855 October. *Descriptions of new species of Achatinella.* Ann. New York Lyceum Nat. Hist., 6, pp. 142-147.

1858, September. *Synopsis of the genus Achatinella.* Ann. Lyceum Nat. Hist. New York, 6, pp. 303-336.

1860, April. *Descriptions of new species of the genera Achatinella and Pupa. Ibid.*, 7, pp. 145-146.

1860, May. *Description of a new species of Helix, from Bougainsville Island. Abid.*, 7, pp. 283-284.

1861, February. *Descriptions of six new species of shells.* California Acad. Nat. Sci., Proc., 2, pp. 91-94.

1861, April. *Descriptions of three new species of shells. Ibid.* 2, pp. pp. 103-104.

1864, March. *Descriptions of nine new species of Helix inhabiting California. Ibid.*, 3, pp. 115-119.

1864, March. *Descriptions of a new species of Pedicularia. Ibid.* 3, pp. 121-122.

1865, January. *Descriptions of new species of land shells. Ibid.* 3, pp. 179-182.

1865, July. *Description of a new species of Helix.* Amer. Jour. Conch., 1, p. 235.

1865, October. *Catalogue of Helices inhabiting the West Coast of America, north of Cape St. Lucas, and west of the Rocky Mountains; together with remarks upon some of the animals, and their special distribution.* Amer. Jour. Conch., 1, pp. 342-350.

1866, January. *Description of a new American species of Helix. Ibid.* 2, pp. 1-2.

1866, January. *Addition to "Catalog of Helices Inhabiting the West Coast of North America, north of Cape St. Lucas". Ibid.* 2, p. 13.

1866, July. *Descriptions of Achatinellae. Ibid.* 2, pp. 209-217.

1870, February. *Descriptions of new species of marine Mollusca. Ibid.* 5, pp. 163-164.

1870, February. *Description of a new American Helix. Ibid.* 5, p. 165.

1874, December. *Description of a new species of shell from San Francisco Bay.* California Acad. Sci. Proc., 5, p. 415.

LIST OF RECENT MOLLUSCA DESCRIBED BY WESLEY NEWCOMB, WITH ORIGINAL CITATIONS AND TYPE LOCALITIES

In the species list, the old name Ranai (now Lanai) has been preserved. In addition, the following abbreviations are used:

AJC	American Journal of Conchology
ALNHNY	Annals of the Lyceum of Natural History, New York.
ANYLNH	Annals of the New York Lyceum of Natural History (an alternate title)
CU	Cornell University Paleontological Museum (Newcomb Collection)
PBSNH	Proceedings of the Boston Society of Natural History
PCANS	Proceedings of the California Academy of Natural Sciences
PCAS	Proceedings of the California Academy of Sciences (a subsequent title for the same society).
S.I.	Sandwich Islands (old name for Hawaiian Islands)
79NSp.	for the first edition of Newcomb's 1854 paper. The date May, 1854 has been used for brevity. Also, since the plate and figure numbers and the remarks are the same in both the first and second editions, the word "ditto" is substituted for these data in citations to the second edition.

All figures of Newcomb specimens published by Newcomb (in *litt.*) or by Tryon (1867) have been cited. Nearly all of Newcomb's achatinellid types and types of his North American species of land mollusks have been figured by Pilsbry, *et al* (1911-1916) and Pilsbry (1939-1948) respectively. These publications are well indexed and citations to figures given therein would be too numerous for inclusion here. Most of the species not figured by one of the above authors are figured here, but in a few cases no specimens were available, and the exact identity of these must remain in doubt for the present.

Original locality data are given in parenthesis after the reference to the literature in which they first appear. Appropriate additional comments by Newcomb on labels or in notes, or published by other early writers, are given in quotes. Corrections and additions by this author are in brackets.

acuta Newc., *Achatinella*: May, 1854: 79NSp.: 16, pl. 23, fig. 36 (Lehui, Oahu. But a solitary specimen was found. . .) ; PZSL, 21: 142, ditto. "The figure is not the shell forwarded, but a true *A. soror*." (Newcomb, in notes). Three idiotypes, CU 29898 "Maui, S.I.".

adamsi Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 19 (Makaweo, Maui) ; 79NSp.: 11, pl. 22, fig. 20 (E. Maui, at the roots of ferns [in] the almost inaccessable ravines of the mountainous districts around Lahania, W. Maui) ; PZSL, 21: 137, ditto.

agglutinans Newc., *Achatinella obesa* var.: 1854 (May), 79NSp.: 17, pl. 23, fig. 39a (Hale a ka la, Mani *sic* [Maui]) ; PZSL, 21: 143, ditto. Four syntypes, CU 30037 "E. Maui".

affinis Newc., *Achatinella*: 1854 (May), 79NSp.: 16, pl. 23, fig. 35 (Kula, E. Maui) ; PZSL, 21: 142, ditto. Five syntypes, CU 29901 "Haleakala, Maui".

albo-labris Newc., *Achatinella*: 1854 (May), 79NSp.: 23, pl. 24, fig. 56 (Waianoe *sic* [Waianae], Oahu) ; PZSL, 21: 149, ditto. Four syntypes, CU 29902.

alexandri Newc., *Achatinella*: 1865, PCANS, 3: 182 (Insula Sandwich, . . . elevation of 7,500 feet, on West Maui) ; 1866, AJC, 2: 216, pl. 13, fig. 14. Six syntypes, CU 29903.

ampla Newc., *Achatinella*: 1854 (May), 79NSp.: 11, pl. 22, fig. 19 (Kolau, Oahu) ; PZSL, 21: 137, ditto. Four syntypes, CU 29904.

angasiana Newc., *Helix*: 1860, ALNHNY, 7: 283 (Baugainsville *sic* Island).

anthonii Newc., *Achatinella*: 1861, PCANS, 2: 93 (Kauai); 1866, AJC 2: 210, pl. 13, fig. 2. Four syntypes, CU 29905.

apicata "Newc." Pfeiffer, *Achatinella*: 1856 (February), PZSL, 23: 210 (no locality given). Three syntypes, CU 30135 (Oahu). "*A. swifti* Newc. var. *apicata*" (Newcomb, on label).

aplustre Newc., *Achatinella*: 1854 (May), 79NSp.: 21, pl. 23, fig. 51 (Kolau, Oahu); PZSL, 21: 147, ditto.

assimilis Newc., *Achatinella*: 1854 (May), 79NSp.: 22, pl. 23, fig. 53 (W. Mani *sic* [W. Maui]); PZSL, 21: 148, ditto. Five syntypes, CU 29907.

ayresiana Newc., *Helix* 1861, PCANS, 2: 103 (northern Oregon); Tryon, 1867, AJC 3, p. 161, pl. 11, fig. 28 ([type locality emended] Santa Cruz [Island, California]). CU 26038a selected as lectotype (Pilsbry, 1939, p. 127); five lectoparatypes, CU 26038.

baldwinii Newc., *Achatinella*: 1854 (May), 79NSp.: 29, pl. 24, fig. 72 (Ranai); PZSL, 21: 155, ditto.

bicolor "Newc." Pfeiffer *Achatinella* 1859, Monographia Heliciorum Viventium 4: 558 (Manoa Val [ley] insulae Oahu). Listed in synonymy under *A. brevis* Pfr. and not described. Specimen(s) catalogued as CU 30026 but not located. "*A. mustelina* Migh. var. *bicolor*. Identity determined by the animals. W. N." (in catalogue, originally copied from Newcomb's label).

biplicata Newc., *Achatinella*: 1854 (May), 79 NSp.: 30, pl. 24, fig. 75 (Ranai, Sandwich Islands); PZSL, 21: 156, ditto. Seven syntypes, CU 29911.

blakeana Newc., *Helix*: 1865, PCANS, 3: 179 (Insula Niphon-Japan). Three syntypes, CU 26102a.

breweri Newc., *Helix*, 1864, PCANS, 3: 118 (prope "Lake Taho", Cal [ifornia], et montibus septentrionalibus). Lectotype, here selected, CU 26131a (see this paper, Pl. 17, fig. 10) and 8 lectoparatypes (the rest of the type lot) CU 26131 (see Pl. 17, fig. 9), all from "Lake Tahoe, Nevada".

bridgesii Newc., *Helix* 1861, PCANS, 2: 91, ("San Pablo", Cal [ifornia]); Tryon, 1867, AJC, 3, pl. 11, fig. 29. Four syntypes, CU 26132 "Contra Costa Co., Cal [ifornia], Coast Range".

buddii Newc., *Achatinella*: 1854, 79NSp.: 29, pl. 24, fig. 73 (Palolo, Oahu); PZSL, 21: 155, ditto. Five syntypes, CU 29912.

californica Newc., *Pedicularia*: 1864, PCANS, 3: 121 (from a coral growing on a monster crustacean of the genus *Echidnocerus*, which was taken in very deep water at the Farallones Islands [off San Francisco Bay, California]). Holotype, CU 20474 (this paper, Pl. 17, fig. 1).

carpenteri Newc., *Helix*: 1861, PCANS, 2: 103 (Tulare Valley, California). "The type was . . . lost on the 'Golden Gate' " (Cooper, 1868, p. 221).

cassiquiensis "Newc." Reeve, *Helix*: 1852, Conchologica Iconica, 7, pl. 65, No. 334 (Hab. Cassigui, Cuba) ; Pfeiffer, 1859, Monographia Heliceorum Viventium 4: 33 (Hab. Cassiguia *sic* in Demerara [British Guiana], *nec.* in insula Cuba, teste Newcomb).

casta Newc., *Achatinella*: 1854 (May), 79 NSp.: 8, pl. 22, fig. 12 (Ewa, Oahu. Its northern limit is the valley below Mouna Roa, and half a dozen ravines, south, in the district of Ewa.) ; PZSL, 21: 134, ditto. Eight syntypes, CU 29920.

cestus Newc., *Achatinella*: 1854, 79NSp.: 7, pl. 22, fig. 8 (Palolo, Oahu) ; PZSL, 21: 132, ditto. Six syntypes, CU 29925.

concinna Newc., *Achatinella*: 1854, 79 NSp.: 31, pl. 24, fig. 79 (Island of Ranai) ; PZSL, 21: 157, ditto. Five syntypes, CU 29932.

conoidea "Newc." Pfeiffer *Pupa*: 1854, PZSL, 22: 70, (Hab. in Demerara [British Guiana]—Newcomb). Lectotype, here selected, CU 29190a (this paper, Pl. 17, fig. 4) and two lectoparatypes, CU 29190.

cornea Newc., *Achatinella*: 1854 (May), 79NSp.: 15, pl. 23, fig. 32 (no type locality) ; PZSL, 21: 141, ditto. "Waialua" (Newcomb, in notes). Five syntypes, CU 29933.

cornelliana Newc., *Proto*: 1870, AJC 5: 164, pl. 17, fig. 3 *sic* [Pl. 17, fig. 6] (dredged in 12 fathoms of water outside the reef near Honolulu, Sandwich Islands). Holotype, CU 21131 (this paper, Pl. 17, fig. 7).

costata Newc., *Physa*: 1861, PCANS, 2: 104 (Clear Lake, California). Lectotype, here selected, CU 30828a (this paper, Pl. 17, fig. 3) and four lectoparatypes, CU 30827, 30828.

crassa Newc., *Achatinella*: 1854 (May) 79NSp.: 29, pl. 24, fig. 71 (Ranai) ; PZSL, 21: 155, ditto. Five syntypes, CU 29936.

crassilabrum Newc., *Achatinella*: 1854 (May), 79 NSp.: 15, pl. 23, fig. 31 (Waianoe *sic* [Waianae], Oahu) ; PZSL, 21: 141, ditto. Five syntypes, CU 29940.

crebri-striata Newc., *Helix*: 1864, PCANS, 3: 116, (San Clemente Island, Cal [ifornia]). Three syntypes, CU 26377.

cronkhitei Newc., *Helix*: 1865, PCANS, 3: 180 (Klamath Valley, Oregon). Five syntypes, CU 26391.

cumingi Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 25 (Hale-a-kala, Maui); 79 NSp.: 24, pl. 74, fig. 59 (Hale-a-ka-la, Maui); PZSL 21: 150, ditto. Four syntypes, CU 29941.

cumingi "Newc." Pfeiffer, *Tomigerus*: 1849, Zeitschrift für Malacozoologie 6: 67 (Habitat propé Para Brasiliae).

curta Newc., *Achatinella*: 1854 (May), 79NSp.: 18, pl. 23, fig. 43 (Waialua, Oahu); PZSL, 21: 144, ditto. Eight syntypes, CU 29942.

cylindrica Newc., *Achatinella*: 1854 (May), 79 NSp.: 8, pl. 22, fig. 11 (Waianoe *sic* [Waianae], Oahu, on the ground); PZSL, 21: 134, ditto. Three syntypes, CU 29943.

cylindrica "Newc." DeKay, *Physa*: 1844: Natural History of New York, part 5, Mollusca, p. 77, pl. 5, fig. 83.

cypreophila "Newc." Binney and Bland, *Helix*: 1869, Land and Fresh Water Shells of North America, 1: 166, fig. 287 (Copperopolis [Calaveras County, California]).

decipiens Newc., *Achatinella*: 1854 (May), 79NSp.: 27, pl. 24, fig. 68 (Kahana, Oahu); PZSL, 21: 153, ditto. Five syntypes, CU 29944.

declivis Newc., *Helix*: 1865, PCANS, 3: 180 (Insula Niphon, (Japan)). Lectotype, here selected, CU 26314a (this paper, Pl. 17, fig. 13) and two lectoparatypes, CU 26414 (fig. 14).

dubia Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 23 (Oahu, among stones); 1854 (May), 79NSp.: 26, pl. 24, fig. 65 (Waianoe *sic* [Waianae], Oahu); PZSL 21: 152, ditto. Seven syntypes, CU 29953.

duranti Newc., *Helix*: 1864, PCANS, 3: 118 (Santa Barbara Island, California). Type specimen(s) catalogued as CU 26483 but not located.

dwightii Newc., *Achatinella*: 1855, ALNHNY, 6: 145 (Molokai); 1866, AJC 2: 213, pl. 13, fig. 9. Five syntypes, CU 29957.

elegans Newc., *Achatinella*: 1854 (May), 79 NSp.: 23, pl. 24, fig. 57 (Hauula, Oahu); PZSL, 21: 149, ditto. Six syntypes, CU 29958.

elevata "Newc." Pfeiffer, *Achatinella*: 1856 (February), PZSL, 23: 209 (no locality).

elongata Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 26 (Oahu). Three idiotypes, CU 29960.

emmersonii Newc., *Achatinella*: 1854 (May), 79NSp.: 30, pl. 24, fig. 74 (District of Waialua); PZSL, 21: 156, ditto.

facta Newc., *Helix*, 1864, PCANS, 3: 118 (Insul. "Santa Barbara" et "San Nicholas" [California]) ; Tryon, 1867, AJC, 3, pl. 11, fig. 32. Six syntypes, CU 26543 (Santa Barbara, Cal.).

flavescens Newc., *Achatinella*: 1854 (May), 79NSp.: 25, pl. 74, fig. 62 (Hawaii) ; PZSL, 21: 151, ditto. Four syntypes, CU 29964.

fulgens Newc., *Achatinella*: 1854 (May), 79NSp.: 4, pl. 22, fig. 24 (Neu, Oahu) ; PZSL, 21: 131, ditto. Five syntypes, CU 29967.

fulva "Newc." Pfeiffer, *Achatinella*: 1856 (February), PZSL, 23: 208 (no locality).

fumosa Newc., *Achatinella*: 1854 (May), 79NSp.: 14, pl. 23, fig. 28 (Manoa, Oahu) ; PZSL, 21: 140, ditto. Six syntypes, CU 29969.

fusca Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 28 (Oahu) ; 1854 (May), 79NSp.: 19, 23, fig. 44 (Manoa, Oahu . . . found among the decaying leaves of the Tutui, near the base of the mountain at the head of Manoa valley.) ; PZSL 21: 145, ditto. Six syntypes, CU 29970.

fusoidea Newc., *Achatinella*, 1855, ALNHNY, 6: 144 (E. Maui) ; 1866, AJC, 2: 213, pl. 13, fig. 8.

gabbi "Crosse and Newcomb" Crosse, *Helicina*: 1873, Journal de Conchyliologie, 21: 354 (Samana, in regione Dominicana insulae Haiti, Antillarum). Lectotype, here selected, CU 24020a (this paper, Pl. 17, fig. 2) and one lectoparatype, CU 24020, both from "Santo Domingo". The shell of this species is bright green.

gabbii Newc., *Helix*, 1864, PCANS, 3: 117 (San Clemente, Cal [ifornia]) ; Tryon, 1867, AJC 3: pl. 11, fig. 31. Five idiotypes, CU 26621. Newcomb wrote: "I have seen but a solitary specimen of this species." It is uncertain which of the specimens in lot 26621 is the original specimen, or if it is now in the Newcomb Collection.

germana Newc., *Achatinella*: 1854 (May), 79NSp.: 25, pl. 74, fig. 61 (Makawao, Mani *sic* [Maui]) ; PZSL, 21: 151, ditto. Syntype, CU 29971.

gigantea Newc., *Achatinella*: 1854 (May), 79NSp.: 10, pl. 22, fig. 17 (Hale a ka la, Maui) ; PZSL, 21: 136, ditto.

glabra Newc., *Achatinella*: 1854 (May), 79NSp.: 13, pl. 22, fig. 25 (Kolau poko, Oahu) ; PZSL, 21: 139, ditto. Five syntypes, CU 29972.

gouldii Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 21 (On Tutui trees, Wailuku valley, Maui); 1854 (May), 79NSp.: 4, pl. 22, fig. 1; PZSL, 21: 129, ditto. Three syntypes, CU 29978.

grana Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 29 (E. Maui); 1854 (May), 79NSp.: 20, pl. 23, fig. 46; PZSL, 21: 146, ditto. Four syntypes, CU 29981.

hartmani "Newc." Hartman, *Achatinella*: 1888, Proc. Acad. Nat. Sci. Phil., 40: 54, pl. 1, fig. 12 (Oahu, fossil). Three syntypes, CU 29987 (Kauai). "*extincta* Pfr. a misnomer as this is not an extinct species." (Newcomb, on label).

helena Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 27 (Molokai); 1854 (May), 78NSp.: 25, pl. 24, fig. 63 (Molokai, within the coil of the Ti tree leaf, as it starts from the trunk); PZSL, 21: 151, ditto. Three syntypes, CU 29988.

hemphillii Newc., *Helix*: 1870, AJC, 5: 165, pl. 17, fig. 4 (White Pine Mining District, [Idaho,] at an altitude of 8000 feet). Three syntypes, CU 26715.

hemphillii Newc., *Mya*: 1874, PCAS, 5: 415 (Bay of San Francisco). Lectotype, here selected, CU 17134a (this paper, Pl. 17, fig. 6) and 1½ (3 valves) lectoparatypes, CU 17134.

hillebrandi Newc., *Helix*: 1864, PCANS, 3:115 (Tuolumne County, California). Specimens catalogued as CU 26724 but not located.

humilis Newc., *Achatinella*: 1855, ALNHNY, 6: 143 (Kalae, Molokai); 1866, AJC, 2: 211, pl. 13, fig. 4. (On the ground, under low bushes). Three syntypes, CU 29989.

hybrida Newc., *Achatinella*: 1854 (May), 79NSp.: 21, pl. 23, fig. 52 (Kolau, Oahu); PZSL, 21: 147, ditto.

idahoensis Newc., *Helix*: 1866, AJC, 2: 1, figs. 1, 2, and 3 (between Idaho City and Cour d'Alene Mining District, Idaho Territory). Three syntypes, CU 26772.

intermedia Newc., *Achatinella*: 1854 (May), 79 NSp., 9, pl. 22, fig. 13 (Waianoe *sic* [Waianae], Oahu); PZSL, 21: 135, ditto. Four syntypes, CU 29990.

japonica Newc., *Succinea*: 1865, PCANS, 3: 118 (Japan). Holotype, CU 30257 (this paper, Pl. 17, fig. 8) "*Succinea lauta* ? Gould" (Newcomb, on label).

johnsoni Newc., *Achatinella*: 1854 (May), 79NSp.: 21, pl. 23, fig. 50 [& 51] (Kolau, Oahu) ; PZSL, 21: 147, ditto. Three syntypes, CU 29991.

kanaiensis Newc., *Achatinella*: 1860, ALNHNY, 7: 145, (Kauai, Ins. Sandwich) ; 1866, AJC 2: 209, pl. 13, fig. 1. Four syntypes, CU 29992.

labiata Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 27, (Oahu) ; 1854 (May), 79NSp.: 15, pl. 23, fig. 33 (Lehui, Oahu) ; PZSL, 21: 141, ditto. Six syntypes, CU 29993.

lineolata Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 29 (Maui) ; 1854 (May), 79NSp.:14, pl. 23, fig. 29 (Hawaii) ; PZSL, 21: 140, ditto. Four syntypes, CU 29996.

maniensis "Newc., Pfeiffer, *Achatinella*: 1856 (February), PZSL, 23: 207 (Mani *sic* [Maui]). *Laps. cal.* for *mauiensis.*

manoaensis "Newc." Pfeiffer, *Achatinella*: 1859, Monographia Heliceorum Viventium 4: 545 (Manoa Val [ley] insulae Oahu). Listed under synonymy of *A. melampoides* Preiffer not described.

mastersi Newc., *Achatinella*: 1854 (May), 79NSp.: 27, pl. 24, fig. 67 (Mani *sic* [Maui]) ; PZSL, 21: 153, ditto. Six syntypes, CU 30012 (Molokai).

mauiensis Newc., *Achatinella*: 1866, AJC, 2: 217, pl. 13, fig. 16 (West Maui). Valid emendation for *maniensis.* Four syntypes, CU 30013.

melanosis Newc., *Achatinella*: 1854 (May), 79NSp.: 18, pl. 23, fig. 41 (Hawaii) ; PZSL 21: 144, ditto. Syntype, CU 30014 (Mouna Loa, Hawaii).

melanostoma Newc., *Achatinella*: 1854 (May), 79NSp.: 6, pl. 22, fig. 7 (Ewa, Oahu) ; PZSL, 21: 132, ditto.

moesta Newc., *Achatinella*: 1854 (May), 79NSp.: 31, pl. 24, fig. 77 (Island of Ranai) ; PZSL, 21: 157, ditto. Three syntypes, CU 30018.

mucronata Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 28 (Molokai) ; 1854 (May), 79NSp.: 20, pl. 23, fig. 49 (Mani *sic* [Maui]) ; PZSL, 21: 146, ditto. Four syntypes, CU 30019 (E Maui).

multilineata Newc., *Achatinella*: 1854 (May), 79NSp.: 12, pl. 22, fig. 23 (Kolau poco, Oahu) ; PZSL, 21: 138, ditto. Four syntypes, CU 30022, 30023. Of the original lot of five specimens the one indicated by Newcomb as type is missing.

nigra Newc., *Achatinella*: 1855, PBSNH, 5: 219 (E. Maui) ; 1866, AJC 2: 210, pl. 13, fig. 3. Five syntypes, CU 30028.

nitida Newc., *Achatinella*: 1853, (May), ANYLNH, 6: 29 (E. Maui); 1854 (May), 79NSp.: 14, pl. 23, fig. 30; PZSL, 21: 140, ditto. Six syntypes, CU 30030.

nivosa Newc., *Achatinella*: 1854 (May), 79 NSp.: 6, pl. 22, fig. 6 (Niu, Oahu); PZSL, 21: 132, ditto.

obesa Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 24 (Hale-a-ka-la, Maui, among decaying leaves); 1854 (May), 79NSp.: 17, pl. 23, fig. 39; PZSL, 21: 143, ditto. Three idiotypes, CU 30038.

obscura Newc., *Achatinella*: 1854 (May), 79 NSp.: 31, pl. 24, fig. 78 (Island of Ranai); PZSL, 21: 157, ditto. Five syntypes, CU 30039 (Kauai).

obtusa "Newc." Pfeiffer, *Achatinella*: 1856 (February), PZSL, 23: 209 (no type locality). Specimen(s) catalogued as CU 30040 but not located.

occidentale Newc., *Pisidium*: 1861, PCANS, 2: 94 (Ocean House, San Francisco, [California]). Lectotoype, here selected, CU 16767a (this paper, Pl. 17, figs. 11, 12) and 3½ (7 valves) lectoparatypes CU 16767.

ornata Newc., *Achatinella*: 1854 (May), 79NSp.: 23, pl. 24, fig. 55 (E. Maui . . . found in a limited locality, in a deep ravine, at the back of Lahaina); PZSL, 21: 149, ditto. Three syntypes, CU 30042 (W. Maui).

ovata Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 22 (Waianai, Oahu); 1854 (May) 79NSp.: 4, pl. 22, figs. 2, 2a (Kahana, Koolan, Oahu); PZSL, 21: 130, ditto. Five syntypes, CU 30044.

oviformis Newc., *Achatinella*: 1855, (October), ANYLNH, 6: 147 (listed as a synonym of *A. sowerbyana* Pfr., and not described); Pfeiffer, 1856 (February), PZSL, 23: 208 (described as a valid species credited to Newcomb).

peasei Newc., *Modiola*: 1870, AJC, 5: 163, pl. 17, fig. 2 [pl. 17, fig. 7] (Sandwich Islands, dredged in 12 fathoms, outer harbor of Honolulu). One half holotype (1 valve), CU 14860. According to Newcomb the other valve is at the Philadelphia Academy of Natural Sciences.

petricola Newc., *Achatinella*: 1855, ALNHNY, 6: 143 (Molokai); 1866, AJC 2: 211, pl. 13, fig. 6 (Molokai, on the rocky sides of a Pali or precipice). Two syntypes, CU 30069.

pfeifferi Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 25 (Molokai); 1854 (May), 79NSp.: 24, pl. 74, fig. 58; PZSL, 21: 150, ditto.

pfeifferi Newc., *Vitrina*: 1861, PCANS, 2: 92 (Carson Valley, [Nevada]). Six syntypes, CU 25870.

physa Newc., *Achatinella*: 1854 (May), 79NSp.: 26, pl. 24, fig. 64 (Mouna Kea, Hawaii); PZSL, 21: 152, ditto. Four syntypes, CU 30072, 30073.

polita Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 24 (Molokai); 1854 (May), 79NSp.: 16, pl. 23, fig. 37; PZSL, 21: 142, ditto. Seven syntypes, CU 30077.

porcellana Newc., *Achatinella*: 1854 (May), 79NSp.: 20, pl. 23, fig. 37 (E. Mani *sic* [E. Maui]); PZSL, 21: 146, ditto.

porphyrea Newc., *Achatinella*: 1854 (May), 79 NSp.: 10, pl. 22, fig. 16 (Waianoe *sic* [Waianae], Oahu . . . terrestrial, not arboreal . . .); PZSL, 21: 136, ditto. Three syntypes, CU 30078.

pulla "Newc." Pfeiffer, *Achatinella*: 1856 (February), PZSL, 23: 209 (Ranai); Newcomb, 1866, AJC, 2: 211, pl. 13, fig. 5 (placed in synonymy with *pusilla* Newc.).

pupoidea Newc., *Achatinella*: 1854 (May), 79 NSp.: 18, pl. 23, fig. 42 (E. Mani *sic* [E. Maui]); PZSL, 21: 144, ditto. Two syntypes, CU 30086 (W. Maui). Newcomb (1858, ALNHNY, 6: 319) synonymized this species with *A. ellipsoidea* Gould but in notes written later stated: "*pupoidea* is distinct from fig. 96 of [Gould's United States] Exp [loring] Exp [edition Mollusks], this species of Gould is a true *textilis* Fer.".

pusilla Newc., *Achatinella*: 1855 (October), ALNHNY, 6: 144 (Ranai); 1866 AJC, 2: 211, pl. 13, fig. 5. Four syntypes, CU 30087.

recta Newc., *Achatinella*: 1954 (May), 79 NSp.: 19, pl. 23, fig. 45 (Waialua, Oahu); PZSL,21: 145, ditto.

redfieldi Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 22 (Wailuku, Maui); 1854 (May), 79NSp.: 6, pl. 22, fig. 5 (Molokai and E. Maui, on Tutui, Ohia, and Ti trees); PZSL, 21: 131, ditto. Five syntypes, CU 30091.

remyi Newc., *Achatinella*: 1855, ALNHNY, 6: 146 (Ranai). Two syntypes, CU 30093.

reticulata Newc., *Achatinella*: 1854 (May), 79NSp.: 22, pl. 24, fig. 54 (Waianoe *sic* [Waianae], Oahu); PZSL, 21: 148, ditto. Three syntypes, CU 30095.

rowelli Newc., *Helix*: 1865, PCANS, 3: 181 (Arizona). Holotype, CU 27517.

rowellii Newc., *Pupa*: 1860, ALNHNY, 7: 146 (near Oakland, California). Lectotype, here selected, CU 29170a and seven lectoparatypes, CU 29170.

rubiginosa Newc., *Achatinella*: 1854 (May), 79NSp.: 28, pl. 24, fig. 69 (Palolo, Oahu); PZSL, 21: 154, ditto. Five syntypes, CU 30103.

rufa Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 21 (Molokai); 1854 (May), 79NSp.: 4, pl. 22, fig. 3; PZSL, 21: 130, ditto. Two syntypes, CU 30105.

rufocincta Newc., *Helix*: 1864, PCANS, 3: 117 (San Diego, et Insula "Santa Catalina", Cal [ifornia]). Four syntypes, CU 27531 (Catalina I., Cal.).

rugosa Newc., *Achatinella*: 1854 (May), 79NSp.: 12, pl. 22, figs. 22, 22a (Ewa, Oahu); PZSL, 21: 138, ditto. Five syntypes, CU 30109.

rutila Newc., *Achatinella*: 1854 (May), 79NSp.: 12, pl. 22, fig. 21 (Niu, Oahu); PZSL, 21: 138, ditto. Six syntypes, CU 30113.

sanguinea Newc., *Achatinella*: 1854 (May), 79NSp.: 9, pl. 22, fig. 15 (Lehui, Oahu); PZSL, 21: 135, ditto. Four syntypes, CU 30114.

semicarinata Newc., *Achatinella*: 1854 (May) 79NSp.: 30, pl. 24, fig. 76 (Island of Ranai); PZSL, 21: 156, ditto. Specimen(s) catalogued as CU 30116 but not located.

solitaria Newc., *Achatinella*: 1854 (May), 79NSp.: 24, pl. 74, fig. 60 (Palolo, Oahu); PZSL, 21: 150, ditto.

sordida Newc., *Achatinella*: 1854 (May), 79NSp.: 13, pl. 23, fig. 27 (Lettui *sic* [Lehui], Oahu); PZSL, 21: 139, ditto. Five syntypes, CU 30118.

soror Newc., *Achatinella*: 1854 (May), 79NSp.: 17, pl. 23, fig. 38 (Mani *sic* [Maui]); PZSL, 21: 143, ditto. Six syntypes, CU 30119.

splendida Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 20 (Waialuku, Maui); 1854 (May), 79NSp.: 5, pl. 22, fig. 4 (Waialuku, Maui, on Tutui trees); PZSL, 21: 131, ditto. Five syntypes, CU 30122.

Striata Newc., *Tornatellina*: 1861, PCANS, 2: 93 (Kauai, Insula Sandwichensis).

subvirens Newc., *Achatinella*: 1854 (May), 79NSp.: 10, pl. 22, fig. 18 (Niu, Oahu); PZSL, 21: 136, ditto. Five syntypes, CU 30130.

succincta Newc., *Achatinella*; 1855, PBSNH, 5: 220 (Ewa, Oahu); 1866, AJC, 2: 213, pl. 13, fig. 7. Four syntypes, CU 30132.

swifti Newc., *Achatinella*: 1854 (May), 79NSp.: 7, pl. 22, figs. 9, 9a (District of Ewa, [Oahu]) ; PZSL, 21: 133, ditto. Three syntypes, CU 30134.

swiftianum "Newc." C. B. Adams, *Cyclostoma*: 1852, Contributions to Conchology, No. 11, p. 216.

terebra Newc., *Achatinella*: 1854 (May), 79NSp.: 18, pl. 23, fig. 40 (W. Mani *sic* [W. Maui]) ; PZSL, 21: 144, ditto. Eight syntypes, CU 30144.

tessellata Newc., *Achatinella*: 1853 (May), ANYLNH, 6: 19 (Molokai) ; 1854 (May), 79NSp.: 13, pl. 23, fig. 26 (Molokai. Found at Kalai on Tutui trees and on the broad leaf of the Ti.) ; PZSL, 21: 139, ditto. Five syntypes, CU 30147.

tetrao Newc., *Achatinella*: 1855 (May), PZSL, 22: 311 [*nomen nudum*]; 1855 (October), PBSNH, 5: 219 (Ranai) ; 1866, AJC, 2: 214, pl. 13, figs. 11, 12. Five syntypes, CU 30149.

traski Newc., *Helix*: 1861, PCANS, 2: 91 (Los Angeles, Cal [ifornia]). Four syntypes, CU 27832.

tryoni Newc., *Helix*: 1864, PCANS, 3: 116 (Santa Barbara, and San Nicolas Islands, Cal [ifornia]). Five syntypes, CU 27858 (Island of Santa Barbara, California).

turgida Newc., *Achatinella*: 1854 (May), 79NSp.: 8, pl. 22, fig. 10, 10a (Ewa, Oahu) ; PZSL, 21: 134, ditto. Five syntypes, CU 30154.

undulata Newc., *Achatinella*: 1855, PBSNH, 5: 218 (Waialua, Oahu) ; 1866, AJC, 2: 216, pl. 13, fig. 15. Four syntypes, CU 30160.

ustulata "Newc." Pfeiffer, *Achatinella*: 1859, Monographia Heliceorum Viventium, 4: 534 [*nomen nudum*].

variabilis Newc., *Achatinella*: 1854 (May), 79NSp.: 28, pl. 24, fig. 70 (Ranai) ; PZSL, 21: 154, ditto. Six syntypes, CU 30164.

venulata Newc., *Achatinella*: 1854 (May), 79NSp.: 20, pl. 23, fig. 48 (Kolau, Oahu) ; PZSL, 21: 146, ditto.

violacea Newc., *Achatinella*: 1853 (May) ANYLNH, 6: 18 (Molokai) ; 1854 (May), 79NSp.: 9, pl. 22, fig. 14; PZSL, 21: 135, ditto. Five syntypes, CU 30174.

vitrea Newc., *Achatinella*: 1854 (May), 79NSp.: 16, pl. 23, fig. 34 (Manoa, Oahu. Its locality is near the summit of the mountain ridge dividing Manoa from Palolo Valley.) ; PZSL, 21: 142, ditto. Six syntypes, CU 30181.

voyana Newc., *Helix* (*Macrocyclis*): 1865, AJC, 1: 235, pl. 25, fig. 4 [fig. 3] (Canyon Creek, Trinity Co., California). Six syntypes, CU 27961.

wheatleyi Newc., *Achatinella*: 1855, ALNHNY, 6: 147. Listed as a synonym of *A. vidua* Pfeiffer and not described. Five specimens in the Newcomb Collection (CU 29977) are labelled "*A. glabra wheatleyi* Newc. mss., Oahu."

whitneyi Newc., *Helix*: 1864, PCANS, 3: 118 (propé "Lake Taho", Cal [ifornia] in montibus "Sierra Nevada", elevatione 6100 ped. Angl. [= English feet]). Three specimens in the Newcomb Collection (CU 27973) are labelled: "*H.* (*Zonites* sub. g. *Hyalina*) *Whitneyi* Newcomb, Nevada". They are *Retinella indentata paucilirata* Morelet and cannot be the types of *Helix whitneyi.*

williamsi Newc., *Mitra*: 1870, AJC, 5: 163, pl. 17, fig. 1 [pl. 17, fig. 5] (Philippine Islands ? . . . . or at Guam). One specimen (CU 19089) labelled "type" is another species. The true type was not located.

zebra Newc., *Achatinella*: 1855, ALNHNY, 6: 142 (East Maui). Three idiotypes, CU 30185.

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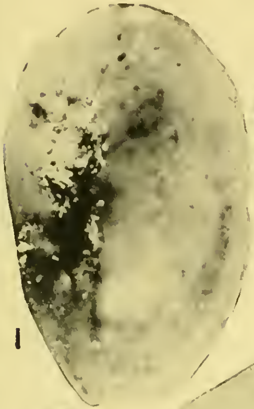
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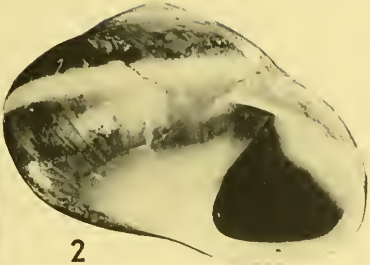
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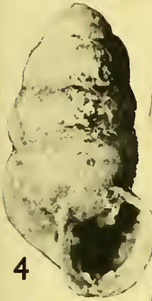
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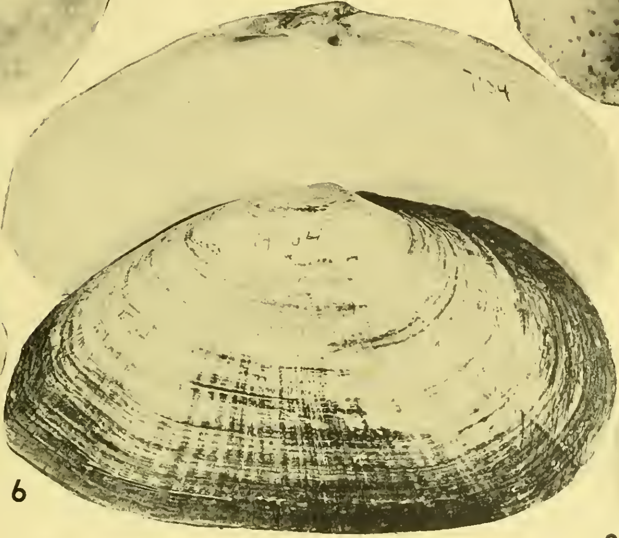
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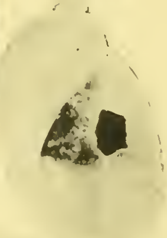
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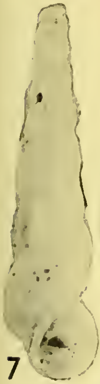
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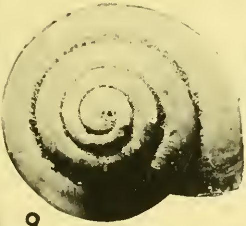
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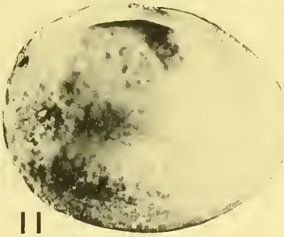
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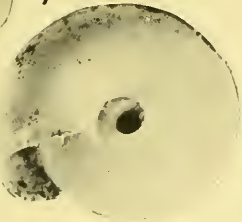
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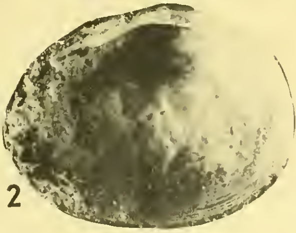
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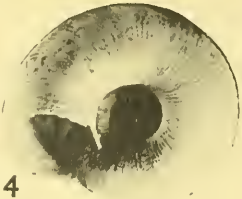
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WISCONSIN MOLLUSCAN FAUNAS FROM JEFFERSON COUNTY, KENTUCKY

By

RUTH G. BROWNE

and

DONALD E. MCDONALD

August 5, 1960

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WISCONSIN MOLLUSCAN FAUNAS
FROM
JEFFERSON COUNTY, KENTUCKY

Ruth G. Browne
and
Donald E. McDonald

ABSTRACT

Molluscan faunas of Wisconsin age are the first described from Jefferson County, Kentucky. Loess and water-laid silts from the Tazewell substage yielded 25 species representing 8 families and 18 genera.

From deductions based on the ecological requirements of the extralimital species it is concluded that the annual mean temperature was lower than at present, the region was provided with permanent water bodies, and the territory was wooded.

The location of the region just beyond the terminus of the Wisconsin ice sheet explains the cool climate as well as accounting for the water bodies either as melt-water streams issuing from the glacier or as proglacial lakes formed by damming of existing streams.

The ice sheet also provided the source material of the sediments as active outwash without protective cover of continuous vegetation.

INTRODUCTION

A short paper by Dr. Louis Ray of the U. S. Geological Survey in the Journal of Geology (Ray, 1957) prompted the study of the molluscan faunas that are the subject of this report. While pursuing a field study concerned with the Quaternary history of the Ohio River Valley, Dr. Ray examined an excavated exposure at Medora, Kentucky, and described three loess formations at this site. Leverett in 1929 called attention to fossiliferous loess in the vicinity of Louisville, Kentucky, but he had not recognized any stratigraphic sequence of loess formations.

A visit to the Medora site and examination of the loess showed that snail remains were sufficiently abundant to warrant study of the faunas. Investigation was undertaken to find other exposures of loess in the area south of Louisville from which collections might be made. Three additional exposures were located and sections of them were made by the authors. The fauna herein recorded is from all four localities.

The hypotypes are deposited with the Paleontological Research Institution at Ithaca, New York.

LOCATION OF SECTIONS

The four sites which comprise the study of this report are all located on the U. S. Geological Survey's Valley Station Quadrangle which lies east of 31-W about 10 miles south of Louisville, Kentucky.

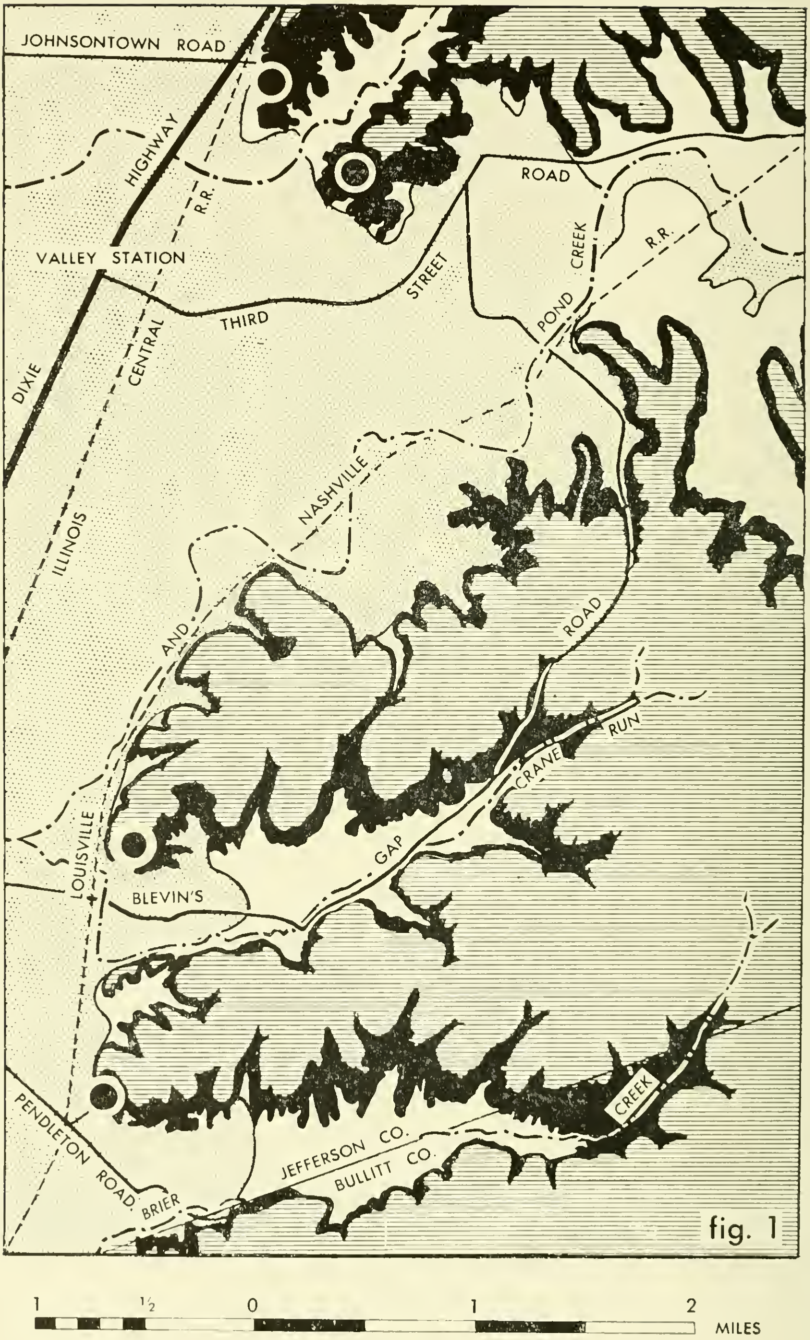
JOHNSONTOWN ROAD
HIGHWAY
R.R.
ROAD
VALLEY STATION
CREEK
R.R.
STREET
THIRD
POND
DIXIE
CENTRAL
NASHVILLE
ILLINOIS
AND
ROAD
RUN
CRANE
LOUISVILLE
GAP
BLEVIN'S
CREEK
JEFFERSON CO.
BULLITT CO.
PENDLETON ROAD
BRIER
1
½
0
1
2
MILES

fig. 1

The original site at Medora, described by Dr. Ray, is located in the west central rectangle, 38° 3′ 20″ north latitude and 85° 52′ 0″ west longitude. The site is 0.3 miles northeast of the intersection of Pendleton Road and the Louisville and Nashville Railroad on Miller's farm. The hill lies directly back of the barn. A second site was located in the same rectangle. This site is 38° 4′ 12″ north latitude and 85° 51′ 42″ west longitude, 600 feet east of the Louisville and Nashville Railroad and 0.3 miles north of Blevin's Gap Road.

Both of the other sites are located in the northwest rectangle about a half mile apart. One is the hill approximately 650 feet east of the Illinois Central Railroad on a dirt road which turns east of 31-W just south of the intersection of Johnsontown Road, 38° 7′ 12″ north latitude and 85° 51′ 9″ west longitude. The other is the hill lying southeast which can be reached by taking Valley Station Road from 31-W for a distance of 0.9 miles to the present subdivision called Mound View, 38° 6′ 51″ north latitude and 85° 50′ 40″ west longitude. The base of the hill lies about 0.4 miles north of the entrance to the subdivision.

For purposes of reference the sites are cited by the names Medora, Blevin's Gap, Johnsontown, and Mound View.

DESCRIPTION OF SECTIONS

Deposits of Pleistocene age occur throughout the Ohio River Valley and the four sections herein described are representative of a portion of these deposits as found in the Valley Station Quadrangle. Using these four localities it is possible to reconstruct the history of Pleistocene deposition in the area shown in Figure 1.

The sediments comprise what appears to be a till of Illinoian or older age. They are overlain respectively by the Loveland loess of Illinoian age on which the Sangamon soil is well developed, and two deposits of Wis-

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Map of Area Studied

Figure 1—The stippled area represents alluvium; the lineated area, the valley wall. The area appearing white is representative of swamps, lakes, and other bodies of water extant at the time of deposition. The black area represents the horizon along which the Pleistocene deposits occur or are likely to occur. The sites studied are circled in white.

The area of the map is from 85° 49′ 00″ to 85° 52′ 30″ west latitude and from 38° 02′ 30″ to 38° 07′ 30″ north longitude.

Map source—The Valley Station Quadrangle of the United States Department of the Interior—Geological Survey, and the Aerial Geological Survey map of Jefferson County, 1931, were used for constructing Figure 1.

consin age, the Farmdale loess and the fossiliferous sediments of the Tazewell substage. The Tazewell sediments are loess deposits at two localities (Medora, Plate 18, and Blevin's Gap, Plate 19), water-laid silts and sand at another (Mound View, figure 3), and a complex deposit of loess and water-laid sediments at the fourth (Johnsontown, Plate 20).

Several streams arise in the hills of the area and flow westward to join the Ohio River. Along the western front of these hills each stream breaks through a barrier at the end of its valley before flowing onto the Ohio River flood plain. These barriers represent deltas or sand bars built by the Ohio River during glacial or Quaternary time when it flowed at that level. The lakes or "wet" areas, shown in white on Figure 1, were then formed as the waters amassed behind the barriers.

It appears that loess deposited against the valley wall constituted another barrier at the Johnsontown site. At this site a cross-section of the deposits exposes water-laid sediments somewhat restricted by and overlying loess deposits.

It may be noted from Figure 1 that the Johnsontown and Mound View sections (appearing in the upper portion of the map) occur in a "wet" area. The Johnsontown section, as above stated, is composed of part aqueous and part loess deposition. The Mound View section appears to be completely aqueous. The Medora and Blevin's Gap sections occur in a dry region and are both composed entirely of loess.

MEDORA SECTION

Northeast 0.3 miles of the intersection of Pendleton Road and the Louisville and Nashville R. R.

Unit	Description	Thickness (feet)
Pleistocene Series:		
Wisconsin Stage		
Tazewell loess		
4.	Soil containing humus: grey, leached	0.5
3.	Silt: yellow-brown (10 YR 5/6)*, clayey, leached	2.0

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*The figures and letters in parenthesis represent colors which approximate as closely as possible, those on the Rock Color Chart which is based on the Munsell system and is distributed by the National Research Council, Washington, D. C. All colors were taken using damp samples.

PLATE 18

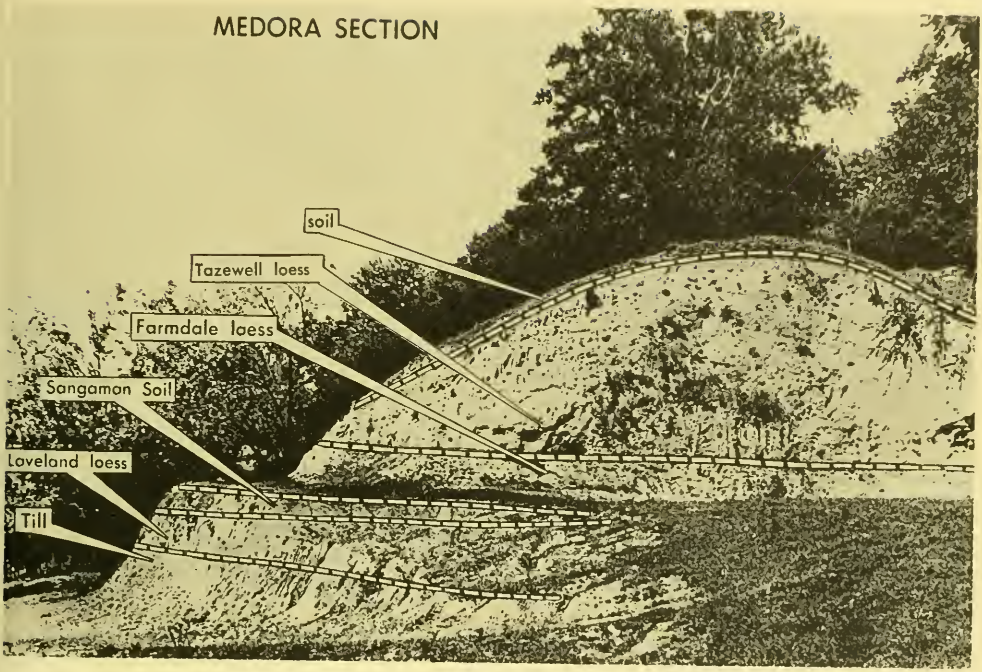
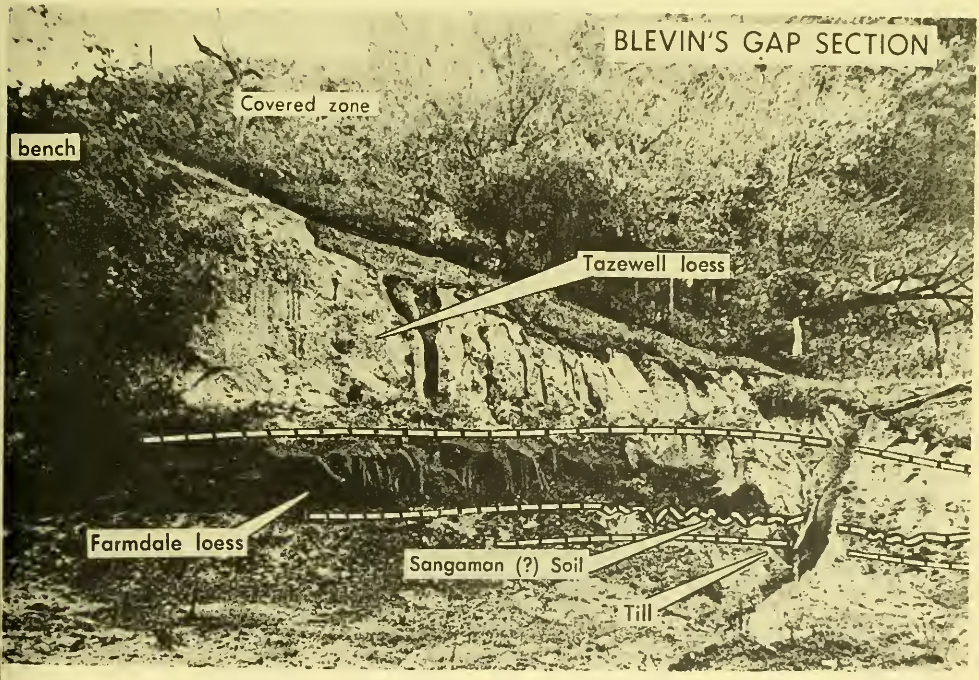
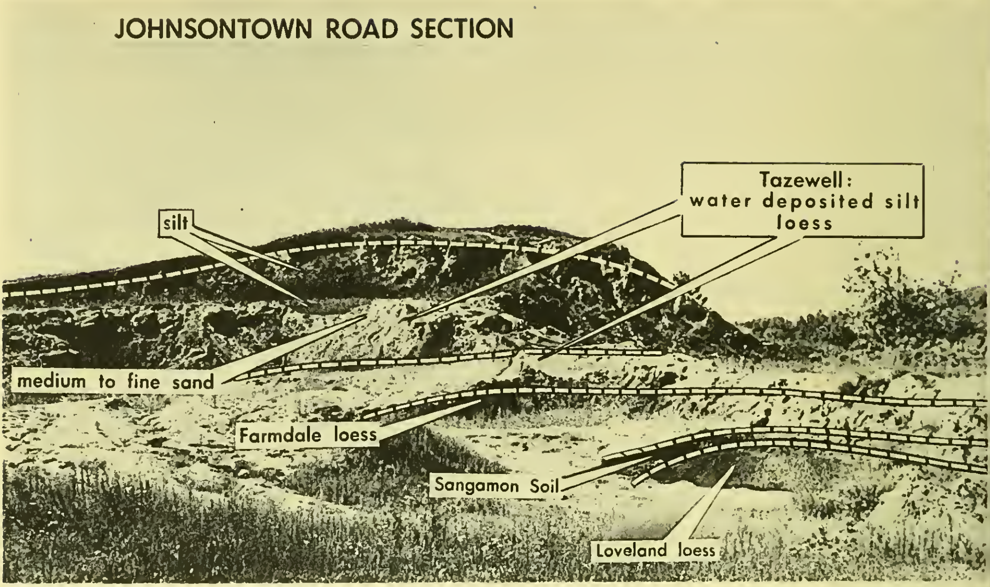
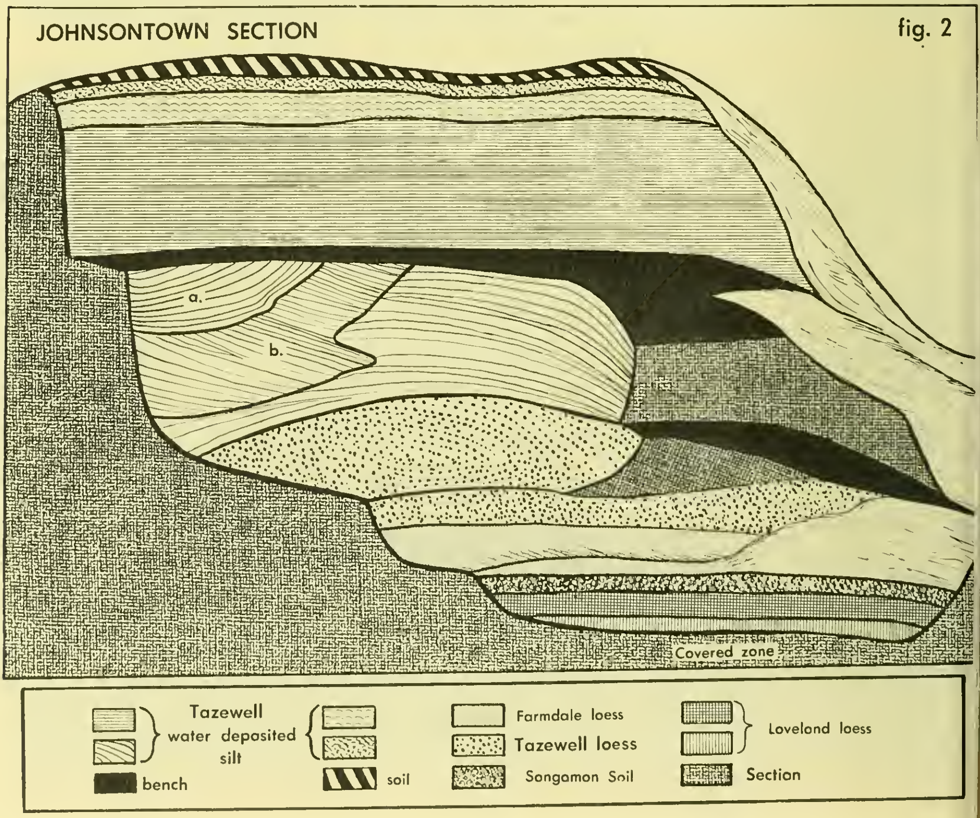


PLATE 19




JOHNSONTOWN ROAD SECTION
silt
Tazewell:
water deposited silt
loess
medium to fine sand
Farmdale loess
Sangamon Soil
Loveland loess


JOHNSONTOWN SECTION
fig. 2
a.
b.
Covered zone
Tazewell
water deposited
silt
bench
soil
Farmdale loess
Tazewell loess
Sangamon Soil
Loveland loess
Section

2. Silt: yellow-brown (10 YR 5/6), uncompacted, leached, fossiliferous	1.0
1. Silt: yellow-brown (10 YR 5/6), powdery, unleached, fossiliferous, contains large nodules of calcite	19.5
Total Tazewell	23.0

Farmdale loess

1. Silt: grey-brown (10 YR 5/4), compact, leached, unfossiliferous, contains abundant small concretions of secondary calcite	5.5
Total thickness of sediments of Wisconsin age	28.5

BENCH

Illinoian and/or older stages

1. Silty clay: mottled red (10 R 3/4) and black by accretions of limonite and manganese, soil profile developed during Sangamon interglacial stage, contains large spinose nodules of calcite	2.0

Figure 2—a. This area is composed of leached, fossiliferous, well-oxidized silt which is somewhat clayey, especially in the lower 6 inches. It is laminated in the direction shown. The darker laminae average 0.75 inches thick and lighter laminae 0.2 inches (average of 10 measurements). b. This area is composed of leached, medium to fine water-deposited sand containing small particles of coal in some of the laminae but absent in others. Average thickness of the laminae is 0.15 inches. The area is laminated in the direction shown.

Illinoian and/or older stages		
Loveland loess		
1.	Silt: yellow-brown (10 YR 6/4), unfossiliferous	7.0
2.	Mudstone (till?) with cobbles, mostly chert, locally derived: mottled red-brown (5 YR 5/6) and orange-brown (10 YR 7/6). A Silurian brachiopod and one small pebble of quartzite were recovered from the matrix	1.0 to 2.5
1.	Covered to base	5.0 to 6.0
	Total thickness of sediments of Illinoian and/or older stages	13.0 to 15.5
	Total Pleistocene	43.5 to 46.0

BLEVIN'S GAP SECTION

East 600 feet of the Louisville and Nashville R. R. and north 0.3 miles of Blevin's Gap Road.

Unit	Description	Thickness (feet)
Pleistocene Series:		
Wisconsin Stage		
Tazewell loess		
1.	Silt: yellow-brown (10 YR 5/6), unleached, powdery, compact, oxidized, very fossiliferous, contains calcified rootlets	2.0
	Covered zone	100.0
	BENCH	
Tazewell loess		
2.	Soil: red, clayey, well oxidized	2.0
1.	Silt: yellow-brown (10 YR 5/4), unleached, powdery, compact, oxidized, fossiliferous, contains calcite nodules at base	16.5
	Total Tazewell	120.5
Farmdale loess		
1.	Silt: grey-brown (10 YR 5/4), leached, oxidized, unfossiliferous, contains large calcite nodules, especially near top	5.0
	Total thickness of sediments of Wisconsin age	125.5

Illinoian and/or older stages		
2.	Clay: grey, (perhaps re-reduced, or perhaps most iron compounds have been leached from this zone), contains particles of red clay, has erosional surface filled by overlying loess	2.0
1.	Mudstone (till?) with cobbles, locally derived: mottled red-brown (5 YR 5/6) and orange-brown (10 YR 7/6)	2.25
Total thickness of sediments of Illinoian and/or older stages		to 129.75

JOHNSONTOWN SECTION

North 1 mile of Valley Station Road; east approximately 700 feet of Highway 31-W.

Unit	Description	Thickness (feet)
Pleistocene Series:		
Wisconsin Stage		
Tazewell (water deposited)		
5.	Soil with humus: grey	1.0 to 1.5
4.	Silt: red, clayey	2.0
3.	Silt: yellow-brown (10 YR 6/4), clayey	3.5
2.	Silt: yellow-brown (10 YR 5/6), laminated, leached, sparsely fossiliferous	15.5
	BENCH	
1.	Silt: yellow-brown (10 YR 5/6), laminated, leached, moderately uncompacted, fossiliferous, contains calcified rootlets, has a laminated area of fine to medium, water-deposited sand and a laminated area of clayey, more oxidized silt *	20.0
Tazewell loess		
1.	Silt: yellow-brown (10 YR 6/5), unleached, powdery, fossiliferous, contains large calcareous nodules at base	12.5
Total Tazewell		54.5 to 55.0

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*See Figure 2 for a more detailed description of this zone.

	Farmdale loess	
1.	Silt: red-brown (10 YR 5/4), leached, unfossiliferous, contains abundant large concretions of secondary calcite	5.5
	Total Wisconsin	60.0
	Illinoian Stage	
1.	Silty clay: mottled red (10 R 3/4) and black by accretions of limonite and manganese, soil profile developed during Sangamon interglacial stage, contains large spinose nodules of calcite	2.0
	Loveland loess	
2.	Silt: orange-brown (10 YR 6/4), mottled, leached, well oxidized, contains nodules of calcite	3.0
1.	Silt: yellow-grey (10 YR 5/6), clayey, unleached	2.0
	Covered to base	4.0
	Total Illinoian	9.0
	Total Pleistocene	71.0 to 71.5

MOUND VIEW SECTION #1

Sand pit north 0.5 miles of Valley Station Road at Mound View Subdivision.

Unit	Description	Thickness (feet)
Pleistocene Series:		
	Wisconsin Stage	
	Tazewell (water deposited)	
3.	Sand: fine to medium, laminated, contains coal particles	8.0
2.	Silt: yellow-brown (10 YR 6/5), sandy, leached, contains thin plates of calcite and calcified rootlets	3.0
1.	Sand: fine to medium, laminated, contains coal particles	11.0
	Total Tazewell	22.0

MOUND VIEW SECTIONS #2 AND #3

Sand pit north 0.5 miles of Valley Station Road at Mound View Subdivision.

Unit	Description	Thickness (feet)
Pleistocene series:		
Wisconsin Stage		
Tazewell (water deposited)		
5.	Soil: red, sandy, well oxidized, contains plant roots	4.5
4.	Silt: yellow-brown (10 YR 5/6), leached fossiliferous	7.0
	BENCH	
3.	Sand: medium to fine, laminated, has inclusions of coal particles	1.5 to 4.5
2.	Silt: yellow-brown (10 YR 5/6), laminated, leached, moderately uncompacted, fossiliferous	7.0 to 14.0
1.	Silt: yellow-brown (10 YR 6/5), sandy, leached, fossiliferous, contains thin plates of calcite	5.0
Total Tazewell		25.0 to 30.0

MOUND VIEW SECTION #4

Sand pit north 0.5 miles of Valley Station Road at Mound View Subdivision.

Unit	Description	Thickness (feet)
Pleistocene Series:		
Wisconsin Stage		
Tazewell (water deposited)		
3.	Sand: laminated	12.0
2.	Silt: yellow-brown (10 YR 5/6), leached, uncompacted, grades upward into laminated sand with zones of more oxidized silt up to 1 inch in thickness	3.0
1.	Silt: yellow-brown (10 YR 6/5), sandy, leached, fossiliferous, contains thin plates of calcite	1.0
Total Tazewell		16.0
Total Pleistocene exposed (average)		23.25

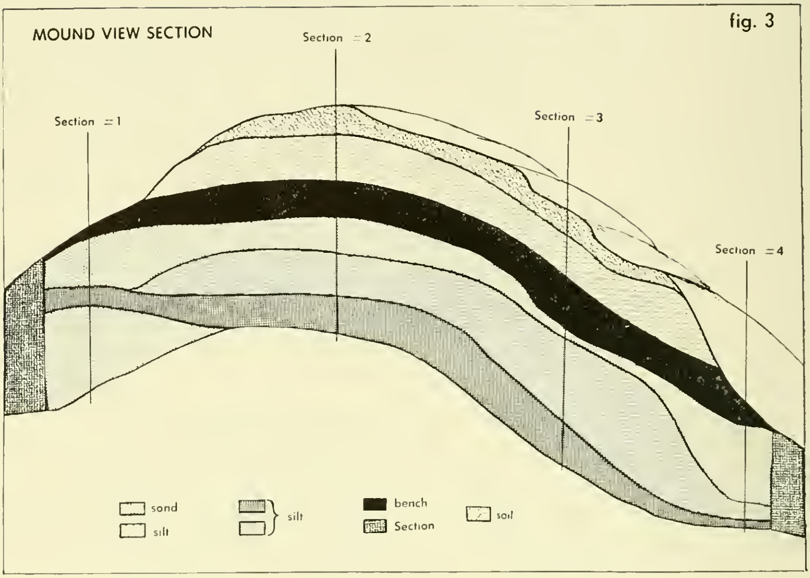

Figure 3. Mound View Section.

FAUNAL LIST

The fauna represents 8 families, 18 genera, and 25 species.

1. Endodontidae	**Anguispira alternata* (Say)
	***Helicodiscus parallelus* (Say)
	Discus cronkhitei (Newcomb)
	Punctum minutissimum (Lea)
2. Pupillidae	**Gastrocopta armifera* (Say)
	Vertigo nylanderi (Sterki)
	Vertigo modesta (Say)
	Columella alticola (Ingersoll)
	Pupoides albilabris (C. B. Adams)
3. Valloniidae	*Vallonia albula* Sterki

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* Mr. Burt Monroe of Anchorage, Kentucky, made a collection of Recent snails while he was a student of the University of Louisville in 1952, and he reported these species from Jefferson County.

** These species have also been reported from Jefferson County since the time Mr. Monroe made his study.

4. Succineidae	*Succinea grosvenori* Lea *Succinea grosvenori gelida* (F. C. Baker) *Succinea ovalis* Say
5. Zonitidae	***Euconulus fulvus* (Muller) *Retinella* cf. *R. binneyana* (Morse) ***Zonitoides arboreus* (Say)
6. Polygyridae	**Stenotrema fraternum* (Say) *Stenotrema leai* (Binney) *Stenotrema leai aliciae* (Pilsbry) **Stenotrema stenotrema* Pfeiffer **Allogona profunda* (Say) *Triodopsis multilineata* (Say)
7. Helicinidae	*Hendersonia occulta* (Say)
8. Haplotrematidae	**Haplotrema concavum* (Say)

Of the 25 species listed, all have living representatives. Six species are extralimital and nine are reported inhabiting the region at the present.

ECOLOGICAL SIGNIFICANCE

A reconstruction of the habitat which includes terrestrial species recovered from both fluvial and loess deposits indicates the prevalence of ponds and lakes throughout the period of deposition of the sediments from which these faunas were collected. A sizeable deposit of bog iron ore is present at the Mound View site and species adapted to an environment close to water are found in the loess as well as the water-laid sediments.

Hendersonia occulta (Say) (Plate 22) is a common fossil at all four localities studied. Shimek, as well as other Pleistocene geologists, considered this a key fossil for interpreting conditions at the time of loess deposition. Professor Shimek (1904, p. 176) credited the species as found in well-wooded territory in loose leaf mould. However, he stated that the shells were not found on grounds subject to overflow. It remained for Dr. van der Schalie (1939, pp. 1-8) to make a study of the species *Hendersonia occulta* in Michigan and to gather sufficient data to show that the species is restricted to areas not only close to water but often on grounds subject to overflow. Dr. van der Schalie also examined the present day distribution of *Hendersonia occulta* as reported by persons from other areas and concluded that the close association of each colony to some lake or stream applied elsewhere.

The species *Discus cronkhitei* (Plate 22), *Succinea grosvenori* (Plate 21), *Vallonia albula* (Plate 21), *Vertigo modesta* (Plate 21), *Vertigo nylanderi* (Plate 21), and *Gastrocopta armifera* (Plate 21) prefer relatively open situations such as woodland borders or dense growths near streams. A. Byron Leonard (1950, pp. 24-25), in referring to another fossil of the present assemblage—*Succinea ovalis* (Plate 21)—stated, "*Succinea ovalis* is an inhabitant of moist situations near ponds, swamps, and streams, often among trees or shrubs—its preference for moist environments is so characteristic that its distribution on a wooded slope may be suddenly truncated above a horizon where contact springs emerge."

The habitat was apparently not only more humid than at present but appears to have supported a floral cover more dense than exists in the area at the present time. Many of the species are woodland species, but the presence of the true forest genera [*Allogona* (Plate 22), *Triodopsis* (Plate 22), and *Anguispira* (Plate 22)] implies woodlands more extensive than woodland strips bordering streams.

A Recent fauna reported by Oughton from Ontario, Canada, (1948, pp. 1-126), is so similar to the faunal assemblage recorded here that a comparison of species is interesting as it bears on the comparison of present climatic conditions with those prevailing at the time the fossil faunas lived. Of the 25 species of this report Oughton listed 20 with one species, *Succinea ovalis*, probably present but not found.

All the pupillids common to both assemblages—*Vertigo nylanderi*, *Vertigo modesta*, and *Columella alticola* (Plate 21) — as well as three other species—*Retinella* cf. *R. binneyana* (Plate 21), *Vallonia albula*, and *Discus cronkhitei*—are extant in North America only in the cool regions of Canada, northern United States, and mountainous areas. Of these six species, those which range southward into mountainous regions are confined to high altitudes. A. Byron Leonard (1952, figure 13) recorded localities where *Columella alticola* is living. Each of these localities is at an elevation of 7,500 feet or more. In the same paper (1952, figure 8) those localities are recorded where *Discus cronkhitei* is living. In the southern part of its range it is confined to altitudes from 7,000 to 8,000 feet. It seems safe to assume that the area of the present study had a climate not unlike that of Ontario, Canada, today which is prevailingly cooler and where lower mean temperatures obtain.

MOLLUSKS RECOVERED FROM THE TAZEWELL OF JEFFERSON COUNTY, KENTUCKY

Genus and Species	Medora	Mound View	Johnsontown		Blevin's Gap	
			Tazewell water deposited silt	Tazewell loess	Tazewell above covered zone	Tazewell below covered zone
Allogona profunda (Say)						R
Anguispira alternata (Say)	C	C	C	C	C	C
Columella alticola (Ingersoll)	R					
Discus cronkhitei (Newcomb)	A	A	A	A	A	A
Euconulus fulvus (Muller)	R	R	R	R	C	C
Gastrocopta armifera (Say)		A	A		A	A
Haplotrema concavum (Say)	R			R		R
Helicodiscus parallelus (Say)	R					
Hendersonia occulta (Say)	A	C	C	C	C	C
Punctum minutissimum (Lea)	R			R		
Pupoides albilabris (C. B. Adams)			R			R
Retinella cf. binneyana (Morse)	C			R		R
Stenotrema fraternum (Say)		R				
Stenotrema leai (Binney)	R	C	C	C	C	C
Stenotrema leai aliciae (Pilsbry)		R				
Stenotrema stenotrema Pfeiffer	R	R	R	R	C	C
Succinea grosvenori Lea	R	R	R	R	R	R
Succinea grosvenori gelida F. C. Baker		A	A		A	A
Succinea ovalis Say	R	R	R	R		
Triodopsis multilineata (Say)		R	R			R
Vallonia albula Sterki	C	C	C	C	C	C
Vertigo nylanderi (Sterki)	C			C		
Vertigo modesta (Say)	A			C	A	
Zonitoides arboreus (Say)	R					

Percentage of total number of specimens collected at each site.
A=Abundant (10% or more), C=Common (2% to 10%), R=Rare (less than 2%).

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Dr. James Conkin, geologist at the University of Louisville, Louisville, Kentucky, who suggested the project. Dr. Conkin made available the facilities of the university as well as literature from his personal library.

Dr. William J. Wayne, glacial geologist, Indiana Geological Survey, visited the sites and reviewed the sections. His comments were extremely helpful. Thanks are also due him for checking the species and reviewing a preliminary draft of this report.

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PLATES

EXPLANATION OF PLATE 21

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1\. **Pupoides albilabris** (C. B. Adams) 177
Apertural view of hypotype P. R. I. No. 15008. Tazewell loess, Johnsontown section.

2\. **Columella alticola** (Ingersoll) 176, 177
Apertural view of hypotype P. R. I. No. 15009. Tazewell loess, Medora section.

3\. **Gastrocopta armifera** (Say) 176, 177
Apertural view of hypotype P. R. I. No. 15010. Tazewell water deposited silt, Johnsontown section.

4\. **Vertigo nylanderi** (Sterki) 176, 177
Apertural view of hypotype P. R. I. No. 15011. Tazewell loess, Medora section.

5\. **Vertigo modesta** (Say) 176, 177
Apertural view of hypotype P. R. I. No. 15012. Tazewell loess, Medora section.

6a-b. **Retinella cf. R. binneyana** (Morse) 176, 177
Dorsal and ventral views of hypotype P. R. I. No. 15013. Tazewell loess, Johnsontown section.

7a-c. **Euconulus fulvus** (Muller) 177
7a Dorsal and 7b ventral views of hypotype P. R. I. No. 15014. Tazewell loess, Blevin's Gap section below covered zone. 7c, apertural view of hypotype P. R. I. No. 15015. Tazewell loess, Medora section.

8a-b. **Haplotrema concavum** (Say) 177
8a. Dorsal view of hypotype P. R. I. No. 15016. Tazewell loess, Johnsontown section. 8b, apertural view of hypotype P. R. I. No. 15017. Tazewell loess, Blevin's Gap section below covered zone.

9\. **Zonitoides arboreus** (Say) 177
Dorsal view of hypotype P. R. I. No. 15018. Tazewell loess, Medora section.

10\. **Vallonia albula** Sterki 176
Ventral view of hypotype P. R. I. No. 15019. Tazewell water deposited silt, Mound View section.

11\. **Succinea grosvenori** Lea 176, 177
Apertural view of hypotype P. R I. No. 15020. Tazewell loess, Medora section.

12a-b. **Succinea grosvenori gelida** (F. C. Baker) 177
Dorsal and apertural views of hypotype P. R. I. No. 15021. Tazewell water deposited silt, Mound View section.

13\. **Succinea ovalis** Say 176, 177
Apertural view of hypotype P. R. I. No. 15022. Tazewell loess Medora section.

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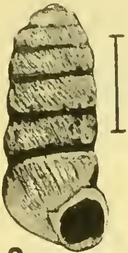

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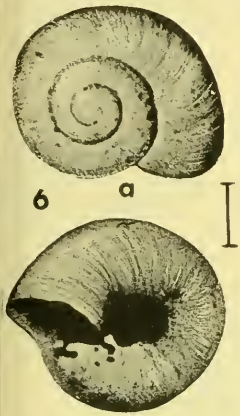

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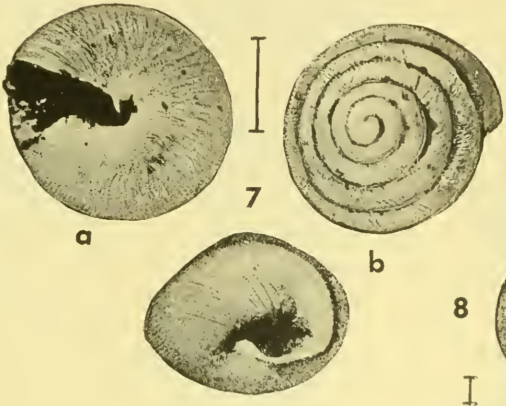

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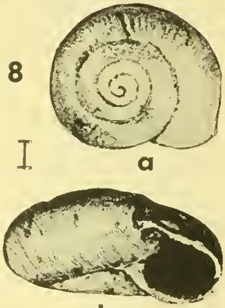

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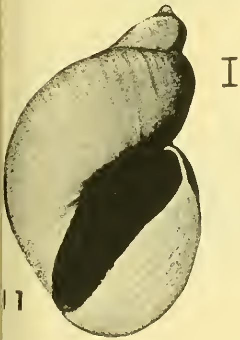

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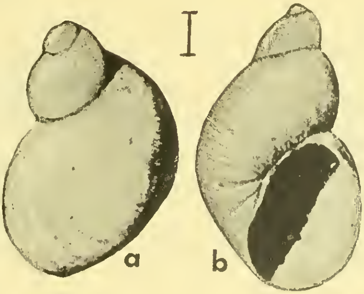

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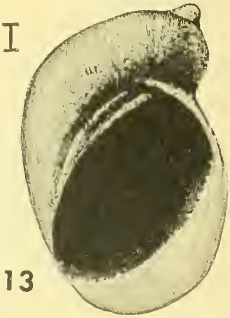

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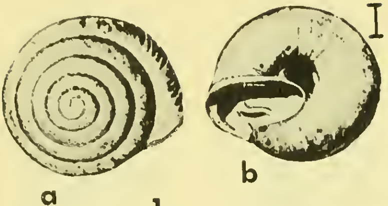

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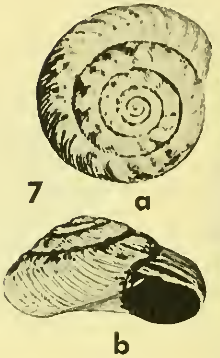

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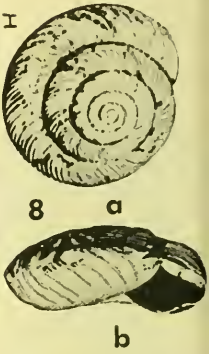

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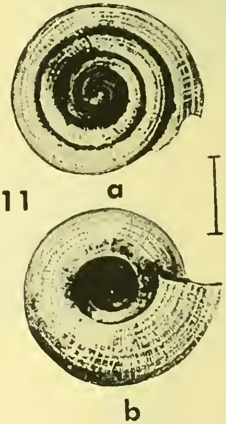

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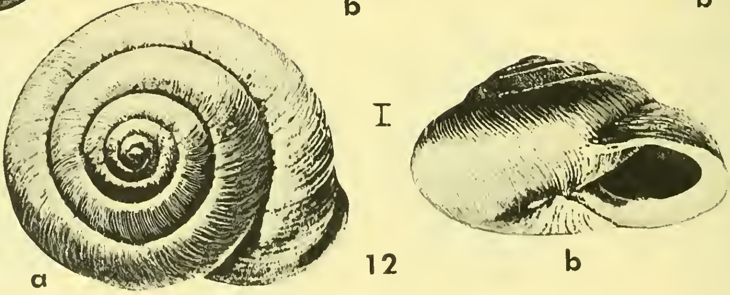

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THE GENUS CAMERINA

By

W. STORRS COLE,

Cornell University

October 7, 1960

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THE GENUS CAMERINA*

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ABSTRACT

The internal structure of representative specimens of the several genera which have been recognized for camerinids with undivided chambers is reviewed. The conclusion is reached that the only valid genera which can be distinguished by internal structure are *Camerina* and *Miscellanea.* The other assumed genera have been based on superficial and intergrading differences in form which are individual and specific, not generic, characters. *Miscellanea* seemingly is confined to the Paleocene, but *Camerina* which may be subdivided in several form lineages extends from Paleocene to Recent.

INTRODUCTION

The camerinids for the purposes of this study are divided into two large categories, those which have open undivided chambers as viewed in median section, and those which have the chambers subdivided by chamberlets. The genera of camerinids with subdivided chambers will not be discussed as these are recognized readily. An attempt will be made to clarify and define the generic names which have been applied to specimens with undivided chambers.

The genus *Miscellanea* which has been described (Cole, 1956, p. 240) in detail is considered to be a valid one. Specimens referred to this genus have distinctive internal structures which serve to separate them immediately from the other genera of camerinids.

Paraspiroclypeus with vacuoles in the spiral wall as its distinguishing structure is not a valid genus. The vacuoles are a specific characteristic, not a generic one. These specimens, except for the vacuoles, are identical in form and structure to species formerly assigned to *Operculinoides.*

The main confusion has resulted from the attempts which have been made to substantiate and distinguish between *Camerina, Planocamerinoides* (= *Assilina* of authors), *Operculina, Operculinoides,* and *Ranikothalia* all of which have similar internal structure.

Carpenter (1862, p. 248) in his classic monograph entitled "Introduction to the Study of the Foraminifera" wrote " . . . the difference

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*The cost of the printed plates was supplied by the William F. E. Gurley Foundation for Paleontology of Cornell University.

between *Operculina* and *Nummulina* (= *Camerina* of most recent authors) comes to rest only on the general form of the spire and the conspicuousness of its convolutions, —characters which seem by no means sufficient for the separation of the former as a genus distinct from the latter." He (p. 248) did retain the two genera because they are " . . . to be at once distinguished by their external conformation . . ."

Although Carpenter demonstrated that generic separation of certain genera of the camerinids was based on external appearance rather than on differences in internal structure of the test, numerous generic, and even subgeneric, names have been proposed and used. Barker (1939, p. 307) reviewed the generic classification of the camerinids and stated (p. 308): "I am not yet convinced as to the advisability of splitting up the group into so many genera, as in all cases forms can be found intergrading from one so-called genus to another."

However, Barker (1939, p. 308) was of the " . . . opinion that Hanzawa (1935) rightly abandoned Hofker's theory that all the genera are synonymous with *Camerina*, and until more work has been done on the evolution and phylogeny of the group it seems preferable to adhere to the accepted classification as modified by Hanzawa."

Since 1935 the classification suggested by Hanzawa has been modified both by the addition and combination of genera. Cole (1953, p. 32) at first combined *Ranikothalia* Caudri (1944, p. 367) with *Operculinoides* Hanzawa (1935), and later he (1959, p. 352) placed these two genera in the synonomy of *Operculina* d'Orbigny (1826). At the same time Cole (1959, p. 352) suggested that *Planocamerinoides* Cole (1958*b*, p. 262) (= *Assilina* of authors) was seemingly a synonym of *Camerina*. Thus, he recognized only two genera, *Camerina* Bruguière (1792) and *Operculina* d'Orbigny (1826).

Nagappa (1959, p. 156) reinstated *Ranikothalia* as a valid genus largely on the double structure of the spiral wall. He (1959, p. 160) recognized as valid genera *Camerina*, *Operculina*, and *Ranikothalia*. In addition he (1959, p. 159) wrote " . . . *Miscellanea* lacks the marginal cord so characteristic of the other nummulitid genera . . . " Vaughan (1945, p. 27) and Cole (1956, p. 241) in contradistinction have stated that *Miscellanea* does have a marginal cord.

This study is an attempt to demonstrate that there are only two valid genera of all those that have been proposed for camerinids with undivided chambers. They are *Camerina* and *Miscellanea*.

LOCALITIES OF THE FIGURED SPECIMENS

Europe

Locality 1. Sands of Wemmel, near Brussels, Belgium; Bartonian.

2. Cuise-la-Motte, near Compiègne, France; Ypresian.

3. Chaumont-en-Vexin, Paris Basin, France, donated by the late T. Wayland Vaughan; Lutetian.

India

4. Kohat District, near Shinki, Wazaristan, collected by the late L. M. Davies; Paleocene.

Borneo

5. Muara Djaing on the Tabalong River, southeastern Borneo, donated by the late T. Wayland Vaughan; Tertiary *d* (Oligocene).

Bonin Islands

6. Shizukazawa, Oki-wura, Haha-jima, (Hillsborough Island), gift of Shoshira Hanzawa; Lutetian.

New Hebrides

7. Espiritu Santo, gift of Mrs. Esther R. Applin; Recent.

8. Station IS-M-149-56, Ishigaki-shima, Yaeyama-guntō, Ryukyu-retto; small patch of Ryukyu limestone 1.1 mile north of the village of Kainan along the west bank of the upper course of the Miyara in central Ishigaki-shima. The exposure extends from the level of the stream channel to about 50 feet above the channel. The limestone is either plastered against or interfingered with unfossiliferous terrace gravels called the Nagura gravel.

Cuba

9. Cut in the Carretera Central below the railroad bridge at Central San Antonio 2 kilometers west of Madruga, Havana Province, Cuba (Palmer sta. 757); Paleocene.

Trinidad, British West Indies

10. Pit at Lizard Springs (Maerky collection 102b III) near Guayaguayare, southeastern Trinidad; courtesy of John B. Saunders; Paleocene.

11. Guaico-Tamana Road, ravine east of mile 13.5, gift of Hans Kugler; Miocene.

COMMENTS ON THE GENUS *RANIKOTHALIA*

The genus *Ranikothalia*, the type species of which is *Nummulites nuttalli* Davies (1927, p. 266), was erected by Caudri (1944, p. 17) to include camerinids with "bluntly rounded chamber tops in horizontal section" and with a greater "thickness of the coarsely gutted supplementary skeleton as compared with the majority of the other *Nummulites*."

Mrs. de Cizancourt (1948, p. 11) considered that American specimens referred to *Ranikothalia* were not sufficiently distinct from *Camerina* to be segregated in a separate genus. However, she did use subgeneric designations for these specimens, some of which were placed in *Camerina* (*Camerina*) and others in *Camerina* (*Operculinoides*).

Cole (1953, p. 33) concluded that specimens referred to *Ranikothalia* should be placed in the genus *Operculinoides*. Later, he (1959, p. 352) demonstrated that *Operculinoides* was a synonym of *Operculina*. Thus, in the classification which he developed *Ranikothalia* became another synonym of *Operculina*.

Recently, Nagappa (1959, p. 159) reinstated *Ranikothalia* for specimens which "have the typical rounded topped chambers and there is also the inner lining on the roofs of the chambers." In addition, Nagappa (1959, p. 157) wrote "Although . . . the marginal cord in *Nummulites* s. l. is extremely variable, the forms of the *O. bermudezi* group do exhibit a coarseness in the marginal cord which is not present in any of the true *Nummulites*." He (p. 159) remarked that Smout (1954, p. 76) had stated that the type species of *Ranikothalia*, *Nummulites nuttalli*, "is also a typical Nummulite."

Mrs. de Cizancourt (1948, p. 10) stated concerning the round-topped chambers which supposedly characterize species of *Ranikothalia* that " . . . other species of *Nummulites* have this likewise . . . " If the illustration of "*Operculina*" *catenula* (fig. 3, Pl. 25) is compared with the illustration of "*O.*" *ammonoides* (fig. 2, Pl. 25), it will be observed that the shape of the chambers is the same in the two species. Moreover, the chambers of *Camerina orbignyi* (fig. 3, Pl. 24) have rounded tops similar to those of species typically assigned to *Ranikothalia*.

The shape of the chambers is governed by the amount of curvature of the chamber wall as it approaches the spiral wall. Species in which the chamber wall is straight and radial have round-topped chambers as viewed in median section. Thus, the shape of the chambers is decidedly a specific, not a generic, character.

The structure of the whorl wall is emphasized by Nagappa (1959, table, p. 156) as one of the outstanding characters of *Ranikothalia.* He recorded this for *Camerina* as "Single, not differentiated, canaliculate"; for *Operculina* "As in *Nummulites*, spiral canals tend to be more numerous"; and for *Ranikothalia* as "Double, inner simple, outer coarsely canaliculate, 'degenerate'." Yet, Nagappa illustrated (fig. 3, pl. 22) a part of a whorl wall of a specimen he identified as *Operculina* sp. which shows a double wall.

Carpenter (1862, p. 269) accurately described the structure of the spiral wall of *Camerina* as follows: "Each septum, in well-preserved specimens, can be distinctly seen to be composed of two lamellae, between which the canal system is interposed . . . ., and it generally happens that the lamella which forms the anterior face of one septum can be traced along the inner edge of the 'marginal cord' . . ., a considerable interval being sometimes left between them, so as to become continuous with that which forms the posterior face of the next septum . . ."

The description of the structure of *Camerina* is identical with that given by Cole and Herrick (1953, p. 53) for *Operculinoides georgianus* (= *Ranikothalia bermudezi* of Nagappa, 1959, p. 159 = *Camerina catenula*). Yet, Nagappa (1959, p. 156) stated that *Camerina* and *Ranikothalia* can be distinguished from each other on the structure of the "whorl wall."

The following illustrations demonstrate clearly the similarity in structure in specimens formerly assigned to various genera:

Pl. 23, fig. 5—formerly classified as *Operculina* (Recent)
Pl. 23, fig. 6—*Camerina* (Ypresian)
Pl. 24, figs. 1, 4, 5—*Camerina* (Lutetian)
Pl. 24, figs. 2, 3—*Camerina* (Bartonian)
Pl. 24, fig. 6—formerly classified as *Operculinoides* (Miocene)
Pl. 25, fig. 2—formerly classified as *Operculina* (Recent)
Pl. 25, fig. 3—formerly classified as *Operculinoides* and *Ranikothalia* (Paleocene)
Pl. 25, fig. 4—*Camerina* (Oligocene)
Pl. 25, fig. 5—formerly classified as *Operculina* (Pleistocene)
Pl. 26, fig. 1—formerly classified as *Operculinoides* and *Ranikothalia* (Paleocene)
Pl. 26, fig. 2—*Camerina* (Eocene)

Thus, there is no fundamental difference either in chamber shape or the structure of the spiral wall in *Ranikothalia, Operculina,* and *Camerina.*

COMMENTS ON THE SPECIES *CAMERINA PLANULATA* (LAMARCK), 1804

Indian specimens which Davies (1927, p. 266) named "*Nummulites*" *nuttalli* had been assigned previously to *Camerina planulata* (Lamarck) (Nuttall, 1926, p. 114). Later Caudri (1944, p. 367) designated *Camerina nuttalli* as the type species of the new genus *Ranikothalia.*

Davies (1927, p. 267) wrote: "The chief distinctions are that the Indian form always has more or less bossed and granulated poles, whereas granules are never seen on *planulatus*; it also has a much thicker marginal cord, and stronger and straighter septal filaments than are normal to *planulatus*". However, Davies (p. 267) did admit that "The Sind specimens are, on the whole, those most like *planulatus*, although they generally exceed *planulatus* considerably in size."

The transverse section (fig. 3, Pl. 23; fig. 3, Pl. 26) of *C. planulata* has a distinct group of pillars in the central area, some of which are continuous to the surface where their ends form small surface bosses. These pillars in the European specimen of *C. planulata* are the same as those found in Indian specimens of "*N.*" *nuttalli* (see: Davies, 1927, fig. 4, pl. 18).

Likewise, the similarity in the development of the marginal cord is apparent if figures 3, 4, Plate 23 are compared with figure 19, plate 6 of Davies (Davies and Pinfold, 1937).

Variation in the development of the marginal cord is a specific feature, not a generic one, as may be demonstrated by comparison of the following illustrations all of which represent specimens traditionally assigned to *Camerina*: Pl. 25, fig. 1; Pl. 26, fig. 7; pl. 2, figs. 8-10 (Cole, 1953).

The median section (fig. 1, Pl. 23) of a European specimen should be compared with figure 9, plate 3 of Davies and Pinfold (1937). These two sections have the same arrangement and pattern of coiling and chambers.

The inner and outer division of the spiral wall (fig. 6, Pl. 23) and of the spiral sheet (fig. 4, Pl. 23) of *C. planulata* is similar to that of specimens of *Operculina ammonoides* (fig. 5, Pl. 23) except in thickness.

Davies (Davies and Pinfold, 1937) illustrated a part of the spiral whorl (fig. 20, pl. 6) of a specimen which he identified as "*Nummulites*" *nuttalli.* The granulation of the outer wall of this specimen is identical with that of *Miscellanea stampi* (= *M. miscella*). Therefore, this incorrectly identified specimen has caused confusion regarding the wall structure in the type species of *Ranikothalia*. "*Nummulites*" *nuttalli* has a wall structure identical with that of *C. planulata.*

The inescapable conclusion is that "*N.*" *nuttalli* is a synonym of *C. planulata.*

At the same time that Davies (1927) named *C. nuttalli*, he described (p. 274) *Operculina sindensis.* Caudri (1944, p. 368) recognized that *O. sindensis* was related to *C. nuttalli* (= *C. planulata*) and placed this species in *Ranikothalia.* Nagappa (1959, p. 158) attempted to justify the retention of the two specific names, but his own analysis demonstrated that only one species can be recognized as all the supposed differences are gradational ones.

So far only microspheric specimens have been discussed. In Europe it has long been recognized that megalospheric specimens, originally named *C. elegans* Sowerby, represent the alternate generation of *C. planulata*, a specific name which has priority and must be used both for microspheric and megalospheric specimens.

Davies (Davies and Pinfold, 1937, p. 41) wrote " . . . *N. nuttalli* probably has *N. thalicus* for its megalospheric companion and merges into *N. sindensis* whose companion is probably *N. thalicus* var. *gwynae.*" *Camerina thalica* is without question the megalospheric form of *C. nuttalli* (= *C. planulata*).

The following species and subspecies from India are considered to be synonyms of *Camerina planulata*:

1927. *Nummulites nuttalli* Davies, p. 266-268, pl. 18, figs. 3, 4; pl. 19, figs. 7-9 (microspheric specimens).

1927. *Nummulites nuttalli* var. *kohaticus* Davies, p. 269, pl. 19, figs. 1-6 (probably microspheric specimens).

1927. *Nummulites thalicus* Davies, p. 269-271, pl. 20, fig. 1-4 (megalospheric specimens).

1927. *Nummulites thalicus* var. *gwynae* Davies, p. 271, pl. 20, fig. 5 (megalospheric specimens).

1927. *Operculina sindensis* Davies, p. 274-276, pl. 19, figs. 10-13 (microspheric specimens).

BASIS OF CLASSIFICATION

The separation of camerinids with undivided chambers into distinct genera has been based on the type of coiling (involute or evolute), the number of coils, the height of the coils, the shape of the chambers, the character of the spiral wall, and the strength of the marginal cord.

The definition of genus (Webster's New International Dictionary) is: "A group of structurally or phylogentically related species, or consisting of an isolated species exhibiting unusual differentiation." Another definition (Mayr, 1942, p. 283) is: "A genus is a systematic unit including one species or group of species of presumably common phylogenetic origin, separated by a decided gap from other similar groups. It is to be postulated for practical reasons that the size of the gap shall be in inverse ratio to the size of the group."

The structural differentiation in the test of specimens assigned to *Miscellanea* is distinct from that in the other camerinids with undivided chambers. *Miscellanea* has a marked and strongly granulated spiral wall, a bulbus ending of the chamber partitions (fig. 6, Pl. 26) and a distinctive marginal cord (figs. 4, 5, Pl. 26).

These structural differences clearly distinguish this genus and separate it from the other genera of camerinids with undivided chambers. However, there are no structural differences which may be used to distinguish between *Camerina, Planocamerinoides* (= *Assilina* of authors), *Operculina, Operculinoides, Ranikothalia*, and *Paraspiroclypeus*. These genera have been defined in terms of intergradational features which are specific rather than generic differences.

Cole (1953, p. 32) demonstrated that the structure of *Ranikothalia* was the same as that of *Operculinoides*. At that time he emphasized (p. 34) that the strength of the marginal cord is a specific, not a generic, character. Later he (Cole, 1959) proved that *Operculinoides* and *Operculinella* were synonyms of *Operculina.*

The internal structure of *Planocamerinoides* (= *Assilina* of authors) is identical with that of *Camerina* except the spiral wall does not cover the preceding whorls. *Planocamerinoides* is evolute, whereas *Camerina* is involute. It has long been accepted in other genera of larger Foraminifera that evolute and involute specimens may occur in the same genus. *Heterostegina* is an example. Moreover, Cole (1959, p. 352) emphasized that individuals of a single species may "grade from those which are involute to others which are evolute." Thus, the definition of *Planocamerinoides* has been based on characteristics of individual specimens.

If sufficient study is made, it can be predicted that the supposed species of *Planocamerinoides* will integrate with species which have been placed in *Camerina.* Cole (1958a, p. 191) has stressed the importance of the ecological environment on the development of the tests of certain American species formerly referred to the genus *Operculinoides.* Therefore, the abundance of evolute specimens at certain horizons might be ecologically controlled rather than genetically controlled.

Gill (1953, p. 832) remarked that "The manner in which *Assilina daviesi* disappeared from the Bhadrar beds at the level of the thick limestone in the middle of this formation, and then reappears in great numbers when shale conditions again spread far to the west, suggests that the communities *A. daviesi* were capable of extensive and rapid migration toward areas of more favorable ecology." An alternate explanation is that this species did not migrate but remained continuously in the area. The evolute form dominated during the time of shale deposition, whereas both involute and evolute forms of the same species existed together during the time of limestone deposition.

Specimens of a species still living run the gamut from individuals with evolute tests (*Planocamerinoides* type) (see: Cole, 1959, fig. 5, 6, pl. 28; fig. 7, 12, pl. 29; fig. 3, pl. 30; figs. 6, 7, pl. 31) to others with involute tests (*Camerina* type) (see: Cole, 1959, fig. 1, pl. 28; fig. 7, pl. 30). Another living species, "*Operculina*" *venosa*, has individuals with the same internal structure as does *Camerina.* Carpenter (1862, p. 241) placed this living species in the genus *Camerina.*

Although species such as "*Operculina*" *complanata* on first inspection appear to be distinct from *Camerina laevigata*, the appearance is misleading. The structure of the test is fundamentally the same and the two species are connected by other species which are entirely intermediate. The superficial difference in appearance is because "*O.*" *complanata* is the end species of one lineage within a single genus.

Inasmuch as there are no decided gaps between *Camerina* on one hand and *Operculina* on the other, and as species heretofore placed in these supposedly distinct genera are phylogenetically related, *Operculina* is a synonym of *Camerina.* Stratigraphically this genus ranges from Paleocene to Recent.

LINEAGES OF THE GENUS *CAMERINA*

Although it might seem desirable to use subgeneric designations to separate certain lineages within this form-fluid genus, there is so much variation in form without any change in fundamental internal structure that a subgeneric separation would encounter the same difficulties as were inherent in the divided generic classification.

The phylogenetic relationships are best expressed by indicating certain dominant lineages which have developed. There are at least four distinct and definite lineages: 1) Those species which are either involute or evolute, multi-whorled with little or slight expansion of the coils and with exceptionally large microspheric individuals (formerly *Camerina* and *Planocamerinoides*) ; 2) Those species which are evolute with relatively few rapidly expanding coils (formerly *Operculina*) ; 3) Those species which are essentially the same as lineage 1 except for their smaller size, relatively few coils and relatively small microspheric generation; and 4) Those species which are intermediate between lineages 2 and 3 (formerly *Operculinoides*).

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PLATES

EXPLANATION OF PLATE 23

Figure Page

1, 3, 4, 6. **Camerina planulata** (Lamarck) 193, 194

1. Median section of a microspheric specimen, x 8, to show the shape of the coils and the pattern of the chamber partitions.

3. Part of a transverse section of a microspheric specimen, x 20, to show the marginal cord and the axial pillars.

4. Enlarged part of the specimen illustrated as figure 3, x 40, to show the details of the marginal cord and the two distinct layers of the spiral wall.

6. Enlarged part of the specimen illustrated as figure 1, x 40, to show the two distinct layers of the spiral wall and the axial canal through the chamber partitions.

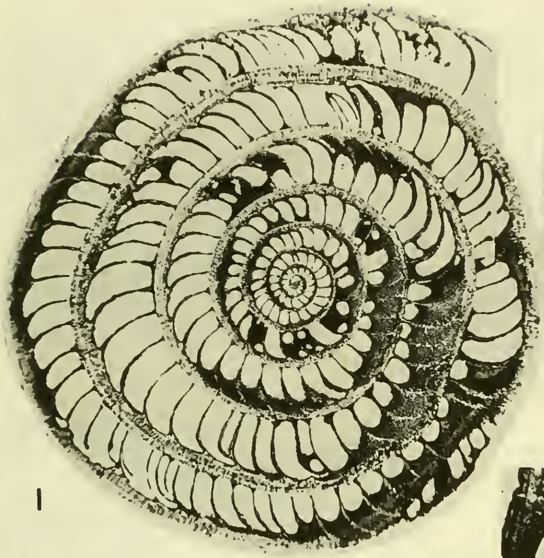
2. **Camerina orbignyi** (Galeotti) 192, 193

Median section of a microspheric specimen, x 8, to show the shape of the coils and the rounded tops of the chambers.

5. **Camerina ammonoides** (Gronovius) 193, 194

Enlarged part of the specimen illustrated as figure 6, plate 30, Bull. Amer. Paleont. v. 39, No. 181, x 40, to show the similarity in structure to that of *C. planulata*.

1, 3, 4, 6—Loc. 2
2—Loc. 1
5—Loc. 7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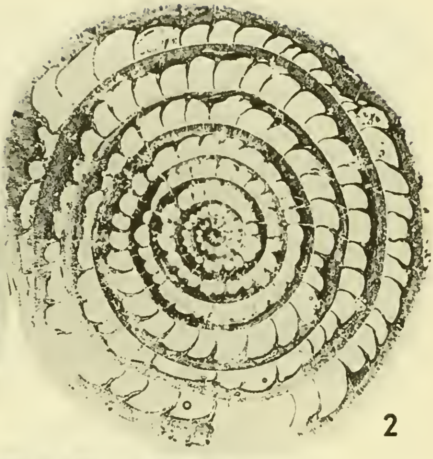
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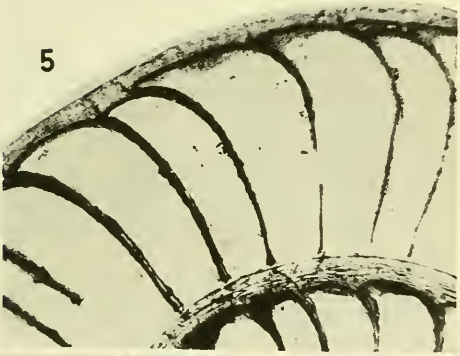
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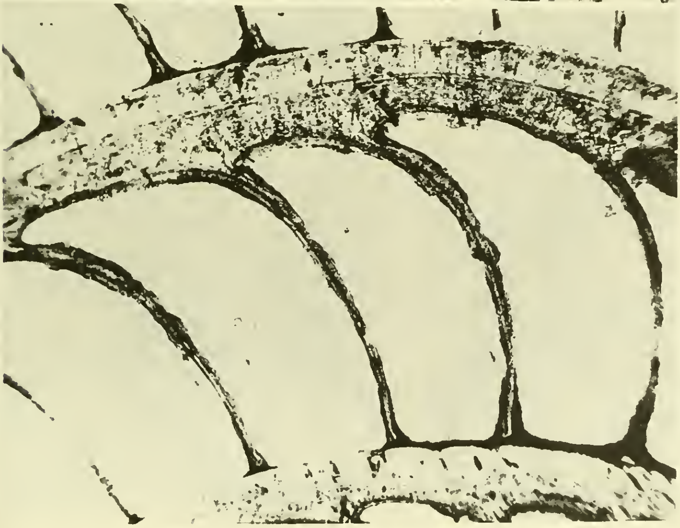
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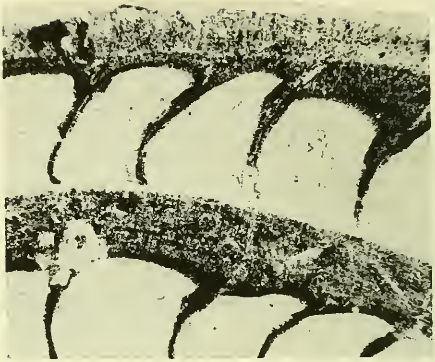

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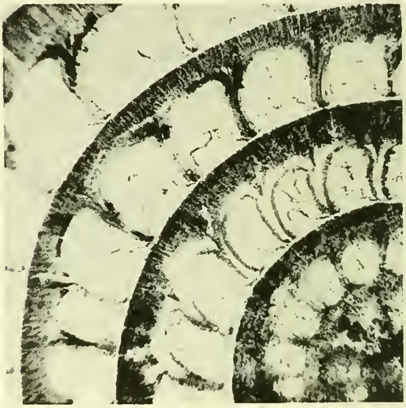

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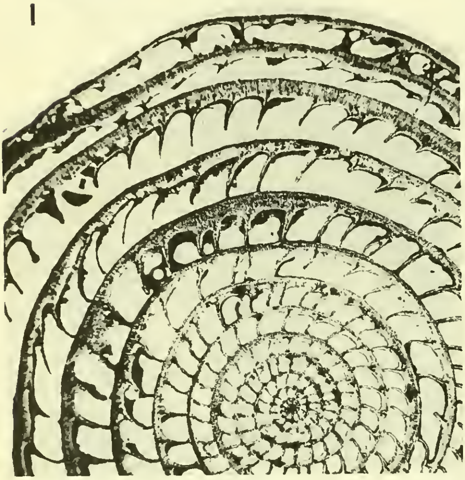

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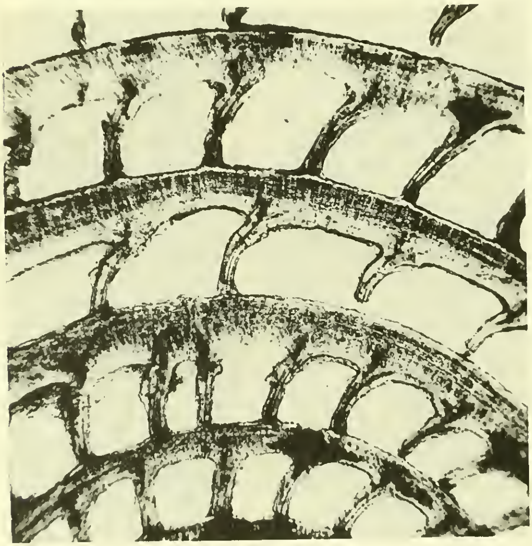

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6

EXPLANATION OF PLATE 24

Figure Page

Parts of median sections, x 40, except 4 which is x 8.

1, 4, 5. **Camerina laevigata** Bruguière 193

1, 5. Enlarged parts of the spiral wall to show the structure.
4. Part of a microspheric specimen to show the character of the coils and the pattern of the chambers.

2, 3. **Camerina orbignyi** (Galeotti) 192, 193

Parts of the spiral wall to show the structure.

6. **Camerina cojimarensis** (D. K. Palmer) 193

Part of a median section introduced for comparison with figures 5, 6, Plate 23.

1, 4, 5—Loc. 3.
2, 3—Loc. 1.
6—Loc. II.

EXPLANATION OF PLATE 25

Figure Page

All illustrations x 40

1. **Camerina boninensis** (Hanzawa) 194

Part of a transverse section to show the marginal cord and the spiral wall.

2. **Camerina ammonoides** (Gronovius) 192, 193

Part of the median section of the specimen illustrated as figure 2, plate 30, Bull. Amer. Paleont., v. 39, No. 181, to show round-topped chambers and the double structure of the spiral wall.

3, 6. **Camerina catenula** (Cushman and Jarvis).......................192, 193

3. Part of a median section which is similar to that of *C. ammonoides,* figure 2.

6. Part of a transverse section to show the marginal cord and the structure of the spiral wall; compare with figure 1.

4. **Camerina fichteli** (Michelotti).. 193

Central part of a median section of a megalospheric individual.

5. **Camerina complanata** (Defrance).. 193

Part of the median section of the specimen illustrated as figure 3, plate 31, Bull. Amer. Paleont., v. 39, No. 181, which has the same structure as that of the specimens illustrated as figures 5, 6, Plate 23.

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3—Loc. 9.
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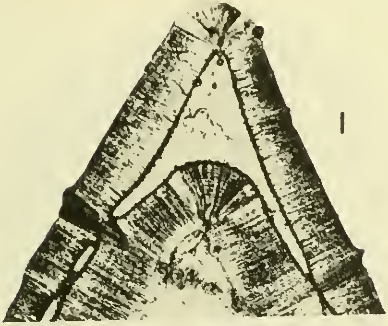
5—Loc. 8.
6—Loc. 10.



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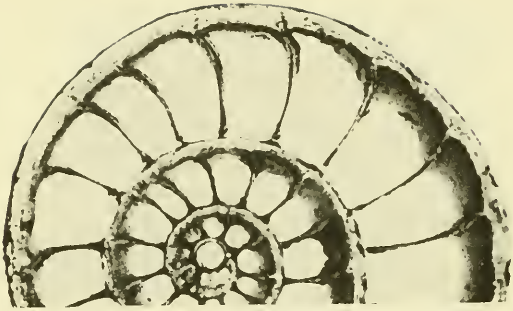

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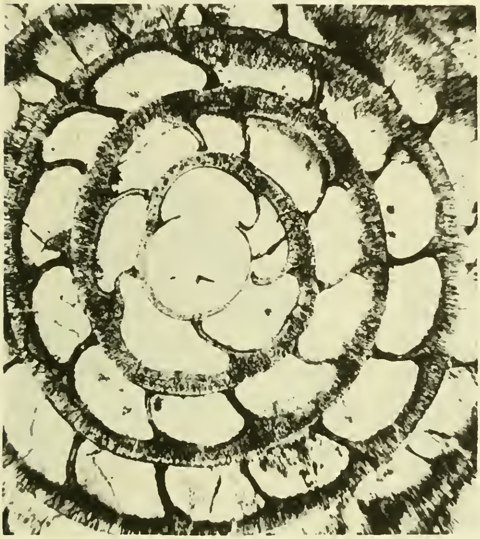

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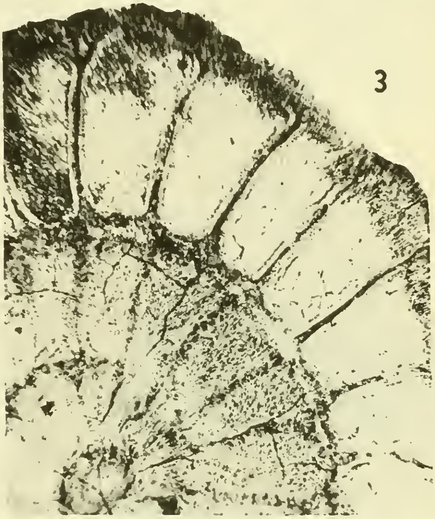

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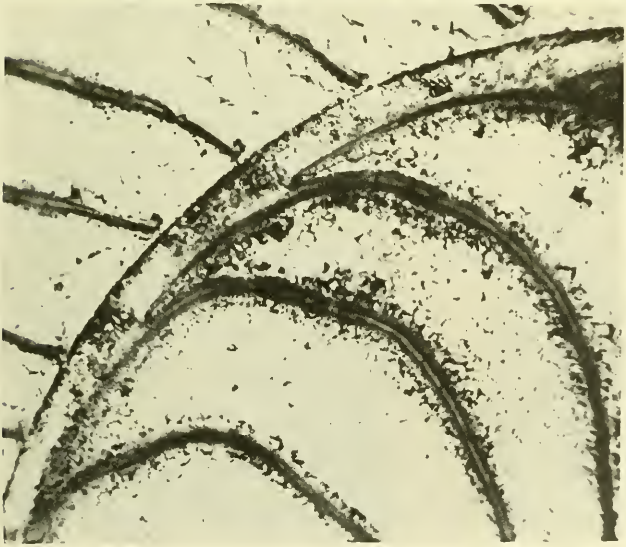

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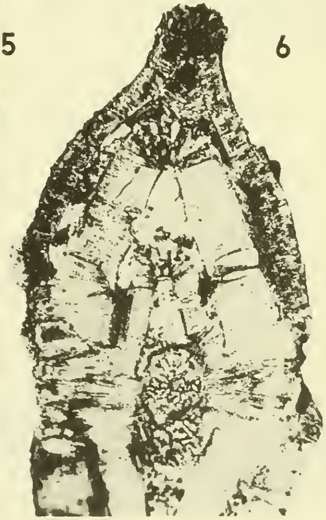

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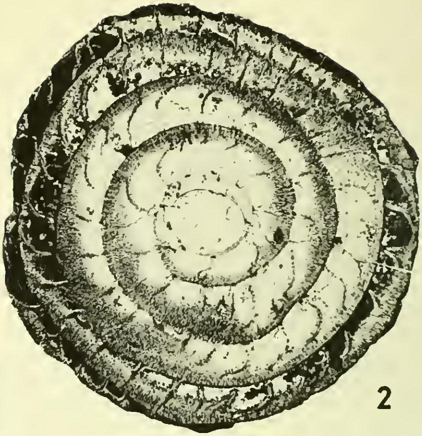
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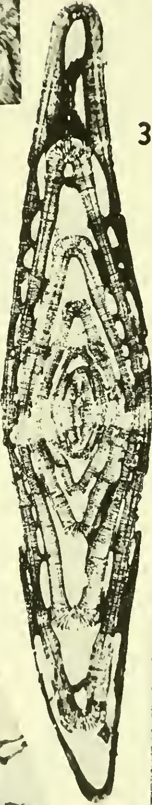
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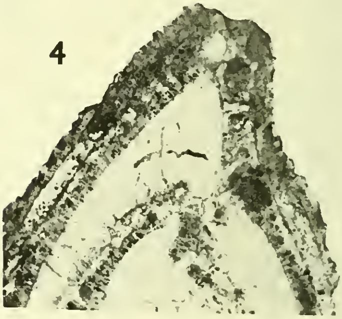
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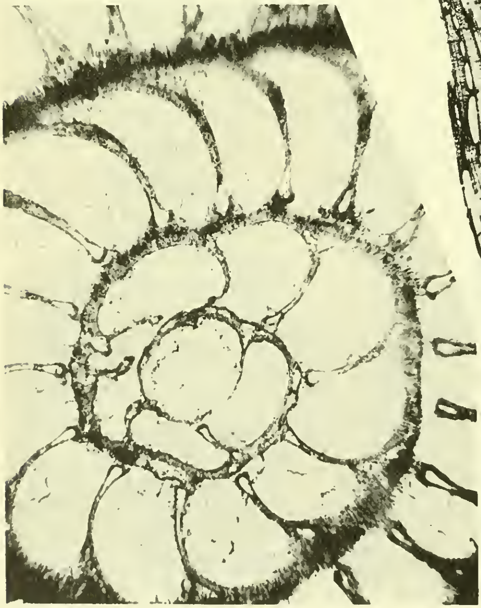
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EXPLANATION OF PLATE 26

Figure Page

1. **Camerina catenula** (Cushman and Jarvis) 193

Part of a median section of a megalospheric specimen, x 40, for camparison with that of *Camerina fichteli*, figure 4, Plate 24.

2. **Camerina boninensis** (Hanzawa) 193

Median section of a megalospheric specimen, x 12.5, to show the large embryonic chambers and the character of the coils.

3. **Camerina planulata** (Lamarck) 194

Transverse section of a microspheric specimen, x 12.5; the same specimen parts of which are enlarged as figures 3, 4, Plate 23.

4-6. **Miscellanea miscella** (d'Archiac and Haime) 196

4, 5. Parts of transverse sections of megalospheric specimens, x 40, to show the coarsely granulated spiral wall and the marginal cord.

6. Part of a median section of a megalospheric specimen, x 40, to show the looplike end of the chamber partitions.

7. **Camerina orbignyi** (Galeotti) 194

Part of a transverse section of a microspheric specimen, x 40, to show the marginal cord.

1—Loc. 10.
2—Loc. 6.
3—Loc. 2.
4-6—Loc. 4.
7—Loc. 1.

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THE MICROFAUNA OF THE YORKTOWN FORMATION FROM JAMES RIVER, SURRY COUNTY, VIRGINIA

by

JOSEPH W. SABOL

November 25, 1960

Paleontological Research Institution
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THE MICROFAUNA OF THE YORKTOWN FORMATION FROM JAMES RIVER, SURRY COUNTY, VIRGINIA

Joseph W. Sabol

ABSTRACT

Foraminifera, Ostracoda, and Mollusca from the Yorktown formation (upper Miocene) of the Cobhams Wharf area, Virginia, are listed, described, and discussed. Twenty-five forms of Foraminifera and 15 forms of Ostracoda are compared stratigraphically and ecologically with other localities of the Yorktown formation on the York-James Peninsula of Virginia. The validity of Mansfield's zonation of the Yorktown is discussed on the basis of present micropaleontological data. Results show that Mansfield's 'zones' are not valid and that the Foraminifera-Ostracoda fauna of the Yorktown formation is related to the *Ecphora-Cancellaria* facies of the Choctawhatchee formation of Florida. The problem and status of the genus *Buccella* and *Lagena* are discussed. It seems that the Yorktown sea was a shifting one with a depth of about 25 meters at the Cobhams Wharf area. This report supplements the work done on the Yorktown formation in the York-James Peninsula by McLean (1956, 1957).

PURPOSE OF THE STUDY

The purpose of this study is to increase and extend the overall knowledge of the Yorktown formation in Virginia. This paper is a supplement to micropaleontological work done on the Yorktown by McLean (McLean, 1956, 1957). Because this study is meant to be a supplement to McLean's work in the York-James Peninsula of Virginia, where there are areas of the two reports that overlap, the author has seen fit to refer the reader to McLean's papers. In the case of illustrations and descriptions of species, only those specimens were figured that differed from McLean's illustrations, or that were not illustrated by him.

It was hoped at the outset of the current study that some of the questions concerning the Yorktown would be answered. To a certain extent this has been the case, at least some of the questions have been answered in the author's mind. Though I have discussed the Yorktown and its problems with a number of individuals I take full responsibility for the views and analysis set forth in this paper.

ACKNOWLEDGMENTS

The author wishes to express his appreciation to all who have aided him during this study. Special thanks are due to James D. McLean, Jr., for his suggestion that the problem was worthy of study, for offering both moral and physical assistance, and for giving freely of his time and facilities. The author is also indebted to Katherine V. W. Palmer of the Paleontological Research Institution for her identifications of the mollusks. Miss Ruth Todd of the U. S. Geological Survey made the Cushman collection available to the author at various times and answered questions con-

cerning certain species. Various members of the U. S. Geological Survey expressed their views to the author concerning the Yorktown formation, particularly in respect to its zonation. The illustrations in this paper were drawn by Mrs. Sally Diana Kaicher, Scientific Illustrator. The reader will agree, I am sure, that the quality of the illustrations speak for the ability and talent of the illustrator. My many thanks to Mrs. Kaicher.

SEDIMENTARY DESCRIPTION OF THE COBHAMS WHARF MATERIAL

The material on which this paper is based was collected by Mr. George C. Barclay of Newport News, Virginia, in 1957. The description of the collecting locality as given by Mr. Barclay is as follows: ". . . material collected from cliffs on west side of the James River, Surry County, Virginia, two miles south of Scotland Wharf pier, known as Cobhams Wharf or Beach." Figure 1 shows the location of the material for this study and also the area covered by McLean (1956, 1957).

The collected material may be described as being a fine-to medium-grained, calcareous sand containing less than one percent size particles. Little evidence of gravel was found in the sample. The grains are mainly subangular in shape and range in size from .5 x .5 x 1 mm. to 1 x 3 x 5 mm. The sample contained a large number of shell fragments most of which were well worn by abrasion. Fragments of shell material and sand grains were found cemented together by calcareous cement and stained by iron oxide.

The microfauna contained in the described sample consisted of Foraminifera, Ostracoda, Mollusca, sponge spicules, and fragmentary organic remains. This fauna showed only a fair degree of preservation, and many of the specimens had been affected by leaching to some degree. For the size of the bulk sample, the number of preserved specimens was low.

PREVIOUS WORK ON THE COBHAMS WHARF AREA

Until the advent of this paper only one other study has been made of the microfauna of the Cobhams Wharf area, Surry County, Virginia. That study was conducted by Cushman and Cahill (1932-33) and was concerned only with the Foraminifera of the area. Cushman and Cahill studied two samples of fossiliferous material from Surry County, Virginia; however, they classified the two as St. Marys in age. The two localities that they

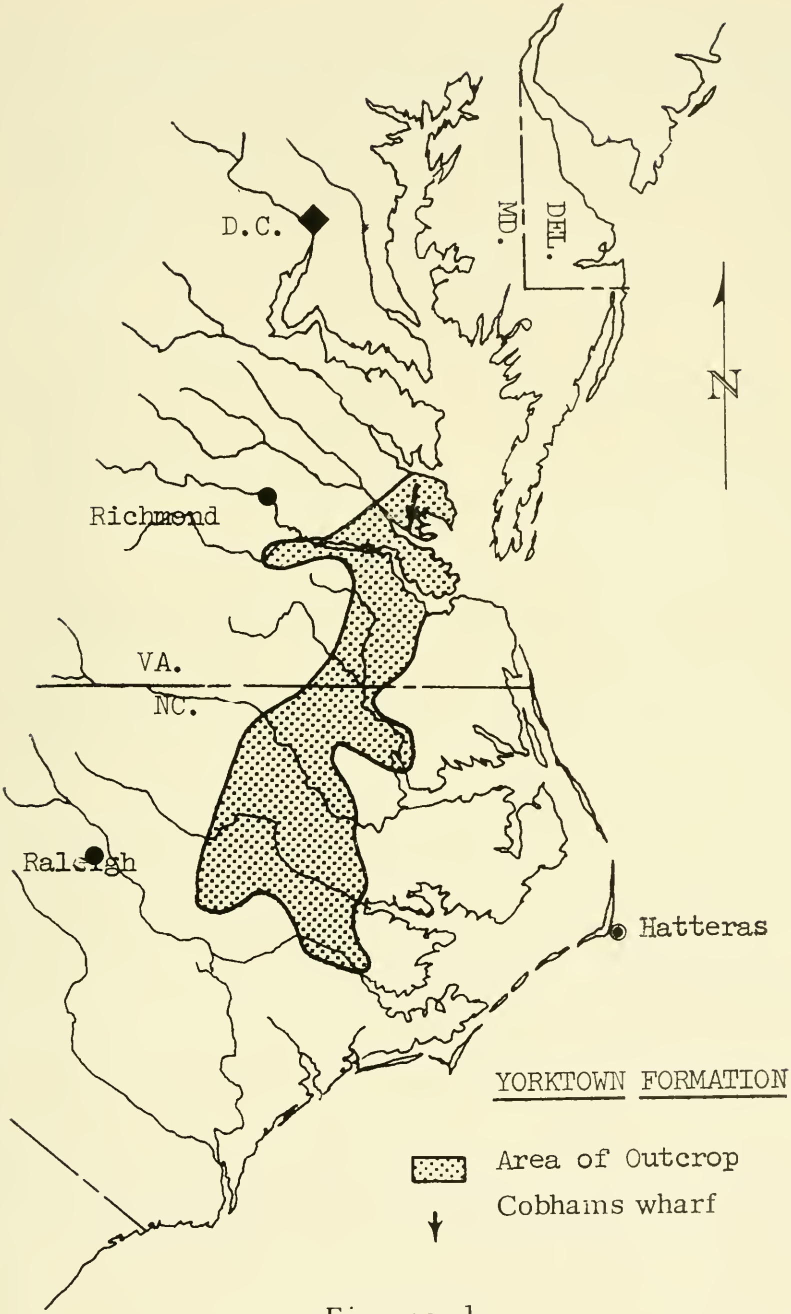
D.C.
MD.
DEL.
N
Richmond
VA.
NC.
Raleigh
Hatteras
YORKTOWN FORMATION
Area of Outcrop
Cobhams wharf

Figure 1

studied are as follows: 1/241; just below College Run on Cobhams Bay, right bank of the James River, Surry County, Virginia, beds outcropping at water level, and 1/543; half a mile to 1 mile below Sunken Marsh Creek, James River, Surry County, Virginia, lowest bed, basal bed along river. The two numbers given to the collections are those found in the catalogue of Tertiary localities of the U. S. Geological Survey. The fraction indicates that the two numbers are 10241 and 10543 respectively. Listed below are the Foraminifera described by Cushman and Cahill (1932-33) from the two Surry County localities mentioned above.

LOCALITY NUMBER 10241

Textularia agglutinans
Dentalina consobrina var. emaciata
Nonion incisum
Elphidium incertum
Discorbis consobrina
Eponides mansfieldi
Eponides lateralis

LOCALITY NUMBER 10543

Textularia gramen
Textularia mayori
Guttulina austrica
Pseudopolymorphina dumblei
Elphidium incertum
Bulimina gracilis
Bolivina paula
Discorbis floridana
Discorbis consorbrina
Discorbis turrita
Eponides lateralis
Rotalia beccarii var. parkinsoniana

For a more extensive resumé and discussion of the past work on the Yorktown formation and its area of surface outcrop, the reader is invited to see McLean, 1956, pp. 266-278.

MOLLUSKS OF THE COBHAMS WHARF AREA

The mollusk fauna of the Cobhams Wharf area was identified by Katherine V. W. Palmer of the Paleontological Research Institution. The specimens identified by Dr. Palmer are listed on page 215.

The mollusks together with ecological data show that a change of some type does occur in the Yorktown formation. Mansfield, on the basis of mollusks alone, divided the Yorktown into two zones; zone 1, the *Pecten clintonius* zone, and zone 2, the *Turritella alticostata* zone, with zone 1 being the older of the two. This zonation is still used by the U. S. Geological Survey.

Zone 1 and zone 2 as set up by Mansfield represent two distinct periods of deposition with respect to time. In the light of the current study and after reviewing recent studies concerning the Yorktown and the units above and below it, I cannot substantiate Mansfield's zonation in its entirety. To this I will agree, there is a change in the faunal elements of the Yorktown approximately at the stratigraphic level of Mansfield's zone 1 and 2. At this point in our knowledge of the Yorktown it is difficult to say that this change denotes the subdivision of two 'zones' in its original connotation. It seems likely that the faunal change that occurs in the Yorktown, especially at McLean's Carter's Grove outcrop, should be attributed to the shifting of environments, and called facies, rather than a definite time break, and called zones. If Mansfield's zones are valid for the mollusks as he states, they should also be recognizable for the other constituents of the fauna, namely the Foraminifera and the Ostracoda.

It should be remembered that when Mansfield worked on the Yorktown in 1927 that little was known and less attention was paid to the ecological subdivisions of geologic units. Had Mansfield had access to our present-day knowledge of ecology and the influence that environment places on faunas he may or may not have subdivided the Yorktown as he did. Also, if at the time of Mansfield's study, more had been known about the rest of the contained fauna in the Yorktown, his final decision may have been altered. No true picture of a geologic unit can be obtained until all elements of that unit, both lithologic and paleontologic have been investigated.

Smith (1959), while working on the Trent formation of North Carolina, which is overlain in places by the Yorktown, refers to the earlier work of Thorson (1957). Thorson discussed several *Venus* communities and pointed out the fact that *Venus fluctuosa* communities give way to *Cardium* communities as the bottom becomes silty. Although Thorson conditions exist in Europe, Smith stated that shifts of this type may occur in the Trent formation of North Carolina. It seems logical to assume that if this type of shift did take place in the Trent, it could have taken place in the overlying Yorktown formation in North Carolina, and in Virginia.

Listed below are the mollusks found in the Cobhams Wharf sample, with Dr. Palmer's notes. They are deposited in the Paleontological Research Institution and bear the catalogue numbers 7063-7080.

Glycymeris sp. probably *G. subovata* (Say)
Ostrea disparilis Conrad
Chlamys (*Placopecten*) *clintonia* (Say), Yorktown
Chlamys jeffersonia (Say)
Chlamys santamaria middlesexensis (Mansfield); same as Powell's Lake top bed.

Cf. *Crassatellites undulatus* (Say)
Astarte (*Ashtarotha*) *undulata* (Say)
Chama congregata Conrad
Venericardia granulata Say: same as Carter's Grove specimen
Mercenaria sp.
Chione sp.
Gafrarium metastriatum Conrad
Corbula sp.
Dentalium carolinense Conrad
Cf. *Turritella alticostata* Conrad

The Cobhams Wharf sample of the Yorktown also contained the following fragmentary bits of microfauna:

3 otoliths
2 Bryozoa fragments
1 pteropod
3 badly worn apical whorls of small gastropods
numerous barnacle plates
1 small coral

OSTRACODA OF THE COBHAMS WHARF AREA

The Cobhams Wharf sample contained 15 species of ostracods, none of which are new. All of the species was reported by McLean (1957) as present in one or more of his samples of Yorktown material from the York-James Peninsula.

The ostracods from Cobhams Wharf area supplement the supposition of McLean (1957, pp. 60, 61) that the Yorktown is related stratigraphically and/or ecologically to the *Ecphora*—*Cancellaria* "facies" of the Choctawhatchee formation of Florida. It is not the author's wish here to expound on the merit of the term "facies" as opposed to "zone". The author is more interested in the actual relationships of the units. However, the problem of the Yorktown—*Ecphora*—*Cancellaria* relationship is still open to some debate and the results of this particular study will by no means answer the entire question. A greater amount of detailed stratigraphic work is needed before this supposition can be substantiated. From the studies of Puri (1954), who used "facies" for the various units of the Choctawhatchee and McLean's (1956, 1957) Yorktown study, it is

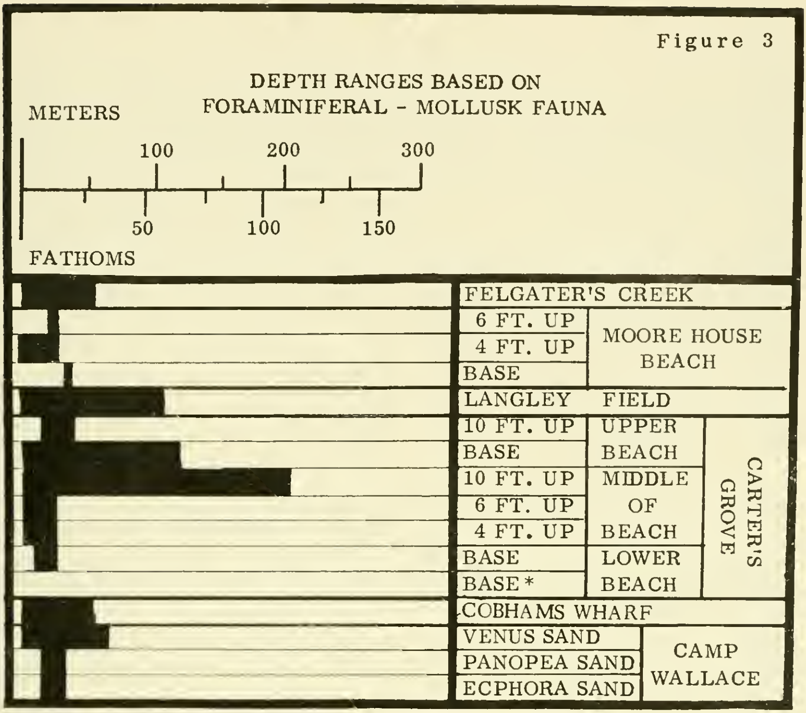
Figure 3

DEPTH RANGES BASED ON FORAMINIFERAL - MOLLUSK FAUNA

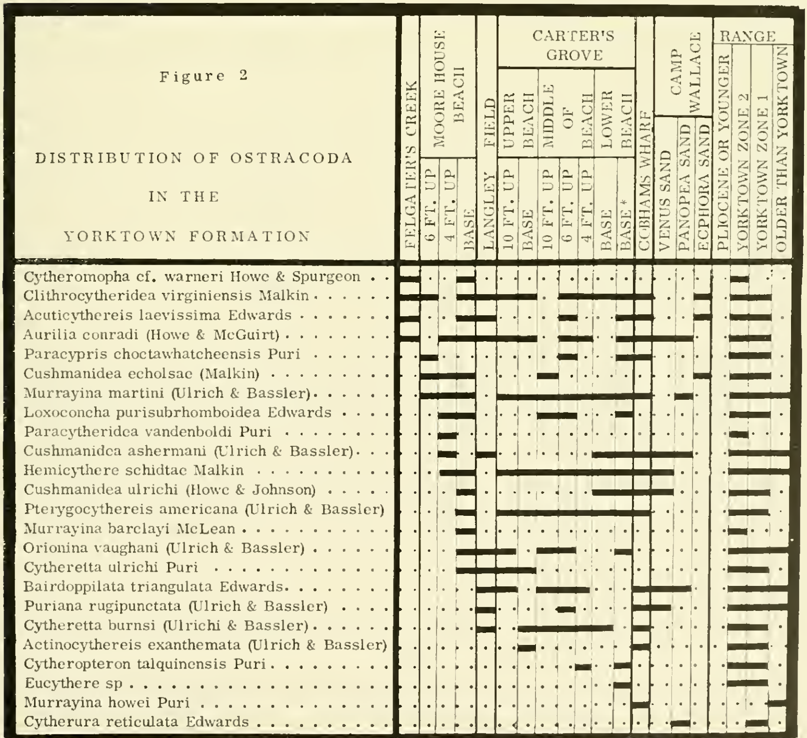
Figure 2

DISTRIBUTION OF OSTRACODA IN THE YORKTOWN FORMATION apparent that certain faunal elements of the Choctawhatchee and the Yorktown are related. The point in question is the extent of this relationship.

The faunal information that is available concerning the Yorktown and the *Ecphora—Cancellaria* facies points out similarities. The sedimentary analysis of the two also coincide as much as 'two units' with such lateral extent can coincide. The author favors the supposition that the two units are stratigraphically similar; however, ecologically divergent. The absence of certain species in one or the other unit points toward different ecological conditions. As stated by McLean, "there are more species which are not present in the two units than are present." Figure 2 shows the relationship of the ostracods from the Yorktown formation at Cobhams Wharf with various other Yorktown localities.

FORAMINIFERA OF THE COBHAMS WHARF AREA

The Cobhams Wharf sample yielded 25 identifiable species of Foraminifera, all except *Lagena sulcata* were reported from one or more of McLean's collecting localities. The relationship of the species found at Cobhams Wharf with those found at other Yorktown localities are shown in Figure 4.

The Foraminifera described in this study as do the ostracods, show a relationship to the *Arca-Ecphora-Cancellaria* facies of the Florida Miocene. Puri (1953) regarded the *Arca* and the *Cancellaria* facies as contemporaneous. If this is the case, there is evidence for a closer relationship between the upper Miocene of Virginia and that of Florida.

The question which remains is whether the relationship is a stratigraphic or ecologic one, or both? Lack of knowledge concerning the two units hampers the answering of the question at the present time. The most probable solution to the problem would be a complete statistical analysis of the faunas of the units, because superficially they show only vague but apparent relationships.

The foraminiferal faunas of the Cobhams Wharf sample corresponds closely with McLean's locality of the base of the Carter's Grove outcrop. The Cobhams Wharf area also compares to the base of the Carter's Grove as far as the lack of certain species of Foraminifera are concerned. Figure 4 shows an absence of such genera as *Massilina*, *Robulus*, and *Dentalina* in the Cobhams Wharf sample. The Carter's Grove basal sample contained no *Massilina* or *Dentalina* and only two specimens of *Robulus vaughani*.

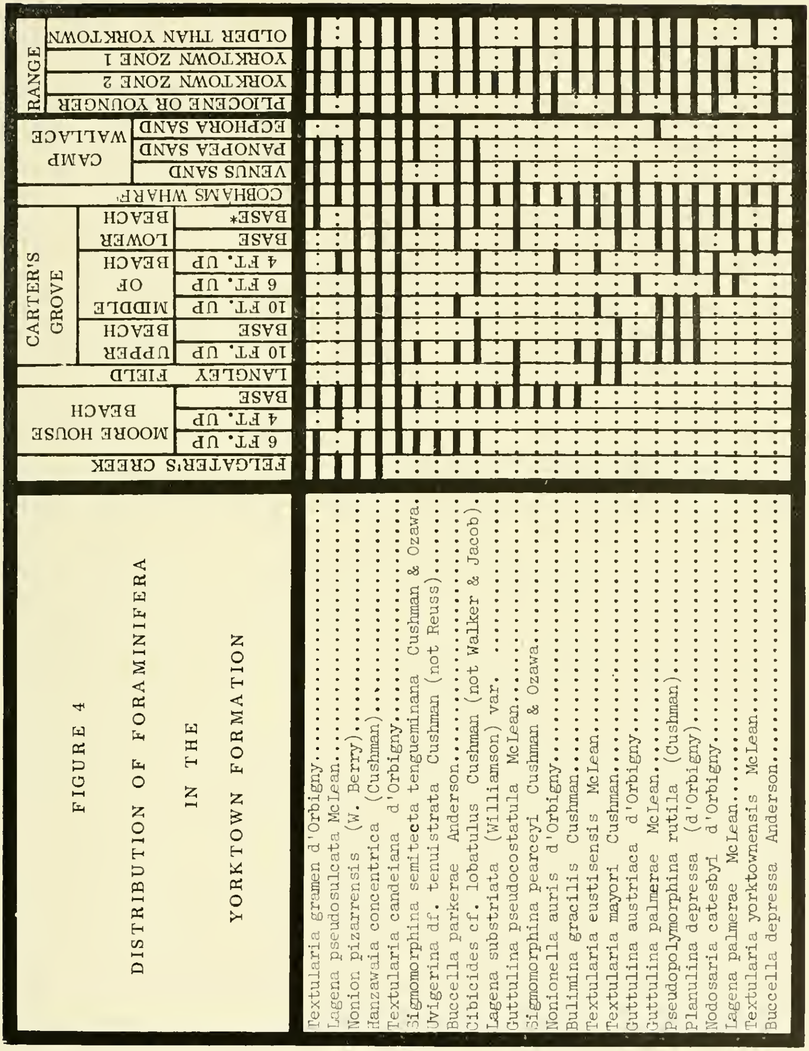
FIGURE 4

DISTRIBUTION OF FORAMINIFERA

IN THE

YORKTOWN FORMATION

The correlation of the Cobhams Wharf sample and the base of the Carter's Grove implies a depth of water at the Cobhams Wharf area of at least 25 meters. This assumption is based on the premise that the fossil faunas of the sample were also the living faunas of the area. Certainly some of the species found in the thanatocoenosis were present in the biocoensis, but which ones and to what extent is not known. Many of the forms contained in the sample appear to be redepositional. On the basis of the present information even the general depth estimation of at least 25 meters may be a misconception.

COMMENTS ON THE GENUS BUCCELLA

I feel the necessity here to state a few facts concerning the genus *Buccella*. After a thorough study of the specimens belonging to this genus, I found no definite criteria for their separation.

Andersen's subdivision of the genus is based, for one thing, on the relative amount and distribution of the pustulose material on the ventral side of the test. In the case of Cobhams Wharf material it was not possible to completely subdivide the specimens, because of the large number that fell between those described by Andersen. In trying to compare the species *B. mansfieldi* and *B. parkerae* from Andersen's description the author found little difference between the two. After studying the Cobhams Wharf material and that of Andersen at the U. S. National Museum, I question the fact that *Buccella parkerae* is a valid species. Andersen stated that *B. mansfieldi* has a greater number of chambers than any other species of *Buccella*. This number is 9-12, with 11 chambers the most common. *Buccella parkerae* then has 9-11 chambers in the last whorl with 11 the most common. Andersen stated in his remarks concerning the genus that, "The most evident characteristic of the genus *Buccella* is exhibited by *B. mansfieldi*, this being the pustulose material covering the ventral side of the test". The description of *B. mansfieldi* states ". . . the basal margin of the last formed chamber bearing a coating of pustulose material (a few specimens have pustules covering the entire ventral side of the test)". For *B. parkerae*, the description points out the pustulose material covering the umbilicus, sutures, and basal margin of the last formed chamber, thickly deposited in the umbilicus, less densely deposited in the outer portion of the sutures. Andersen's specimens show a definite difference in size, but in many cases all other features seem the same.

In the current study I have refrained from subdividing all my specimens of *Buccella*. Of the 81 specimens found in the sample all were worn to some degree, many greatly. I found it unwise to try to separate all the species on the basis of pustulation because of the worn condition of the test and because of the large number of individuals that did not fit Andersen's original descriptions but fell between these. In the case of *B. mansfieldi* and *B. parkerae*, taking all else into consideration, I do not feel that size is a valid factor for determining the species. There is a possibility that *B. parkerae* is a young form of *B. mansfieldi* or an individual variation.

If the ecological conditions that were present at the time of growth were favorable, the size of the individual should reach its maximum, if they are not favorable growth may be retarded. Changes in one or all of the ecologic factors effecting marine animals have a definite reaction on the physical form of the animal, but what effect and to what extent is often impossible to say. Certainly some of the members of the marine community will be able to withstand environmental changes greater than others. All this leads me to think that if when we are trying to classify marine animals such as the *Buccella* that possibly we should be thinking in terms of the lineation of the group and not try to make species. The specimens of *Buccella* that were present in the Cobhams Wharf sample vary slightly from individual to individual. If all the forms are lined up one after another and shifted around until at one end of the line we have the individual with the greatest amount of pustulation (which is the most outstanding characteristic of the group) and at the opposite end of the line we had the individual with the least amount of pustulation we see that we also have individuals between these two which vary one after another from one end of the line to the other. We can make the same type of lineation using the size of the individual and find that the variation holds true, within limits. There are of course, gaps in the line of individuals, but I believe that these gaps can be filled.

I am by no means discounting Andersen's work on the *Buccella*, it cannot be overlooked. I do feel that this group represents one of the major problems in taxonomy, the breakdown on the species level. Lineations according to size, shape, arrangement of chambers, may be found in other groups of animals. Darwin admitted that the process of natural selection depends to a great extent on some of the individuals of a population slowly becoming modified. This modification disturbs the mutual relations of the population as a whole. In effect, at a given time, a species as we know it may not be a true representation of its present species group, although it exhibits the overall characteristics of the parent group.

COMMENTS ON THE LAGENID FORAMINIFERA

The status of the genus *Lagena* in Cushman's classification presents certain problems in regard to individual forms. The species *Lagena sulcata*, for example, is represented by a variety of forms with varying characteristics, but all of which more or less fit Cushman's classification. This is due to the broad interpretation given to the genus by Cushman.

A more definite breakdown of the forms belonging to this group was devised by Parr (1947). Parr's classification contains two main subdivisions; tests with terminal apertures and tests with subterminal apertures and entosolenian tube. The latter of the two subdivisions Parr called *Parafussurina*. Those forms with terminal apertures are further divided into forms with neck and no entosolenian tube, Parr's *Lagena*; and those with or without a neck but having an entosolenian tube. This latter subdivision Parr broke up into *Oolina* and the *Fissurina*. The only difference, according to Parr, between *Oolina* and *Fissurina* is that *Oolina* has a circular test in cross section whereas the *Fissurina* have a compressed test.

Parr's classification for some of the forms now contained in the genus *Lagena* seems to fill a gap in Cushman's classification of the Foraminifera. In this study the author has used Cushman's classification rather than to confuse the issue, but pointing out for each specimen of *Lagena* the corresponding name under Parr's classification.

NOTES ON THE SYSTEMATIC DESCRIPTIONS

The author has in the current study described and illustrated only those forms which vary from the holotype description, in the case of new species or species differing from those described and illustrated by McLean. In the case of the genus *Globigerina* the author did not find sufficient recognizable features to allow him to separate species. The classification used for the Foraminifera is that of Cushman, with the inclusion of the genus *Buccella*. The classification used for the Ostracoda is that of Puri. The specimens on which this study is based are all on file at the Paleontological Research Institution, Ithaca, New York, catalog numbers 7000 to 7062.

SYSTEMATIC DESCRIPTIONS

FORAMINIFERA

Family **Textulariidae**

Genus **Textularia** Defrance, 1824

Textularia canadeiana d'Orbigny

Textularia canadeiana d'Orbigny, 1839, in De la Sagra, Hist. Fisc. Pol. Nat. Cuba, "Foraminiferes", p. 143, pl. 1, figs. 25-27; Cushman, 1922, Carnegie Inst. Washington, pub. 311, p. 23, pl. 2, fig. 2; Cushman, 1922, U. S. Nat. Mus., Bull. 104, p. 8, pl. 1, figs. 1-3; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 36, p. 80, pl. 30, figs. 9-10; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 317, pl. 35, figs. 4, 6, 7, 10, 11.

Frequency.—Five specimens. P. R. I., No. 7000.

Dimensions.—Length, 0.80-1.50 mm.; breadth, 0.56-0.75 mm.

Remarks.—Wall coarsely arenaceous; tests contain large dark grains.

Textularia eustisensis McLean

Textularia eustisensis McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 318, pl. 35, figs. 5a-b.

Frequency.—Eighteen specimens. P. R. I., No. 7001.

Dimensions.—Length, 1-.78-0.78 mm.; breadth, 0.60-0.43 mm.

Remarks.—The average form is nearly three times as long as broad.

Textularia gramen d'Orbigny

Textularia gramen d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 248, pl. 15, figs. 4-6; Cushman, 1918, U. S. Geol. Sur., Bull. 676, p. 8, pl. 9, figs. 4-5 (not figs. 2, 3, 6); Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 17, pl. 1, figs. 5a-b; Puri, 1953, Florida Geol. Sur., Bull. 36, p. 81, pl. 30, figs. 7-8; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, pl. 36, figs. 7, 12-13.

Frequency.—Six specimens. P. R. I., No. 7002.

Dimensions.—Length, 0.68-0.98 mm.; breadth, 0.51-0.65 mm.

Remarks.—Finely arenaceous as opposed to *T. canadeiana*; sutures definitely curved downward; tests increase in width rapidly with respect to length.

Textularia mayori Cushman

Textularia mayori Cushman, 1922, Carnegie Inst. Washington, pub. 311, p. 23, pl. 2, fig. 3; Cushman, 1922, U. S. Nat. Mus., Bull. 104, pt. 3, p. 7; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 17, pl. 1, figs. 6-8; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 40, pl. 1, figs. 2-3; Phleger and Parker, 1948, Geol. Soc. Amer., Memoir 46, pt. 2, p. 5, pl. 2, figs. 1-5; Puri, 1953, Florida Geol. Sur., Bull. 36, p. 82, pl. 20, figs. 7-8; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 320, pl. 36, figs. 1-3.

Frequency.—Five specimens. P. R. I., No. 7003.

Dimensions.—Length, 0.70-1.10 mm.; breadth, 0.55-0.76 mm.

Remarks.—Test finely arenaceous with very fine cement; easily distinguished by elongated conical spine at periphery of each complete chamber, although spines are easily broken and worn down.

Textularia pseudobliqua McLean

Textularia pseudobliqua McLean, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 320, pl. 35, figs. 8-9, pl. 36, figs. 17a-b.

Frequency.—Five specimens. P. R. I., No. 7005.

Dimensions.—Length, 1.22-1.51 mm.; breadth, 0.62-0.71 mm.

Remarks.—Sutures slanted downward as opposed to *T. gramen* which has sutures curved downward, test varies from fine to coarsely arenaceous with coarse cement.

Textularia yorktownensis McLean Pl. 27, figs. 1a-b

Textularia pseudobliqua aspera (McLean), 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 320, pl. 36, figs. 8, 14.

Textularia yorktownensis McLean, Sept., 1959, Jour. Paleont., vol. 33, No. 5, p. 969, not *T. aspersa* Ehrenberg, 1838 not Terquem, 1882, nor Brady, 1882.

Test triangulate, stubby, slightly compressed, periphery rounded test outline somewhat lobate due to deeply depressed sutures; chambers generally distinct, broader than high, increasing gradually in size as added, final chambers quite high, nine visible chambers in holotype; sutures deeply depressed in later portion of test, indistinct in early portion, slanted downward; wall coarsely arenaceous, with much cement; aperture a low arch within a distinct reentrant at the base of the last formed chamber. Length of holotype, 138 mm.; breadth, 0.78 mm. (McLean 1956).

Frequency.—Ten specimens. P. R. I., Nos. 7004 and 7006.

Dimensions.—Length, 0.82-2.01 mm.; breadth, 0.68-1.21 mm.

Remarks.—This form has been elevated to a full species. It differs from *T. pseudobliqua* by having an extremely rough test which completely obscures the details of the form.

Textularia spp.

Several forms were found that could not be classified according to particular species because of broken or worn test. P. R. I., No. 7007.

Family **Miliolidae**

Genus **Quinqueloculina** d'Orbigny, 1826

Quinqueloculina sp.

One form was found that belonged to this genus, but it was too badly worn to permit positive identification. The specimen was relatively close to the description of *Q. wheeldoni*. P. R. I., No. 7008.

Family **Lagenidae**

Genus **Nodosaria** Lamarck, 1812

Nodosaria catesbyi d'Orbigny Pl. 27, figs. 2-3

Nodosaria catesbyi d'Orbigny, 1839, in De la Sagra, Hist. Fisc. Pol. Nat. Cuba, "Foraminiferes", p. 16, pl. 11, figs. 8-10; Cushman, 1930, Florida Geol. Sur., Bull. 4, pp. 28-29, pl. 5, fig. 4; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-a, p. 14, pl. 5, fig. 5; Puri, 1953, Florida Geol. Sur., Bull. 36, p. 101, pl. 26, fig. 6; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 329, pl. 39, figs. 1-4.

Nodosaria sp ? Cushman, 1922, Carnegie Inst. Washington, vol. 17, No. 311, p. 32, pl. 4, fig. 2.

Test composed of two chambers, the proloculum subglobular, with a short basal spine, the second chamber more pyriform apertural end somewhat prolonged; suture district and depressed; wall ornamented with numerous very distinct costae which extend the entire length of the two chambers to the aperture. Length 0.45 mm.; diameter 0.17 mm. (Cushman and Cahill.)

Frequency.—Two specimens. P. R. I. numbers 7009-7010.

Dimensions.—Length, 0.82-0.90 mm.; breadth, 0.30 mm.

Remarks.—Specimens of this form were found that did not coincide with the description given above. The author suggests that the description of this species be redefined to include those forms that are composed of more than two chambers. McLean, (1956) also noted the occurrence of this species with more than two chambers. This fact does not, in the author's opinion, necessitate the erection of a new species. More probably the difference should be considered as a variation in form of the species until such time as the percent of the variation can be more closely checked.

Genus **Lagena** Walker and Jacob, 1798

Lagena sulcata (Walker and Jacob) Parker and Jones

Lagena sulcata Cushman, 1923, U. S. Geol. Sur., Prof. Paper 133, p. 25, pl. III, fig. 8.

Test flask-shaped, body portion subglobular, ornamented with numerous platelike costae running the length of the test, a few often more prominent than others, rather closely set and numerous, sometimes ending in spinose projections at the apical end; neck variously ornamented by costae or annular rings. Maximum length 0.45 mm. (Cushman.)

Frequency.—One specimen. P. R. I., No. 7011.

Dimensions.—Length 0.40 mm.; max. dia. 0.30.

Remarks.—*L. sulcata* would be classified as *Oolina* sp., probably *Oolina collaris* according to Parr's (1945) classification. In all other respect the Cobhams Wharf forms fit the description above.

Lagena palmerae McLean

Lagena palmerae McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 332, pl. 39, figs. 11a-b.

Frequency.—One specimen. P. R. I., No. 7012.

Dimensions.—Length 0.60 mm.; max dia. 0.35 mm.

Remarks.—Truncated base and fluted neck make this form relatively easy to identify. *L. palmerae* would be classified as belonging to the genus *Lagena* according to Parr's (1945) classification.

Lagena pseudosulcata McLean

Lagena pseudosulcata McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 332, pl. 39, figs. 11a-b.

Frequency.—One specimen. P. R. I., No. 7013.

Dimensions.—Length, 0.39., max. dia. 0.35 mm.

Remarks.—This form may be easily confused with *L. sulcata* especially in the case of worn specimens. Parr's classification would eliminate this confusion by classifying *L. pseudosulcata* as belonging to the genus *Oolina.*

Lagena substriata (Williamson)

Lagena substriata Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 31, pl. 5, fig. 14.

Test elongate, body of the test longer than broad, basal end rounded apertural end tapering into an elongate neck; wall ornamented with numerous, fine, longitudinal costae, continuous from the base of the chamber to the neck, sometimes a few on the neck itself. Length 0.50 mm.; diameter 0.25 mm. (Cushman).

Frequency.—One specimen.

Dimensions.—Length, 0.55 mm.; dia., 0.35 mm.

Remarks.—P. R. I., No. 7014.

Lagena sp.

One form was found in the sample that represents *L.* sp. It is not so finely costate as *L. substriata* and does not have the truncated base of *L. palmerae.* P. R. I. No. 7015.

Family **Polymorphinidae**

Genus **Guttulina** d'Orbigny, 1839

Guttulina austrica d'Orbigny

Guttulina austrica d'Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 223, pl. 12, figs. 23-25; Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., vol. 77, art. 6, pp. 29-30, pl. 4, figs. 3-5; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 333, pl. 40, figs. 1-3.

Frequency.—Seven specimens.

Dimensions.—Length, 0.50-0.85 mm.; breadth, 0.35-0.40 mm.

Remarks.—P. R. I., No. 7016.

Guttulina pseudocostatula McLean

Guttulina pseudocostatula McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 334, pl. 40, fig. 8, 10-11.

Frequency.—One specimen.

Dimensions.—Length, 0.63 mm; breadth, 0.44 mm.

Remarks.—This form is easily confused with *G. costatula* when working with worn specimens with indistinct costae. In worn specimen there is also a resemblance to *G. palmerae* which had costae only on the apertural end. P. R. I., No. 7017.

Guttulina sp.

One form was found that is probably *G. austrica* but is too badly worn to make a positive identification. P. R. I., No. 7018.

Genus **Pseudopolymorphina** Cushman and Ozawa, 1928

Pseudopolymorphina rutila (Cushman)

Pseudopolymorphina regina var. *rutila* Cushman, 1923, U. S. Geol. Sur., Prof. Paper 133, p. 34, pl. 5, figs. 7-8.

Pseudopolymorphina rutila Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc. vol. 77, art. 6, p. 100, pl. 26, figs. 3a-b; Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 36, pl. 5, fig. 20; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 67; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-A, p. 19, pl. 6, fig. 11; Puri, 1953, Florida Geol. Sur., Bull. 36, pp. 105-106, pl. 21, fig. 18; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, pl. 41, figs. 6-9, 16-17.

Frequency.—Two specimens.

Dimensions.—Length, 0.82-0.98 mm.; breadth, 0.30-0.41 mm.

Remarks.—P. R. I., No. 7019.

Genus **Sigmomorphina** Cushman and Ozawa, 1928

Sigmomorphina concava (Williamson)

Polymorphina lactea var. *concava* Williamson, 1858, Recent Foram. Great Britain, p. 72, pl. 6, figs. 151-152.

Sigmomorphina concava Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc., vol. 77, art. 6, p. 139, pl. 38, figs. 5-7.; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 336, pl. 41, figs. 14, 18.

Frequency.—One specimen.

Dimensions.—Length, 0.54 mm.; breadth, 0.50 mm.

Remarks.—P. R. I., No. 7020.

Sigmomorphina semitecta "var." **terquemiana** Cushman and Ozawa

Sigmomorphina semitecta "var." *terquemiana*, Cushman and Ozawa, 1930, U. S. Nat. Mus., Proc. vol. 77, art. 6, pp. 129-130, pl. 33, figs. 4-5, pl. 34, figs. 2-3, pl. 35, fig. 1; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 337, pl. 41, figs. 12, 19-24.

Frequency.—Twelve specimens.

Dimensions.—Length, 0.31-0.63 mm.; breadth, 0.31-0.54 mm.

Remarks.—P. R. I., No. 7021.

Family **Nonionidae**

Genus **Nonion** Montfort, 1808

Nonion pizarrensis (W. Berry)

Nonionina boucana Cushman, 1918 (not d'Orbigny), U. S. Geol. Sur., Bull. 676, p. 68, pl. 25, fig. 3.

Nonion pizarrensis W. Berry, 1928, Jour. Paleont., vol. 1, p. 269, text figure I, figs. 1-3; Cushman 1930, Florida Geol. Sur., Bull. 4, p. 37, pl. 6, figs. 7-8; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 69; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-A, p. 20, pl. 7, figs. 2a-b; McLean 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 340, pl. 42, figs. 6, 8, 10, 12.

Nonion pizarrense Cushman 1939, U. S. Geol. Sur. Prof. Paper 191, p. 24, pl. 6, fig. 27; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol. Mines, and Water Res., Bull. 2, p. 300, pl. 35, figs. 6a-c; Puri 1953, Florida Geol. Sur., Bull. 36, p. 145.

Frequency.—Forty-six specimens.

Dimensions.—Length, 0.51-0.76 mm.; breadth, 0.41-0.73 mm.

Remarks.—This form was abundant in all of McLean's localities. P. R. I., Nos. 7022-7023.

Genus **Nonionella** Cushman, 1926

Nonionella auris (d'Orbigny)

Valvulina auris d'Orbigny, 1839, Voyage dans l' Amerique Méridionale, vol. 5, pt. 5, Foraminiferes, p. 47, pl. 2, figs. 15-17.

Nonionina auris Cushman, 1925, Contr. Cushman Lab. Foram. Res., vol. 1, pt. 2, p. 44, pl. 7, figs. 3a-c.

Nonionella auris Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 38, pl. 7, figs. 1a-c; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-A, p. 21, pl. 7, figs. 6a-b; Cushman, 1939, U. S. Geol. Sur., Prof. Paper 191, p. 33, pl. 9, fig. 4; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines and Water Res., Bull. 2, p. 301, pl. 35, figs. 3a-c; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, p. 341, pl. 43, figs. 1, 4.

Frequency.—Four specimens.

Dimensions.—Length, 0.55-0.63 mm.; breadth, 0.37-0.50 mm.

Remarks.—P. R. I., No. 7024.

Family **Buliminidae**

Genus **Bulimina** Cushman

Bulimina gracilis Cushman

Bulimina gracilis Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 43, pl. 8, figs. 5a-b; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 76; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-A, p. 24, pl. 7, figs. 16a-b; Cushman, 1936, Geol. Soc. Amer., Bull. 47, p. 431, pl. 5, figs. 8a-b; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 344, pl. 44, figs. 6, 8-10.

Bulimina elongata, Cushman and Parker, 1937 (not d'Orbigny), Contr. Cushman Lab. Foram, Res., vol. 13, pt. 2, p. 49, pl. 7, figs. 1a-b, 3 a-b (not 2a-b); Cushman, 1946 (not d'Orbigny), U. S. Geol. Sur., Prof. Paper 210-D, pl. 25, figs. 16a-c (not others).; Clapp, Ann Dorsey, 1948 (not d'Orbigny), Maryland Dept. Geol. Mines and Water Res., Bull. 2, p. 303, pl. 36, figs. 5-6.

Frequency.—Three specimens.

Dimensions.—Length, 0.54-0.98 mm.; breadth, 0.13-0.19 mm.

Remarks.—P. R. I., No. 7025.

Genus **Uvigerina** d'Orbigny, 1826

Uvigerina calvertensis Cushman

Uvigerina calvertensis Cushman, 1948, Maryland Dept. Geol., Mines Waters Res., Bull. 2, p. 22, pl. 15, figs. 9-10; McLean, 1956, Bull. Amer., Paleont., vol. XXXVI, No. 160, p. 348, pl. 46, figs. 2a-b.

Uvigerina kernensis Clapp, Ann Dorsey, 1948, (not Barbat and Von Estorff). Maryland Dept. Geol., Mines Water Res., Bull. 2, p. 308, pl. 36, fig. 24.

Frequency.—One specimen.

Dimensions.—Length, 0.68 mm.; breadth, 0.43 mm.

Remarks.—P. R. I., No. 7026.

Uvigerina cf. **tenuistriata** Cushman (not Reuss)

Uvigerina cf. *tenistriata* McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 349, pl. 45, figs. 9a-b, pl. 46, figs. 3a-b.

Frequency.—Two specimens.

Dimensions.—Length, 0.51-0.72 mm.; breadth, 0.29-0.33 mm.

Remarks.—The two forms found fit Cushman's description except for size. P. R. I., No. 7027.

Family **Rotaliidae**

Genus **Buccella** Andersen, 1952

Buccella cf. **depressa** Andersen Pl. 27, figs. 4a-c

Eponides peruvianus Cushman and Parker, 1931 (not d'Orbigny), U. S. Nat. Mus., Proc. vol. 80, art. 3, p. 19 (not figured).

Buccella depressa Andersen, 1952, Washington Acad. Sci., Jour. vol. 42, No. 5, pp. 145-146, tf. 7a-c, 8; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 355, pl. 50, figs. 2-4.

Eponides peruvianus campsi Boltovskoy, 1954, Revista del Inst. Nacional Invest. Ciencias Nay. y Mus. Argentino Ciencias Nat "Bernadino Rivadavia", tomo 3, No. 3, p. 204, pl. 17, figs. 6a-c, 7, 8,; Boltovskoy, 1954, *idem*, tomo 3, No. 4, p. 287, pl. 27, figs. 8a-b.

> Test of medium size; trochoid; dorsal and ventral sides equally biconvex. Dorsal side with surface smooth, finely perforate and hyaline (in well-preserved specimens): and with slightly curved sutures oriented oblique to the peripheral margin. Ventral side with surface more coarsely perforate than the dorsal surface, sutures greatly depressed, nearly radial, and partly filled with opaque pustulose material; chambers inflated; and with depressed umbilicus and basal margin of last-formed chambers bearing a moderate coating of pustulose material. Periphery broadly acute to rounded and lobulate. The number of chambers in the last-formed whorl ranges from 7 to 9, the most common being 8. Adult tests have 2½ to 3 coils.
>
> In well preserved specimens all apertures are concealed by pustulose material. Weathered specimens exhibit . . . . a low arched primary aperture at the basal margin of the last-formed chamber and slitlike supplementary apertures that extend along the outer postero-suturel margins of each chamber. (Andersen, 1952.)

Frequency.—Twenty specimens (?).

Dimensions.—Diameter, 0.41-0.52 mm.; thickness, 0.16-0.29 mm.

Remarks.—The specimens recorded as *B.* cf. *depressa* fit the description given by Andersen sufficiently to be classified as such. All the specimens do not fit Andersen's description exactly, especially as far as the amount and distribution of pustulose material is concerned. P. R. I., Nos. 7028-7029.

Buccella parkerae Andersen Pl. 27, figs. 5a-c

Eponides mansfieldi Cushman and Parker, 1931 (not Cushman, 1930), Contr. Cushman Lab. Foram. Res., vol. 7, pt. 1, pl. 2, fig. 10a-c.

Buccella parkerae Andersen, 1952, Washington Acad. Sci., Jour. vol. 42, No. 5, p. 149, tf. 9a-c; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 356, pl. 51, figs. 2a-c.

Test small; trochoid; biconvex, dorsal side nearly conoidal, ventral side with an umbilical flattening. Dorsal side with surface coarsely perforate; and with sutures of variable intensity; in the early coils concealed by a thin exogenous covering of shell material, in the last coil distinct, limbate, and in some specimens slightly raised above the surface of the test. Ventral side with surface coarsely perforate; depressed sutures radial near the umbilicus and abruptly curved backward at the peripheral margin; umbilicus depressed; and with umbilicus, sutures, and basal margin of the last-formed chamber bearing a coating of pustulose material, thickly deposited in the umbilicus, less densely deposited in the outer portion of the sutures. Periphery acute, limbate and slightly lobulate. The number of chambers in the last-formed whorl range from 9 to 11, 11 being the most common. Adult tests with 2½ to 3 coils.

The primary aperture is concealed by pustules. Supplementary apertures on the ventral side of the test are located in the slight depression at the outer margin of the suture near the periphery. Each aperture is a long slitlike opening barely visible under high magnification. (Andersen, 1952.)

Frequency.—Ten specimens (?).

Dimensions.—Diameter, 0.35-0.49 mm.; thickness, 0.12-0.20 mm.

Remarks.—The 10 specimens that I have reported as *B. parkerae* fit Andersen's description closely. There is less variation in the distribution of the pustulose material, however, the range in size is greater than that given by Andersen. As I have stated previously in this paper I do not feel that size, in this case, is a valid delineation between *B. parkerae* and *B. mansfieldi.* The specimens of *B. parkerae* reported here were classified using the illustrations of Andersen and those of McLean. The reader is invited to compare McLean's figures of *B. parkerae* (McLean, 1956, pl. 51, figs. 2a-c) and the author's figures of *B. parkerae,* Pl. 27, figs. 5a-c. Both McLean's figures and those of this study were drawn by the same illustrator from slides that were identifiable by number only. P. R. I., No. 7030-7031.

Buccella spp. Pl. 27, figs. 6a-b

Several forms were found that could not be placed under one of Andersen's or McLean's descriptions. This was due in part to the worn condition of the tests and also to the variation found from individual to individual. P. R. I., Nos. 7032-7034.

Family **Globigerinidae**

Genus **Globigerina** d'Orbigny, 1826

Globigerina spp.

Twelve forms were found that were not classified as to species. McLean (1956) classified the *Globigerina* from his Yorktown localities as forms A, B, C, D, and E. This pelagic form is another example of a group in which the variation in forms might best be described by lineation. It is true that certain differences can be seen in the group, but the question in the author's mind is if these differences are valid species characteristics. In many forms the difference may be so slight that it should be called a variation, but where is the line to be drawn between a variation and a new species? P. R. I., No. 7035.

Family **Globorotaliidae**

Genus **Globorotalia** Cushman, 1927

Globorotalia sp.

One specimen of this genus was found in a slightly worn condition.

Family **Anomalinidae**

Genus **Planulina** d'Orbigny, 1826

Planulina depressa (d'Orbigny)

Truncatulina depressa d'Orbigny, 1839, Voyage dans l' Amerique Méridionale, vol. 5, pt. 5, Foraminiferes, p. 39, pl. 6, figs. 4-6.

Planulina depressa Cushman, 1930, Florida Geol. Sur., Bull. 4, p. 60, pl. 12, figs. 2a-c.; Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-A, p. 34, pl. 12, figs. 6a-c; Puri, 1953, Florida Geol. Sur., Bull. 36 pp. 141-142, pl. 27, figs. 1-3; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 366, pl. 48, figs. 8-11.

Frequency.—Abundant.

Dimensions.—Diameter, 0.76-0.93 mm.

Remarks.—This was the most abundant form in the sample. McLean found this species apparently to be restricted to Carter's Grove outcrop beds on the York-James Penninsula. P. R. I., Nos. 7037-7038.

Genus **Cibicides** Montfort, 1808

Cibicides cf. **lobatulus** (Cushman)

Truncatulina lobatula Cushman, 1918, U. S. Geol. Sur., Bull. 676, pp. 60-61, pl. 17, figs. 1-3.

Cibicides lobulatulus Clapp, Ann Dorsey, 1948, Maryland Dept. Geol. Mines Water Res., Bull. 2, pp. 315-316, pl. 39, figs. 5a-c; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 366, pl. 48, figs. 12-13.

Frequency.—Five specimens.

Dimensions.—The dimensions of this form were not taken because of irregular outline of the test.

Remarks.—The tendency of this form to coil inwardly over the dorsal side makes the outline highly irregular. The amount of coiling varies greatly between individuals. P. R. I., No. 3709.

Cibicides sublobus (Cushman)

Truncatulina subloba Cushman, 1918, U. S. Geol. Sur., Bull. 676, p. 62, pl. 19, figs. 1a-c.
Cibicides sublobus McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 366, pl. 48, figs. 8-11.

Frequency.—Ten specimens.

Dimensions.—Diameter, 0.53-0.63 mm.

Remarks.—P. R. I., No. 7040.

Genus **Hanzwaia** Asano, 1944

Hanzwaia concentrica (Cushman) Pl. 27, figs. 7a-b, 8a-b

Truncatulina concentrica Cushman, 1918, U. S. Geol. Sur., Bull. 676, pp. 64-65, pl. 21, figs. 3a-c.
Cibicides concentrica Cushman, 1930, Florida Geol. Sur., Bull. 4 pp. 61-62, pl. 12, figs. 4a-c.; Cushman 1931, U. S. Nat. Mus., Bull. 104, pt. 8, pp. 120-121, pl. 21, figs. 4-5, pl. 22, figs. 1-2; Parker, 1948, Bull. Mus. Comp. Zool., Harvard Univ., vol. 100, No. 2, pl. 1, figs. 16a-b.
Cibicides concentricus Cushman and Cahill, 1933, U. S. Geol. Sur., Prof. Paper 175-A, p. 35, pl. 13, figs. 3a-c; Cushman, 1944, Cushman Lab. Foram. Res., Spec. Publ. No. 12, p. 37, pl. 4, figs. 29a-b.; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol., Mines Water Res., Bull. 2, p. 315, pl. 39, figs. 1-2.; Phleger and Parker, 1948, Geol. Soc. Amer., Mem. 46, pt. 2, p. 29, pl. 15, figs. 14-15; Bermudez, 1949, Cushman Lab. Foram. Res., Spec. Publ. No. 25, p. 296, pl. 26, figs. 7-12.
Cibicidina concentricus Parker, 1954, Bull. Mus. Comp. Zool., Harvard Univ., vol. 3, No. 10, pl. 13, figs. 7, 10.
Hanzawaia concentrica Puri, 1953, Florida Geol. Sur., Bull. 36, p. 140, pl. 12, figs. 7-9; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 367, pl. 49, figs. 4-6.

Frequency.—Seventy-three right-hand coiling specimens; ninety-four left-handed coiling specimens.

Dimensions.—Diameter 0.61-1.12 mm.

Remarks.—The number of left-hand coiling specimens as opposed to the right-hand coiling forms may infer something as to the environment of the Yorktown sea, but just what the author is not certain. More detailed statistical work with this species may reveal the relative worth of noting the difference in the coiling. At this point in our statistical knowledge as related to ecology the author does not feel that the opposed coiling forms represent anything in particular. P. R. I., No. 7041-7044.

Genus **Cibicidella** Cushman, 1927

Cibicidella variabilis (d'Orbigny)

Truncatulina variabilis d'Orbigny, 1839, in Barker, Webb and Berthelot, Hist. Nat. Iles Canaries, vol. 2, pt. 2, "Foraminiferes" p. 135, pl. 2, fig. 29; Bagg, 1912, U. S. Geol. Sur., Bull. 512, p. 84, pl. 24, figs. 1-4 (not pl. 25, figs. 4-5).

Cibicidella variabilis Cushman, 1931, U. S. Nat. Mus., Bull. 104, pt. 8, p. 127, pl. 24; fig. 3.; Cushman and Ponton, 1932, Florida Geol. Sur., Bull. 9, p. 192, pl. 15, figs. 5-7; Cushman and Todd, 1945, Cushman Lab. Foram Res., Spec. Publ. No. 15, p. 72, pl. 12, fig. 11.; Clapp, Ann Dorsey, 1948, Maryland Dept. Geol. Mines Water Res., Bull. 2, pp. 316-317, pl. 39, figs. 8a-b.; Puri, 1953, Florida Geol. Sur., Bull. 36, p. 140-141, pl. 8, figs. 4-6; McLean, 1956, Bull. Amer. Paleont., vol. XXXVI, No. 160, p. 369, pl. 49, figs. 9-11, 14.

Frequency.—Fifty-three specimens.

Dimensions.—Because of the irregularity of this form no dimensions were taken.

Remarks.—P. R. I., No. 7045.

Order OSTRACODA Latreille
Suborder PODOCOPA Sars

Family **Bairdiidae**

Subfamily **Bairdiinae** Sars, 1923

Genus **Bairdoppilata** Coryell, Sample, and Jennings, 1935

Bairdoppilata triangulata Edwards

Bairdoppilata triangulata Edwards, 1944, Jour. Paleont., vol. 18, p. 507, pl. 85, figs. 5-7.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 223, 225, pl. 1, figs. 3-4, text figs. 1a-b.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 69, pl. 7, figs. 1a-d.

Frequency.—Two valves.

Remarks.—P. R. I., No. 7046

Family **Cypridae**

Genus **Paracypris** Sars, 1866

Paracypris choctawhatcheensis Puri

Paracypris choctawhatcheenis Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 227-228, pl. 1, figs. 10-12, text figs. 2a, b, d; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 70, pl. 7, figs. 2a-d.

Frequency.—Two valves.

Remarks.—P. R. I., No. 7047.

Family **Cytheridae**

Subfamily **Loxoconchinae** Sars, 1926

Genus **Loxoconcha** Sars, 1866

Loxoconcha sp.

The one specimen of this group that was found was too worn to make a positive identification. P. R. I., No. 7048.

Subfamily **Cytherideinae** Sars, 1925

Genus **Clithrocytheridea** Stephenson, 1936

Clithrocytheridea virginiensis Malkin

Haplocytheridea sp. aff. *H. israelskyi* Swain, 1953, U. S. Geol. Sur., Prof. Paper 234-A, p. 20, pl. 1, figs. 15-17.
Clithrocytheridea virginiensis Malkin, 1953, Jour. Paleont., vol. 27, p. 783-784, pl. 79, figs. 23, 25-28.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 74, pl. 8, figs. 2a-g.

Frequency.—All the specimens of this form were inarticulate.

Remarks.—P. R. I., No. 7049.

Subfamily **Eucytherinae** Puri, 1954

Genus **Cushmanidea** Blake, 1933

Cushmanidea ashermani (Ulrich and Bassler)

Cushmanidea ashermani McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 77, pl. 8, figs. 5a-f.

Frequency.—Two articulated specimens, eight valves.

Dimensions.—Length, 0.87-0.94 mm.; height, 0.42-0.45 mm.; thickness, 0.38-0.40 mm.

Remarks.—P. R.I., No. 7050.

Cushmanidea ulrichi (Howe and Johnson)

Cytherideis ulrichi Howe and Johnson, 1935, in Howe *et al.*, Florida Geol. Sur., Bull. 13, p. 16, pl. 3, figs. 11-14; Puri, 1952, Jour. Paleont., vol. 26, p. 911, Bull. 36, p. 287, pl. 9, figs. 11-13.
Cytherideis subaequalis ulrichi Malkin, 1953, Jour. Paleont., vol. 27, p. 779, pl. 78, figs. 18, 21.
Cushmanidea ulrichi McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 79, pl. 9, figs. 3a-d.

Remarks.—P. R. I., No. 7051.

Subfamily **Brachytherinae** Puri, 1953

Genus **Pterygocythereis** Blake, 1933

Pterygocythereis americana (Ulrich and Bassler)

Cythereis cornuta var. *americana* Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, text, p. 122; plates, pl. 37, figs. 29-33 (vol. II).
Cythereis alaris Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, text, pp. 123-124; plates, pl. 38, figs. 34-36.
Cythereis (*Pterygocythereis*) *cornuta* var. *americana* Howe *et al.*, 1935, Florida Geol. Sur., Bull. 13, p. 26, pl. 2, figs. 19, 21-24, pl. 4, fig. 24; Swain, 1948, Maryland Dept. Geol. Mines, and Water Res., Bull. 2, p. 206-207, pl. 14 (13), fig. 4.
Pterygocythereis cornuta americana Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 41-42.; Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 261, pl. 13, figs. 1-5, text figs. 9d-f.

Pterygocythereis americana Malkin, 1953, Jour. Paleont., vol. 27, p. 795, pl. 80, figs. 26-29.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 80, pl. 9, figs. 5a-d, 6a-e.

Remarks.—P. R. I., No. 7052.

Subfamily **Trachyleberinae** Sylvester-Bradley, 1948

Genus **Actinocythereis** Puri, 1953

Actinocythereis exanthemata (Ulrich and Bassler)

Cythere exanthemata Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, text, p. 117; plates, pl. 36, figs. 1-5.

Cythereis exanthemata Swain, 1948, Maryland Dept. Geol., Mines and Water Res., vol. 2, p. 204, pl. 12, figs. 14-15.

Trachyleberis exanthemata Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 37, pl. 6, fig. 5.; Malkin, 1953, Jour. Paleont., vol. 27, p. 791, pl. 81, figs. 16, 19-20.

Actinocythereis exanthemata Puri, 1953, Amer. Midland Naturalist, vol. 49, p. 179-181, pl. 2, figs. 4-8, text. figs. 3-f.; Puri, 1954 (1953), Florida Geol. Sur., Bull., vol. 36, p. 252-253, pl. 13, figs. 6-13.

Actinocythereis aff. *exanthemata* Swain?, 1955, Jour. Paleont., vol. 29, p. 634, pl. 63, figs. 5a-b, text figs. 37c, 38, 7a-c.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 82, pl. 10, figs. 1a-c.

Remarks.—P. R. I., No. 7053

Genus **Echinocythereis** Puri, 1953

Echinocythereis clarkana (Ulrich and Bassler)

Cythere clarkana Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, text, p. 98; plates, pl. 35, figs. 1-10 (vol. II).

Cythere clarkana var. *miniscula* Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene, text, p. 99; plates, pl. 35, figs. 11-14 (vol. II).

Leguminocythereis clarkana Swain, 1948, Maryland Dept. Geol. Mines and Water Res., Bull. 2, p. 207, pl. 14, fig. 6.; Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 43, pl. 6, fig. 18.

Trachyleberis clarkana Malkin, 1953, Jour. Paleont., vol. 27, p. 792, pl. 82, figs. 1-3.

Echinocythereis clarkana McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 84, pl. 10, figs. 3a-c.

Frequency.—Two inarticulate specimens and one articulate specimen. P. R. I., No. 7054.

Remarks.—McLean (1957, p. 85) considered this species to be pre-Yorktown and noted that it had not been found in Yorktown formation outcrops.

Genus **Murrayina** Puri, 1954

Murrayina howei Puri

Cythere producta Ulrich and Bassler (not Brady), 1904, Maryland Geol. Sur. Miocene, text, p. 115; plates, pl. 36, fig. 17; pl. 38, figs. 28-30.

Cythereis producta Howe, 1935, in Howe *et al.*, Florida Geol. Sur., Bull. 13, p. 22, pl. 1, figs. 31-32, 35, 37, pl. 4, figs. 11-12.

Trachyleberis martini Malkin, 1953, Jour. Paleont., vol. 27, p. 793, pl. 82, figs. 6-9 ?, 11-13 ?.

Murrayina howei Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 255-256, pl. 12, figs. 9-10, text figs. 8g-h.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 85, pl. 10, fig. 4a-e.

Frequency.—Six inarticulate specimens.

Dimensions.—Length, 0.85 mm. to 0.92 mm., height, 0.36 mm. to 0.42 mm.

Remarks.—P. R. I., No. 7055.

Murrayina martini (Ulrich and Bassler)

Cythere martini Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene, text, pp. 112-113; plates, pl. 36, figs. 11-15.

Cythere micula Ulrich and Bassler, 1904, Maryland Geol. Sur. Miocene, text, p. 116; plates, pl. 36, figs. 18-20.

Cythereis martini Swain, 1948, Maryland Dept. Geol., Mines, and Water Res., Bull. 2, p. 196, pl. 12, figs. 16-17.

Trachyleberis ? martini Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 29, pl. 3, figs. 8, 15.

Trachyleberis martini Malkin, 1953, part, Jour. Paleont., vol. 27, p. 793, pl. 82, fig. 10 ? (not other figures).

Murrayina martini Puri, 1954 (1953), Florida Geol. Sur., Bull. 36, p. 256, pl. 12, figs. 11-13, text figures 8e-f.; McLean, 1957, Bull. Amer. Paleont., vol. XXVIII, No. 167, p. 86, pl. 11, figs. 1a-c, 2a-b, 3a-d.

Frequency.—Seven inarticulate and four articulate specimens.

Dimensions.—Length, 0.79 mm. to 0.84 mm.; height, 0.37 mm. to 0.41 mm.

Remarks.—P. R. I., No. 7056.

Murrayina sp.

Two specimens were found that did not compare with any published descriptions, however, both specimens were too badly worn to make a positive identification. P. R. I., No. 7057.

Genus **Puriana** Coryell and Fields, 1954

Puriana rugipunctata (Ulrich and Bassler)

Cythere rugipunctata Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, text, p. 118; plates, pl. 38, figs. 16-17.

Cythereis rugipunctata Howe *et al.*, 1935, Florida Geol. Sur., Bull. 13, p. 23, pl. 1, figs. 18, 20-22; pl. 4, figs. 22-23.

Favella rugipunctata Edwards, 1944, Jour. Paleont., vol. 18, p. 524, pl. 88, figs. 5-6; Malkin 1953, Jour. Paleont., vol. 27, p. 797, pl. 82, fig. 24; Van den Bold, 1950, Jour. Paleont., vol. 24, p. 86.; Van den Bold, 1946, p. 100, pl. 10, fig. 3.

Trachyleberis ? rugipunctata Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 38, pl. 6, fig. 8.

Puriana rugipunctata Coryell and Fields (in Puri, 1953), Jour. Paleont., vol. 27, p. 751; Puri, 1954 (1953), Florida Geol. Sur., Bull 36, p. 257-8, pl. 12, figs. 18-19, text fig. 8 k.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 89, pl. 11, figs. 5a-d.

Frequency.—Nine articulate specimens.

Dimensions.—Length 0.66 mm. to 0.67 mm.; height, 0.37 mm. to 0.38 mm.

Remarks.—P. R. I., No. 7058.

Cytheretta ulrichi Puri

Cythere plebeia Ulrich and Bassler (not Reuss), 1904, Maryland Geol. Sur. Miocene, text, pp. 102-103; plates, pl. 35, figs. 20-29 (vol. II).
Cythere plebeia var. *capax* Ulrich and Bassler, 1904, Maryland, Geol. Sur., Miocene, text, p. 103; plates, pl. 35, figs. 30-33.
Cythere porcella Ulrich and Bassler, 1904, Maryland Geol. Sur., Miocene, text, pp. 106-107; plates, pl. 36, figs. 26-33.
Cytheretta plebeia Swain, 1948, Maryland Dept. Geol. Mines and Water Res., Bull. 2, p. 212, pl. 14, figs. 3-4.; Malkin, 1953, Jour. Pal., vol. 27, p. 790, pl. 81, figs. 1-6, 9.
Cytheretta ulrichi Puri, 1952, Jour. Paleont., vol. 26, p. 204-205, pl. 39, fig. 3, text figs. 5-7.
Cytheretta porcella Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 45, pl. 4, fig. 7; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 92, pl. 11, figs. 3a-d.

Remarks.—P. R. I., No. 7059.

Subfamily **Hemicytherinae** Puri, 1953

Genus **Hemicythere** Sars, 1925

Hemicythere schmidtae Malkin

Trachyleberis ? cf. *T. angulata* Swain, 1951 (not Sars), U. S. Geol. Sur., Prof. Paper 234-A, 29-30, pl. 3, figs. 9-12.
Trachyleberis ? reesidei Swain, 1951, U. S. Geol. Sur., Prof. Paper 234-A, p. 30, pl. 3, fig. 13.
Hemicythere schmidtae Malkin, 1953, Jour. Paleont., vol. 27, p. 796-797, pl. 82, figs. 16-8.; McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 92, pl. 12, figs. 2a-d.

Frequency.—Two inarticulate and two articulate specimens.

Remarks.—P. R. I., No. 7060.

Genus **Aurilia** Porkorny, 1955

Aurilia conradi (Howe and McGuirt) Pl. 27, figs. 9a-c

Aurilia conradi McLean, 1957, Bull. Amer. Paleont., vol. XXXVIII, No. 167, p. 94, pl. 11, figs. 7a-b.

Frequency.—Three inarticulate and sixteen articulate specimens.

Remarks.—P. R. I., No. 7061, 7062.

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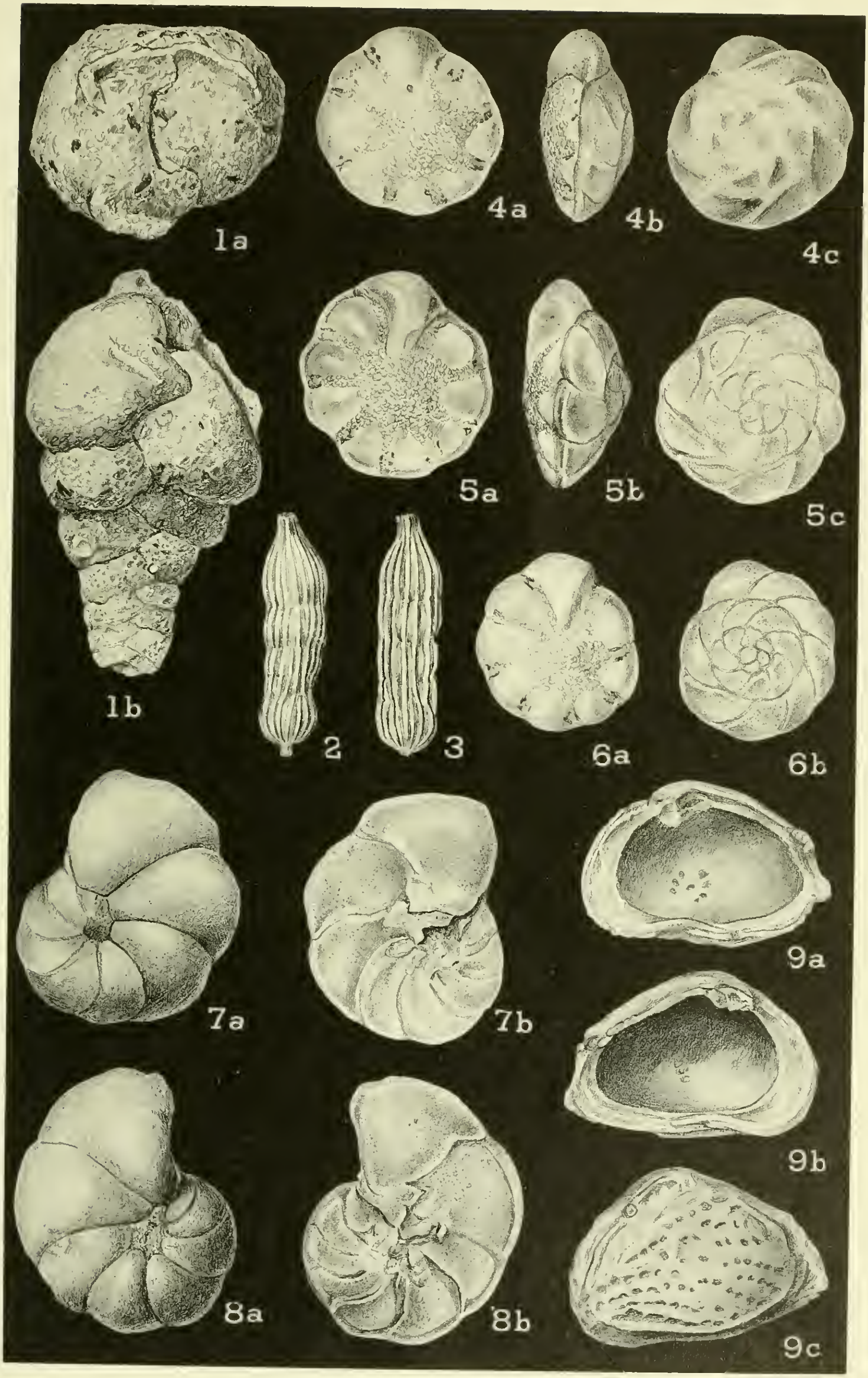
1a
4a
4b
4c
1b
5a
5b
5c
2
3
6a
6b
7a
7b
9a
9b
8a
8b
9c

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VOL. 41

NO. 192

SOME ASPECTS OF THE PALEONTOLOGY, STRATIGRAPHY, AND SEDIMENTATION OF THE CORRY SANDSTONE OF NORTHWESTERN PENNSYLVANIA

By

Daniel B. Sass

November 22, 1960

PALEONTOLOGICAL RESEARCH INSTITUTION
ITHACA, NEW YORK, U. S. A.

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This work is dedicated to the memory of the writer's late father, Julius Sass, whose respect for truth was passed on to a grateful son.

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SOME ASPECTS OF THE PALEONTOLOGY, STRATIGRAPHY, AND SEDIMENTATION OF THE CORRY SANDSTONE OF NORTHWESTERN PENNSYLVANIA

Daniel B. Sass

ABSTRACT

A thorough study of the fauna of the Corry sandstone of northwestern Pennsylvania is herein initiated. Species of four genera, two of the Porifera and two of the Brachiopoda, are described. Some hitherto unrecognized morphological characteristics of the Dictyospongiidae are emphasized.

Four species of the brachiopod genus *Paraphorhynchus* Weller (1905) are described, one of which, *P. casteri* is new. A new criterion of the genus is proposed in the presence of a "posterior adductor process" in the pedicle valve. Characteristics of the genus *Syringothyris* Winchell (1863), *s.s.*, are evaluated; two Corry species are redescribed and compared with similar forms in the underlying Knapp formation. The synonymous relationship between *S. randalli* and *S. angulata* postulated by Caster (1930, p. 174) is rejected.

An attempt is made to reconstruct the former continuity of the Corry sandstone throughout its area of surface outcrop in northwestern Pennsylvania. The formation is divided into three members including: (1) a lower sandstone member; (2) a middle siltstone; and (3) an upper sandstone member.

The Lower Mississippian (Kinderhookian) age of the Corry is reaffirmed. A correlation of the lower Corry member with the upper portion of the Bedford shale of Ohio is suggested.

ACKNOWLEDGMENTS

All of the work was performed while the writer was a student and Curator of the Museum at the University of Cincinnati. The faculty and staff of the Department of Geology not only granted permission for the use of departmental facilities but also gave freely of their time and experience to lighten the problems which frequently accompany a study of this kind. Dr. K. E. Caster was particularly helpful in accompanying the writer in the field, granting access to his personal library, field notes and collections, and volunteering information from his own experience in northwestern Pennsylvania.

In the course of the field investigation and the preparation of the manuscript it was necessary to seek financial assistance to defray a portion of the expenses involved. Such aid was acquired in the form of grants from the American Association of Petroleum Geologists Research Fund and the Fenneman Fund of the University of Cincinnati.

Dr. William S. Lytle of the Pennsylvania Geological Survey granted access to both published and unpublished maps and bulletins of the Survey. Dr. J. F. Pepper and Wallace de Witt, Jr., of the United States Geological Survey, sent copies of their publications and information from their field notes. Dr. F. D. Holland, Jr., of the University of North Dakota, supplied copies of diagrams and photographs from his dissertation. Mr. William H. Heers, Librarian of the United States Geological Survey, sent rare foreign periodicals. All of these individuals and the organizations they represent, have thus contributed to the completion of this work.

At times when the type specimens of certain species were necessary for the accurate indentification of material at hand, their receipt was expedited by the personal attention of Dr. K. V. W. Palmer, Director of the Paleontological Research Institution, and Dr. D. W. Fisher, State Paleontologist of the New York Geological Survey.

Permission to reproduce a road map of the State of Pennsylvania was graciously accorded by Mr. Richard E. Scully of the General Drafting Co., Inc., Covent Station, New Jersey.

Fellow students at the University of Cincinnati were helpful in many ways. Mr. Orville D. Naegele accompanied the writer in the field during the summer of 1958. Mr. John L. Carter and Mr. John K. Pope made helpful suggestions concerning photographic technique. Miss Ruth Brill assisted in the typing of the manuscript.

Elizabeth A. Dalvé draughted many of the text figures used in the manuscript.

Grateful acknowledgment is made to the Graduate School of Arts and Sciences of the University of Cincinnati for the financial help defraying the cost of the engraving of the plates.

INTRODUCTION

PURPOSE AND SCOPE OF THE INVESTIGATION

The Corry sandstone has been cited (Dickey, *et al.,* 1943) as one of the most readily recognizable formations in the Oil Region of northwestern Pennsylvania. It is the first markedly nonconformable unit in the Devono-Mississippian terrane of the region. The Corry lies above the Devono-Mississippian facies (Big Bend and Chagrin magnafacies of Caster, 1934, p. 24) without being an integral

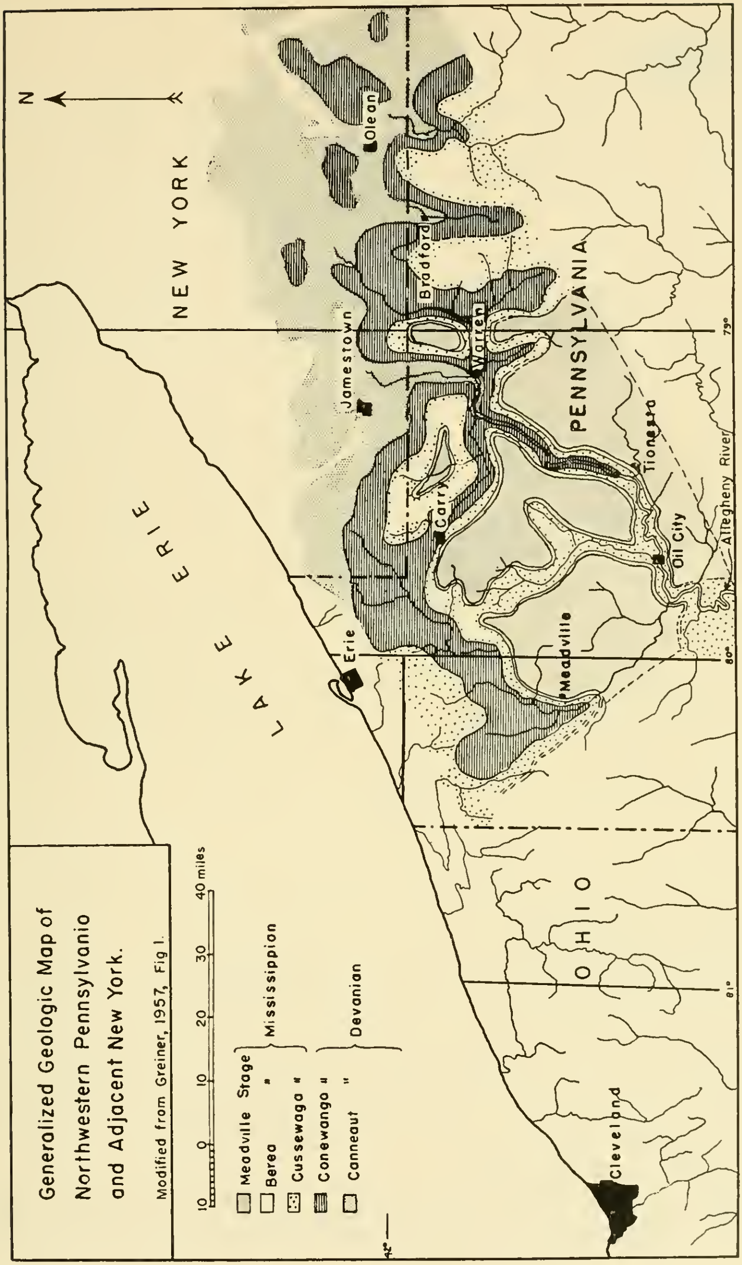

Generalized Geologic Map of Northwestern Pennsylvania and Adjacent New York.
Modified from Greiner, 1957, Fig I.
10 0 10 20 30 40 miles
Meadville Stage
Berea "
Cussewaga "
Conewango "
Canneaut "
Mississippian
Devonian
N
NEW YORK
PENNSYLVANIA
OHIO
LAKE ERIE
Olean
Bradford
Jamestown
Warren
Corry
Erie
Tionesta
Oil City
Allegheny River
Meadville
Cleveland
79°
80°
81°
42°

Figure 1

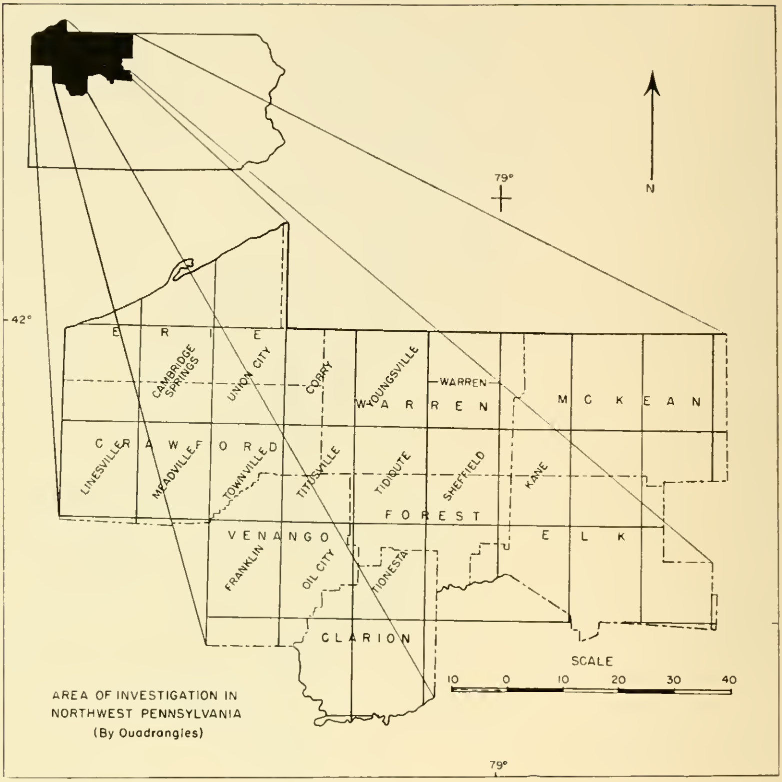


Figure 3

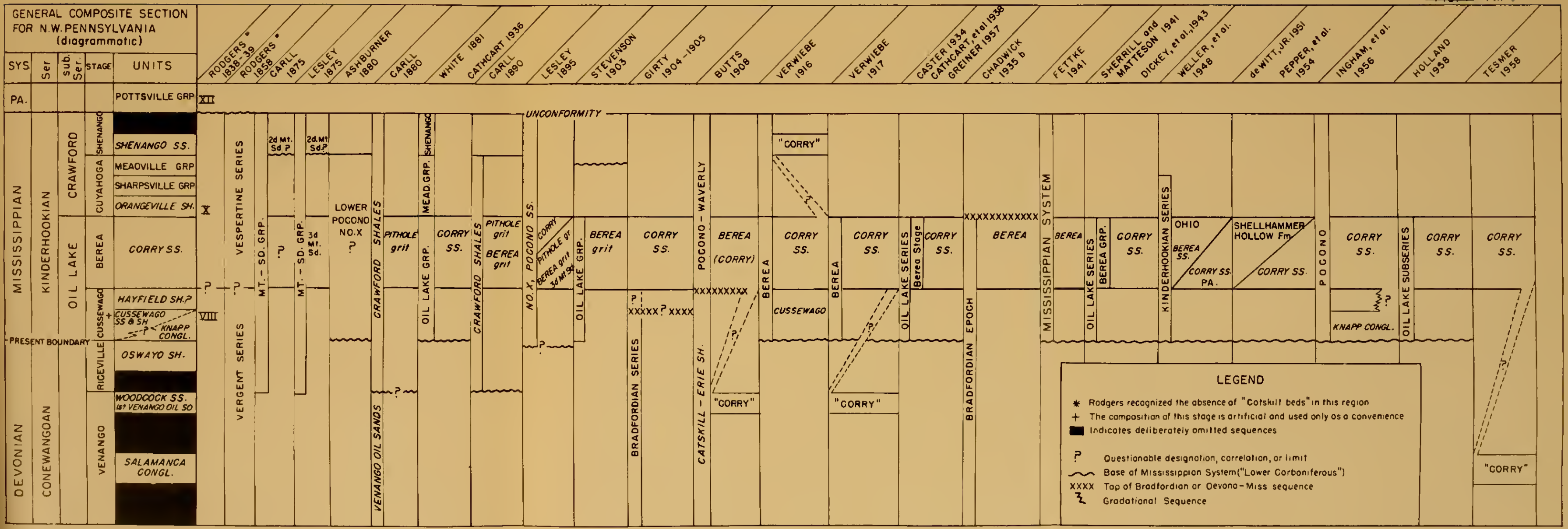
part of the facies pattern expressed by the antecedent record in the Penn-York Embayment.

The present study of the surface expression of the Corry has a threefold objective: (1) to establish the stratigraphic continuity of the Corry in northwestern Pennsylvania; (2) to initiate a study of its fauna and the relationship of this fauna to temporally and spatially adjacent faunas; (3) to further knowledge of the faunal and sedimentary history of the Devono-Mississippian boundary in northwestern Pennsylvania.

Although a fauna has long been recognized, it has never been thoroughly studied. Girty (1912, p. 303) apparently undertook such

A HISTORY OF THE NOMENCLATURE AND STRATIGRAPHIC POSITION OF THE CORRY SANDSTONE
(In Northwestern Pennsylvania)

~~FIG. 4~~ FIG. 2



a study which, but for a list, was never published. Chadwick (1935b, p. 337) documented the fauna from the fragmentary lists of others. Caster (1930, 1934) is the only worker to date to give serious attention to the fauna. However, his study was only incidental to a more ambitious undertaking. Questioned generic and specific identifications have marked a larger part of the faunal studies of the Corry.

There has been no thorough sedimentological investigation of the Corry sandstone. The recent work of Pepper, *et al.*, (1954), dealing with the Berea sandstone of Ohio, gives little sedimentary data about the Corry—the supposed temporal correlative of the Berea. A more thorough study along sedimentological lines could enable geologists to better understand the paleogeography and dynamics of early Mississippian time in the Oil Region.

The field work on which this report is based was conducted during portions of the summers of 1957 and 1958. The primary purpose of this phase of the investigation was to supplement relevant faunal material in the Museum of the University of Cincinnati with specimens collected *in situ.*

No effort was made to map the Corry in detail. Instead, as many locations as possible were visited, the sections measured and collections of both a lithologic and faunal nature assembled. Opportunities to measure complete sections and delimit faunal zones within the Corry were the exception rather than the rule.

The time-rock terminology at the left of Fig. 2 is a compilation from a number of sources which include Caster (1934), Dickey (1941, p. 5), Lytle, *et al.* (1958, p. 6), and Holland (1958, p. 27). Because there is no general agreement among geologists as to the higher stratigraphic nomenclature for northwestern Pennsylvania, only an arbitrary selection such as this is now feasible.

In order to avoid unnecessary duplication the designation of outcrops throughout the remainder of the text conforms to the usage of the various authors cited. A correlation of the preferred and synonymous designations is given herein on Table 1. Authorship of individual outcrop designations is accorded by hyphenated capital letters as follows; S, Sass (this report); C, Caster (1934); P, Pepper, *et al.* (1954); CT, Cathcart (1936, unpublished). The coordinates for each outcrop are given on Table 1.

TABLE I

LOCATION OF OUTCROPS

AUTHORS						QUADRANGLES															LOCATION					
SASS	CASTER	PEPPER	deWITT	CATHCART	OTHERS																LATITUDE N			LONGITUDE W		
(1959)	(1934)	(1954)	(1946)	(1936)		W	Y	C	UC	CS	K	Sh	Td	Ti	To	M	L	Tn	OC	F	°	′	″	°	′	″
9																		X			41	29	44	79	27	48
10																			X		41	29	18	79	35	44
11																X					41	37	30	80	09	00
14						X															41	49	08	79	08	05
15							X														41	55	27	79	23	33
16							X														41	49	27	79	19	12
17															X						41	40	49	79	48	02
19					INGHAM, et. al. (1956:14)						X										41	36	46	78	58	24
20													X								41	32	51	79	15	54
	19						X														41	49	31	79	18	06
	29					X															41	51	36	79	04	09
	31					X															41	48	42	79	04	06
	68	118	107																X		41	28	30	79	41	30
	102							X													41	54	45	79	38	57
	103	104	93	130	WHITE (1881:230)			X													41	54	15	79	38	00
	112						X														41	48	51	79	16	06
	116					X															41	48	10	79	12	26
	123					X															41	50	06	79	05	54
	129	114	103											X							41	33	50	79	39	40
	140			433									X								41	40	28	79	25	48
	203			1565										X							41	43	06	79	32	15
	214			1298	VERWIEBE (1917. 306)									X							41	37	53	79	34	12
		59		258	PROSSER (1912:401)												X				41	43	30	80	15	05
		65														X					41	36	25	80	10	10
		73														X					41	41	00	80	08	30
		87	78	819											X						41	43	00	79	53	00
		90	81	493											X						41	43	30	79	47	15
		94	84		WHITE (1881:192)				X												41	46	20	79	48	30
		95							X												41	46	18	79	48	30
		96	85	482					X												41	46	40	79	47	15
		97	86					X													41	47	50	79	43	50
		98	87						X												41	47	25	79	54	40
		102	91	139				X													41	53	00	79	41	00
		103	92	377				X													41	52	40	79	39	45
		105	94	387				X													41	52	10	79	37	30
		106	95	379				X													41	49	00	79	40	25
		110	99	961										X							41	40	30	79	42	55
		111	100	963a	WHITE (1881:186)									X							41	40	15	79	40	45
		113	102	1000										X							41	38	10	79	40	25
		117	106																X		41	29	00	79	41	30
		119	108																X		41	27	30	79	41	20
	108	**121**	110																X		41	26	00	79	42	45
				38									X								41	40	58	79	20	33
				56									X								41	40	36	79	24	12
				259	PROSSER (1912 399)											X					41	42	24	80	14	26
				398			X														41	48	12	79	28	27
				432			X														41	47	39	79	23	05
				486					X												41	47	56	79	56	00
				588										X							41	37	48	79	36	20
				767					X												41	50	43	79	56	21
				910									X								41	43	32	79	26	32
				963										X							41	39	48	79	41	56
				979				X													41	48	36	79	33	30
				1005											X						41	41	32	79	49	00
				1061											X						41	41	30	79	58	24
	203			**1565**										X							41	43	06	79	32	15
					DICKEY (unpublished)													X			41	29	05	79	27	48

* THE OUTCROP DESIGNATIONS USED FOR THIS REPORT ARE INDICATED BY THE BOLD-FACED NUMERALS.

SYMBOLS AND QUADRANGLE DESIGNATIONS FOR PENNSYLVANIA

W - Warren Quadrangle.
Y - Youngsville.
C - Corry Quadrangle.
UC - Union City Quadrangle
CS - Cambridge Springs Quadrangle
K - Kane Quadrangle
Sh - Sheffield Quadrangle
Td - Tidioute Quadrangle
Ti - Titusville Quadrangle.
To - Townville Quadrangle
M - Meadville Quadrangle
L - Linesville Quadrangle
Tn - Tionesta Quadrangle.
OC - Oil City Quadrangle.
F - Franklin Quadrangle.

PREVIOUS WORK

The Corry sandstone of northwestern Pennsylvania is an integral part of the vast Devono-Mississippian sedimentary complex called by Barrell (1913, p. 470) the "Coastal Plain or Catskill Delta." The present study is confined to the Corry sandstone, except for paleontologic or stratigraphic excursions into other units as the prime objective seems to require. For further information on the history of the Catskill delta, Barrell (1913, 1914), Chadwick (1933), Caster (1934), and Greiner (1957) should be consulted. The accumulation of these Penn-York (Caster, 1935b) sediments was initiated by orogenic pulsations beginning in either early or late Lower-Middle Devonian time—the Schickschockian orogeny of Kay (1942) or Acadian "revolution" of Schuchert and Dunbar (1933). The rocks resulting from this combination of circumstances early received the attention of American geologists.

SUMMARY OF PREVIOUS WORK

EVOLUTION OF THE STRATIGRAPHIC NAME "CORRY"

In the earlier reports on the geology of Pennsylvania there is little to indicate that the Corry sandstone was recognized as a distinct stratigraphic unit. The First Pennsylvania Geological Survey (1836-1841), under the directorship of H. D. Rogers, was primarily concerned with expanding the resources of the growing coal industry. Exploratory emphasis was directed toward the eastern and northeastern portions of Pennsylvania.

Rogers' attempt to translate his stratigraphic units from eastern Pennsylvania across the state to the Ohio border was tempered by his suspicion that lithologic changes might occur. Hence his reluctance to give formational designations to his stratigraphic units, as expressed (1838, p. 20):

> For the present I have studiously abstained from framing a nomenclature for the several formations of the extensive system of rocks here enumerated, preferring (until I become entirely familiar with the many modifications, which they undergo in their course through the Appalachian region,) to designate them as well by their numerical position, counting from the bottom of the group, as by distinctive features in the rocks, and a reference to their geographical situation.

Rogers (1838) presented a hasty sketch of the general geology of Erie and part of Crawford Counties in northwestern Pennsylvania. In ascending order, he described the stratigraphic sequence as consisting of nos. VIII, X, and XII of his total of 13 formations projected from his "Lower Secondary Formations of Pennsylvania" east of the Susquehanna River. A year later the sequence remained essentially the same (see Rogers, 1839, p. 109).

In his final report for the "First Survey" Rogers (1858, p. vi) apparently decided to name his formations. He applied the term "Paleozoic" to the system previously called "Lower Secondary" but rejected the existing formational terminology of the British and New York State Surveys as being, respectively, not applicable and too local. Rogers (1858, p. 104-109) also gave "series" designations to units formerly called "Formations." (Both classifications encompassed thick sequences of strata which have been long-since subdivided.) Each "series" name, of which there were 15, corresponded to a different period of the day, *e. g.* Primal (Dawn) through Seral (Nightfall). In the vicinity of Warren, Pennsylvania, Rogers (1858, p. 144) recorded the presence of the "Vespertine series" overlying the "Vergent series" (the Chemung and Portage of New York State).

Northwestern Pennsylvania received little further attention until the advent of the Second Pennsylvania Geological Survey (1874-1895). In Report I for Venango County, Carll (1875, p. 12) referred to a series of nonproductive sandstones and conglomerates as the "Barren Oil-measures of Venango; or the Mountain-sand Group"—terms adopted from the usage of drillers. These beds were defined as lying between the "Great Conglomerate" and the "Oil-Sand Group." In a diagram opposite p. 34 (*op. cit.*) Carll illustrated the relative position of the three "Mountain-sands." The lowermost, although not discussed in the text, approximates the position of the Corry sandstone as the sequence is interpreted today.

Carll (1875, p. 13) planned to restrict the usage of the terms to Venango County, not wishing to apply them to the whole Oil Region of western Pennsylvania. His superior, J. P. Lesley, (then State Geologist) apparently overruled Carll and not only applied the terms outside of Venango County but also attempted to trace the three "Mountain-sands" across the state line into Ohio and correlate them with the Berea grit. He (Lesley, 1875, p. 60) remarked that the third "Mountain-sand" had no Ohio equivalent.

Ashburner (1880, p. 43), working in McKean County, Pennsylvania, in a diagram showing a refinement of the Carboniferous system, divided the Lower Carboniferous into a lower, middle, and upper Pocono sandstone and equated them to "Formation X" and the "Vespertine series" of Rogers (1838, 1858). The term "Pocono" was attributed by Ashburner (1880, p. 41) to J. P. Lesley, the State Geologist.

J. F. Carll, in a report on Warren and adjacent counties, decided to put an end to the ambiguity of the "Mountain-sand" designation for the portion of the geological column which Ashburner had just refined elsewhere. In proposing a new terminology he compounded the duplication which Rogers had tried so unsuccessfully to avoid. Carll (1880, p. 81-82) declared:

> The designation *First, Second* and *Third Mountain sands,* used provisionally in 1874, answered very well for the purposes of that local report; but, to adhere to the use of these ordinal numbers still, . . . , would only perpetuate confusion in our geological nomenclature. Other rocks than those thus numbered in early oil well borings have been found intruding into the series; and to these additional rocks fixed *geographical* names have been assigned in districts outside of and adjoining the oil regions proper. I propose therefore to adopt in this report such geographical names, and to drop the use of the terms First, Second and Third Oil sands as no longer available . . .
>
> The *Third mountain sand* will receive in this report a new name, the *Pithole grit.*
>
> This rock was first recognized as a persistent sandstone in the *Pithole oil* wells . . . . , and making conspicuous outcrops along the Allegheny river on the south and along Oil Creek on the west.
>
> The term *grit* sufficiently designates it as a sandstone; but what is more important, will serve to associate it in the reader's mind with the *Berea grit* of Ohio, which seems to have been a contemporaneous formation; although the two rocks have not been traced across country towards each other to a common place of actual meeting.

In addition, Carll (1880, p. 82 and pl. XI) designated as the "Crawford shale" a portion of the sequence of strata which he (Carll, 1875) called the "Mountain-sand Group."

In 1881 I. C. White published his report on the geology of Erie and Crawford Counties and proposed a considerable number of changes in the geological nomenclature of the area. Within his newly created "Oil Lake Group" White (1881, p. 230) named, correlated, and designated the type section for the Corry sandstone in the following terms:

> About one mile south from Corry are two extensive quarries in the summit of the hill just west from the Methodist church; one east from the Corry road owned by Mr. Colegrove, the other west from it and owned by Mr. Heath. Eight feet of the rock is found on the summit, and it has probably suffered from erosion, as the upper half is so badly shattered that it cannot be used except for riprap . . . ; the lower half comes in layers 2″ or 3″ up to 12″ thick. The whole bed has a yellowish or buffish white tinge, is quite hard and tolerably fine-grained. From this locality I have named it the *Corry Sandstone,* and it is identical with the *3rd Mt. Sand* of Mr. Carll. Few fossils occur in it, but in the lower portion were seen species of *Allorisma,* and *Orthis* and a broadwinged *Spirifer.*

Despite White's formal designation, the name "Corry" was not readily accepted. Many contemporaneous authors preferred the older terminology. From the series of changes which followed, it would almost appear as though White had labored in vain. His correlation of the Corry with the Berea of Ohio (White, 1881, p. 94), supporting the earlier contention of Carll (1880), did not go unchallenged even as it was proposed. Lesley (1881, p. xiii), in the introduction to White's report, said, " . . . [White's correlation] is only probable in his opinion and has not been completely demonstrated."

STRATIGRAPHIC CONTINUITY IN NORTHWESTERN PENNSYLVANIA

Early attempts to trace the Corry within Pennsylvania were beset with uncertainty despite White's lucid descriptions. Carll (1883, p. 341) observed, "The *Pithole grit* is not massive; nor is its horizon always constant, or clearly defined." Lesley (1885, p. cii) expressed somewhat the same opinion; using the terms "Third Mountain-Sand" and "Pithole grit" he remarked that the formation could not be traced from Tidioute to Warren.

Carll (1890, pl. 4) employed the terms "Berea" and "Pithole grit" interchangeably—still including the formation within his somewhat modified sequence, designated earlier, the "Crawford shales." His references to the Corry at a number of localities established the following generalizations:

1. At Tidioute, the "Pithole grit" appeared to be a sandy horizon—not a massive sandstone.

2. Throughout the highlands of Venango County the "Berea grit" appeared to be a persistent and ideal key horizon.
3. The "Berea grit" appeared to thin out and disappear eastwards in Forest and Clarion Counties, Pennsylvania.
4. The top and base were not clearly defined.
5. The base frequently contained irregular lentils of limestone.

Lesley (1895, p. 1629) was determined to use the term "Pocono" (subtended by the "No. X" of Rogers) to delimit the strata of the "first, oldest or lowest subdivision of the great Carboniferous System." In what was apparently an effort to clarify the nomenclatorial maze, he objected strongly to the use of the Ohio term "Waverly", declaring (p. 1779):

> The Waverly formation of southern Ohio occupies the same general horizon as the sub-conglomerate formations of western Pennsylvania; and that is all that can be said of it. Its use has produced confusion and hence has been kept out of Pennsylvania reports.

While condemning dual nomenclature in one instance, Lesley encouraged it in others. He apparently recognized the Corry's synonymies since he used them when referring to its horizon in the Venango area; but for the area of northwestern Pennsylvania, he (Lesley, 1895, p. 1785) declared:

> . . . such names as Shenango shales and conglomerate, sub-Olean, Meadville, Cussewago, Corry, will always be confined to the special districts in which they were first applied; . . . . In a word, the geological nomenclature of Erie, Crawford, Warren and Stateline counties to the south and east of them, must remain isolated and peculiar, ...

Lesley's decision appears to have encouraged the use of archaic nomenclature rather than hastening its demise. The stratigraphic interval occupied by the Corry was not effected, except for the overlapping terminology; the situation remained static until the turn of the century.

The first of several radical changes in the classification of the Corry was suggested by Stevenson in 1903. He left the formation in the Oil Lake Group of White (1881); but, relying on the Ohio paleontology of Herrick (1891), placed the entire group of Pennsylvania formations in the Upper Devonian.

Girty (1904) created the "Bradfordian Series" for the New

York formations below the Olean (Pottsville) conglomerate, stating (p. 24) that:

> The position of this series is quite apart from the determination of its age as Devonian or Carboniferous, a question reserved for further study.

He traced the Corry from the type section into the region of Warren, Pennsylvania, recognizing its occurrence immediately above the "sub-Olean conglomerate" (Knapp, in this instance). Girty repeated this observation in 1905 and proceeded to defeat his own good work by (1905, p. 6) equating the Berea grit of Ohio (supposedly of Mississippian age) with the Corry and Cussewago sandstones of White (1881) and then (1905, p. 7) contending that the "Bradfordian" (including the Cussewago) had "its true relations with the Devonian."

In Butts' 1906-1908 report of the Pennsylvania Topographic and Geologic Survey the Berea (Corry) sandstone was depicted, in several instances, (1908, p. 129 and 191) to be the basal member of the Mississippian Pocono-Waverly sequence. He cited the Berea-Corry correlation of Girty (1904) and recognized the occurrence of the Corry below the Olean (Pottsville) conglomerate in the Warren, Pennsylvania, region. However, Butts (1908, p. 192) only traced the Berea (Corry) to the vicinity of Tionesta, Pennsylvania, where it purportedly dipped beneath the surface and (*op. cit.*, p. 195) correlated with the Venango-first sand. In 1910 Butts, then working in the Warren Quadrangle, designated the Corry as "Berea" and reported the formation to be present as a "feather edge" immediately overlying the Knapp formation in that area. He stated that the "Berea" could not be found in place but its characteristic fauna made it readily recognizable in the float. The Berea (Corry) was classified as basal Mississippian while the underlying Knapp was placed in the "Devono-Carboniferous" category. Butts did not here mention his previous correlation of the Corry with the Venango-first sand.

Verwiebe (1916) discounted Butts' (1908) correlation of the Corry with the Venango-first sand and (p. 55) declared:

> In tracing the Knapp formation to the south, it strikes one immediately as not improbable that the Knapp is the northern representative of the Venango 1st Oil sand.

This paved the way for his suggestion that in the Warren Quadrangle the "Berea" was absent because of erosion. He (Verwiebe, 1916, p. 47) contended that the Corry, in the Allegheny River section, was represented by a sandstone 160′ higher than its usually designated position and characterized at its base by a limestone layer which Caster (1943, p. 171) identified as the Conneaut (upper Meadville) limestone. Caster's work made possible the identification of Verwiebe's "Corry" as the Shenango sandstone.

In 1917 Verwiebe visited White's fossiliferous sections of the Corry sandstone at Cobham's Hill and along the road to Enterprise in the Warren area. He decided (1917, p. 306) that these sections represented the First Venango oil sand rather than the Corry—a correlation which he denied to Butts (1908).

In the years between 1917 and 1934 a number of authors referred to the Corry without altering its stratigraphic position as defined by White. However, changes were made with respect to the superformational classification of it and the adjacent beds and the position of the Devono-Mississippian boundary.

In 1934 Caster, as part of a study of the general stratigraphy of northwestern Pennsylvania, made the most comprehensive evaluation of the Corry to date. Some of Caster's formational and superformational designations have since been altered but his work appears to be sound and has been used as a starting point for more recent stratigraphic work. His designation of the Devono-Mississippian boundary (1934, chart facing p. 63) has been strengthened by the recent faunal analysis of Holland (1958).

Among the contributions of Caster was the recognition of the importance of the Corry and the subjacent beds to a fuller understanding of the stratigraphy of northwestern Pennsylvania. Within his then newly created Oil Lake series (the former Oil Lake group of White, 1881) Caster (1934, p. 52) erected a new category to include the Corry, stating:

> The "Berea stage" is at present designed to account for the Corry sandstone at the top of the Oil Lake series. There is reasonable certainty that this formation is the eastward continuation of the upper Berea sandstone of Ohio. The Corry belongs in the Oil Lake series faunally, and lithically, rather than the Crawford series. It cannot justifiably be included in the Cussewago stage. Wherefore a separate stage is created for it.

In 1935 Caster (p. 912) disposed of the "Bradfordian" of Girty (1904) citing both a "minor disconformity" and faunal differences between the basal Mississippian, Oil Lake series, and the Upper Devonian, Conewango series. The same year Chadwick, who previously agreed with most of Caster's conclusions, reversed himself and questioned the correlation of the "Corry" at Stoney Lonesome (Warren Quadrangle) with that of Pithole Creek (Oil City Quadrangle) on both a faunal and a stratigraphic basis. Chadwick (1935b, p. 338) concluded:

> In short, until and unless further collecting and further stratigraphic tracing prove that these Cussewago beds (Kushequa, Knapp, Hayfield and probably the so-called "Berea") are not really the latest and highest Devonian, it will be best to adhere to the original definition and scope of the Bradfordian epoch of Dr. Girty . . . .
>
> The faunal groups now recognized are . . . (6) the Conewango, which with probably the overlying (7?) Cussewago (including perhaps also the false "Berea" of Pennsylvania) constitute the closing epoch (*Bradfordian*) of the Upper Devonian.

The Bradfordian was, therefore, revived, if only briefly, and the Corry sandstone placed in the Devonian.

The boundary and correlational disputes outlined above must have been disheartening to Cathcart (1936) who decided that the stratigraphic subdivisions of White (1881) were "as satisfactory as any." In 1938 Cathcart, *et al.,* reporting on the Tidioute Quadrangle of Pennsylvania, tentatively accepted the Devono-Mississippian boundary of Caster (1934) and set the pattern for much of the more recent deliberation concerning the place of the Corry in the stratigraphic sequence of northwestern Pennsylvania. However, there was still little uniformity in the superformational designations and the terms "Corry" and "Berea" were used interchangeably.

Fettke (1941) accepted Caster's boundary but preferred to use the term "Berea" instead of "Corry" for the Pennsylvania stratum. Sherrill and Matteson (1941, p. 16) accepted most of Caster's designations but preferred "Berea group" to "Berea stage" and used "Corry" in preference to "Berea." Dickey, *et al.,* (1943) followed Sherrill and Matteson in their terminology.

In 1946 three separate investigations by Rittenhouse, Demarest, and de Witt, Jr. indicated that an equivalency between the terms

"Corry" and "Berea" might be inaccurate. This distinction is reflected in Chart No. 5 of Weller, *et al.,* (1948).

In 1951 de Witt, Jr. crystallized his earlier ideas and demonstrated (pl. 2) that in central Crawford County the Corry graded laterally into a siltsone sequence called (p. 1362) the Shellhammer Hollow formation. This conclusion was well documented and expanded in 1954 in the paper of Pepper, de Witt, Jr., and Demarest. These authors (1954, p. 34) concluded:

> The Corry sandstone of eastern Crawford County and Venango County, which has been confused with the Berea in some places, cannot be distinguished from the Berea by its elevations alone; for the top of the Corry and the top of the Berea probably do not differ by more than 10 feet stratigraphically. Nevertheless, the Corry is not an eastern siltstone phase of the Berea, ...

The Corry-Berea union was dissolved and the westernmost limit of the Corry established.

In 1956 Ingham, *et. al.,* suggested that the Corry might be traceable slightly eastward beyond the line established by Caster (1934, p. 123), " . . . from Big Bend southwestward between Tionesta and Marionville, Pennsylvania." The section described at Brookston (Ingham, *et al.,* 1956, p. 14), visited during this investigation, would appear to justify that expansion.

The work of Greiner (1957), concerned largely with paleontological problems, and mainly related to the Devonian sequence, adds little to the immediate discussion. His usage of stratigraphic units exemplifies the cyclical nature of nomenclature in that Greiner accepted the terminology of Caster (1934) as Cathcart (1936) accepted that of White (1881).

Despite the gradual convergence of ideas pertaining to the Corry, the formation has not undergone its last change of status. In a recent publication Tesmer (1958) placed the Corry in the Cattaraugus formation (Devonian) and equated it to the Pope Hollow conglomerate, the upper member of Caster's Salamanca "formational suite." In a personal communication Dr. Tesmer explained that the Corry and Pope Hollow "appear to occupy the same horizon but may not be temperal equivalents." The idea is an interesting one but contradicts all previous correlations and leaves the position of the Devono-Mississippian boundary unsettled. It is possible that

Tesmer may have fallen victim to the "trap" which Caster (1934, p. 115) cautioned against when he said:

> In its wide-spread development in an east-west direction the Cobham conglomerate [= Corry] is similar to the Pope Hollow and Panama conglomerates of the underlying Venango formation.

CORRELATION WITH THE BEREA SANDSTONE OF OHIO

Until recently, the traditional correlative of the Corry, as already indicated above, was the Berea sandstone of Ohio. This relationship had been postulated, almost without exception, on the basis of the relative stratigraphic position of the two formations in their respective areas. Complications have arisen because of: (1) the failure of various workers to agree on the nature of the Devono-Mississippian sequence in northeastern Ohio and northwestern Pennsylvania; (2) disagreement as to the nature of the Berea and Corry sandstones themselves; (3) a lack of sufficient paleontological evidence; and (4) the scarcity of good outcrops in critical areas. Only the salient points of the proposed correlations are covered here as an introduction to the complex stratigraphy of the Pennsylvania-Ohio border.

Some of the difficulties which accompany the inferred Corry-Berea relationship antedate the actual association of the two formations. The failure of two prominent geologists to agree on the nature of the Berea grit of Newberry (1870) early set the stage for much of the problem which arose.

M. C. Read (1873, p. 508), in describing the geology of Trumbull County, Ohio, casually inferred, under the heading of "Bedford Shale", that the Berea was a tripartite formation consisting of two sandstones and a medial shale. He had not previously, in the text or illustrations (*e. g.*, 1873, p. 506), made such an assertion. J. P. Lesley believed the "Berea" to be a tripartite formation in Pennsylvania but declared (1875, p. 60), "The Berea grit is a single formation in Ohio." The dichotomy which was to plague stratigraphers was thus established.

In 1880 Carll (p. 82) suggested that his newly designated "Pithole grit" (Corry) was deposited contemporaneously with the Berea grit of Ohio. He did not, at the time, comment on the nature of this relationship other than to say that it was readily demonstrable. The following year I. C. White (1881, p. 91-94) stated that the Corry sandstone continued into Ohio as the Berea grit; the remainder of his Oil Lake group he correlated with the Bedford shale underlying the Berea. White, therefore, accepted Lesley's postulated single-unit Berea in Ohio. Subsequently, a number of geologists followed White's lead in accepting a direct Berea-Corry correlation. The work of Cushing (1888, p. 215), Carll (1890, p. 93), and Orton (1893) reflect this usage.

Girty (1905, p. 6), in accordance with an earlier suggestion of Stevenson (1903), declared, "The Berea grit of Ohio is White's Cussewago sandstone, together probably with the Cussewago flags and Corry sandstone." Such a correlation would infer that the Berea was a tripartite formation (in the sense of Read, 1873) and that the Corry would be related, because of its stratigraphic position, to the uppermost Berea. Schuchert (1910, p. 548), Prosser (1912, p. 351, 394, 396), and Verwiebe (1916, p. 43, 44, 46) subscribed to a correlation of this nature.

Chadwick (1923 and 1925) considered the Corry and Berea to be direct correlatives but differed from previous workers concerning the nature of the beds subjacent to the two formations. He (Chadwick, 1925, p. 436) correlated the Knapp formation of Glenn (1903) with the Cussewago sandstone of White (1881) and renamed White's Cussewago shale and limestone Hayfield shale and limestone. In addition, he postulated the presence of a great transgressive disconformity extending from the base of the Cleveland shale of Ohio to the base of the Corry sandstone in Erie County, Pennsylvania. Such a disconformity would have the effect of splitting White's Oil Lake group, making the Corry Mississippian in age and the subjacent beds "Bradfordian" and unrelated to the Bedford shale which underlies the Berea.

Caster (1934) did not accept Chadwick's stratigraphy in its entirety and proposed two alternate Corry-Berea relationships based on the premise of a threefold Berea formation in Ohio. The first choice, which Caster favored, would correlate the Corry sandstone, Hayfield shale, and Cussewago sandstone of Pennsylvania with, respectively, the upper Berea sandstone, medial Berea shale, and basal Berea sandstone. The Bedford shale of Ohio would, in this scheme, correlate with the Kushaqua shale, the basal member of Caster's newly erected Cussewago "Monothem." The second alternative would equate only the Corry with the basal Berea sandstone, and the Hayfield shale (underlying the Corry) with the Bedford shale of Ohio which Caster (1934, p. 164) recognized as disconformable with the overlying Berea sandstone. Caster, like Chadwick, designated the Knapp formation of Warren County as the equivalent of the Cussewago sandstone of Crawford and Erie Counties.

The various correlations outlined above do not represent all of the possible relationships between the Berea and Corry sandstones, as subsquent workers were prompt to point out. Cathcart, *et al.,* (1938, p. 3) described the Corry itself as a tripartite formation consisting of two sandstones and a medial shale; the basal sandstone was judged to be the equivalent of the upper Knapp formation. All three Corry units were correlated with the three-part Berea of Ohio but no details of the relationship were given in this 1938 report on the Tidioute Quadrangle. Dickey's (1941, p. 5) publication on the Titusville Quadrangle affirmed Cathcart's three-part Corry but equated it to the upper Berea rather than the entire formation.

The search for additional petroleum reserves during the Second World War stimulated a series of oil and gas investigations conducted in the area of Pennsylvania covered in this study. From these investigations a series of papers and reports emerged which altered many of the concepts of the stratigraphy of northwestern Pennsylvania as well as the relationship between the Berea and Corry sandstones. Among the published reports from which the more recent opinions crystallized were those of Rittenhouse (1946), Demarest (1946) and de Witt, Jr., (1946 and 1951). The essence of these reports is contained in the United States Geological Survey Professional Paper 259 by Pepper, de Witt, Jr., and Demarest (1954).

Pepper, *et al.,* (1954, p. 39) asserted that the Berea sandstone is a single, not tripartite, formation in Ohio. Evidence was presented to prove that the Corry, Cussewago, and Berea formations are three entities — each representing an independent lobe of a vast deltaic complex which developed during Lower Mississippian time. Rather than being direct correlatives, the authors believed that the Corry and Berea sandstones are temporal equivalents which, in the area between Meadville and Riceville, Pennsylvania, lose their identity in a common siltstone facies called by de Witt, Jr., (1951, p. 1362) the Shellhammer Hollow formation.

Pepper, *et al.,* (1954, p. 21) rejected the Knapp-Cussewago sandstone correlation of Chadwick and Caster and (p. 25) equated White's (1881) Cussewago shale (the Hayfield of Chadwick) with the Bedford shale of Ohio.

STRATIGRAPHY AND SEDIMENTATION

In conformity with previously stated objectives, the comments which follow are based upon general observations in the field and an evaluation of existing literature pertinent to the Corry sandstone. Text figure 4, based upon these sources represents the writer's present views of the spatial relationships of the Corry and the adjacent formations. With the ultimate completion of the paleontological study and the devotion of more specific efforts in the field of sedimentation, it is anticipated that some modification of the present interpretation may be necessary.

The precise relationship between the Corry sandstone and the adjacent formations is, at present, inadequately known. A portion of the difficulty can be attributed to the general absence of extensive outcrops in northwestern Pennsylvania and the erratic distribution of those which do exist. Then too, except for the work of Caster (1930/1934) and Holland (1958) in the eastern portions of the area under consideration (see Text fig. 3), the faunas of the underlying formations have not been thoroughly studied. The litho-facies changes which occur in the adjacent beds contribute further difficulties.

With few exceptions knowledge of the beds above and below the Corry stems from uncoordinated individual studies of quadrangle-sized or county areas. These studies cover the better part of a century and only a resumé of their conclusions is herein presented. Table 2, which follows, summarizes the designations accorded to the formations above and below the Corry sandstone by various authors.

TABLE 2

The formation above and below the Corry sandstone as designated by various authors.

Area	*Source*	*Fm. Below*	*Fm. Above*
Warren Quad.	Butts, 1910, fig. 5, pg. 38.	Knapp fm.	Cuyahoga fm. (= Orangeville sh.)
Warren Quad.	Caster, 1934, p. 116.	Hayfield sh.	Orangeville sh.
E. Erie and Crawford Co.	White, 1881, p. 66, fig. 7.	Cussewago ss.	Orangeville sh.
E. Crawford & Venango Co.	Demarest, 1946, (Prelim. Map & Text)	Cussewago ss. (= Murrysville sd.)	?
W. Crawford & Venango Co.	de Witt, 1946, (Prelim. Map & Text)	Bedford sh. (= Hayfield sh.)	Orangeville sh.
E. Crawford Co. [Corry & Union City Quads.]	de Witt, 1951, p. 1362.	Riceville sh. [= Knapp?]	Orangeville sh.
Kane Quad.	Ingham, *et al.*, 1956, p. 14.	U.? Knapp ss. & congl.	"shale"
Sheffield Quad.	Ingham, *et al.*, 1956, pl. 7.	Knapp ss. & congl.	Shenango & Cuyahoga ss. & sh.
Tidioute Quad.	Cathcart, *et al.*, 1938, & Caster, 1934, p. 119.	Hayfield sh. & white ss.	Orangeville sh.
Titusville Quad.	Dickey, 1941, p. 5-6.	Cussewago fm.	Cuyahoga fm.
Tionesta Quad.	Dickey, 1941, [unpublished]	Cussewago sh. & ss.	Cuyahoga sh. & sdy. sh.
Oil City Quad.	Dickey, *et al.*, 1943, p. 20.	Cussewago ss. & sh.	Cuyahoga sh. & ss.
Franklin Quad.	Sherrill & Matteson, 1941, p. 16.	Cussewago sh.	Cuyahoga sh.

THE FORMATIONS BELOW

White (1881, p. 94-95), discussing his Oil Lake Group of Erie and Crawford Counties, stated:

> These [Cussewago shales] separate the *Corry sandstone* above from the *Cussewago sandstone* below, and hold (near the top) the *Cussewago limestone;* . . .
>
> In some places the interval between the *Corry sandstone* and the *Cussewago sandstone* is filled, not with shales (with the limestone,) but with sandy flags (without the limestone;) . . .

These generalizations were modified or enlarged upon by subsequent writers. Cushing (1888, p. 215), among others, correlated White's Cussewago shale with the Bedford shale of Ohio. [White did not make this correlation himself but noted that the Bedford shale belonged in the interval represented by the Cussewago shale.]

Chadwick, discussing the stratigraphic relationships of the Chagrin formation of Ohio, declared (1925, p. 457), "Following down the Allegheny River in Pennsylvania, the Knapp is overlain by the Corry (Berea), a shale wedging in between . . . . " He further correlated the Cussewago sandstone of White (1881) with the Knapp beds of Glenn (1903) and postulated an unconformity between the Knapp and the Corry to account for the thinning of the Cussewago shale and the discontinuity he assumed to separate it from the Bedford shale of Ohio. He (Chadwick, 1925, p. 463) summarized his case as follows:

> This unconformity I believe to be the same as that found at the top of the Chagrin in Ohio; so that, just as the Millers and Woodcock sandstones are let into the series in passing east from Cleveland to the Grand River, so in turn the Cussewago sand is inserted in crossing the Grand River Valley, to be followed by an increasing thickness of true (non-Bedford) Cussewago shale, which for distinction we will rename the (*Hayfield shale*) and limestone.
>
> In this view the shale between the Cussewago sandstone and the Corry (Berea) is at first all Bedford, but the plane of unconformity rises eastward, beveling out the Bedford, as already the Cleveland, and gradually substituting the Hayfield shale in the sections. Some undulations in the plane will account for the erratic behavior of the thin Cussewago (Hayfield) limestone beneath this plane. The shale above the Knapp at Warren probably is Hayfield.

In 1934 Caster re-classified the Devono-Mississippian sequence of northwestern Pennsylvania. On paleontological grounds he

(Caster, 1934, p. 155-165) related the Bedford shale of Ohio to his "Knapp formational suite"; more specifically, to its basal member, the then newly designated Kushequa shale. Caster also designated Chadwick's Hayfield shale and limestone as the Hayfield monothem stating (1934, p. 116):

> The monothem is really composed of two parts, seemingly of member rank. The upper is the Hayfield *sensu stricto,* which includes Hayfield limestone (here called *Littles Corner limestone*), and a lower member which enters toward the east and south which is only meagerly developed in the type Hayfield area. This lower member is being termed the *Tidioute* shale member.

Caster traced the Hayfield monothem from the Warren to the Meadville area and with reference to the Corry sandstone (*op. cit.,* p. 116) declared:

> At Glade, Warren County, on the Allegheny River, the Corry sandstone has been mapped as immediately overlying the Knapp upper conglomerate (Cobham). This is not actually the case, for about from 10 to 15 feet of Hayfield shale (Tidioute) intervene.

On page 119 of the same report Caster said:

> The contact of the Hayfield shale with the overlying Corry sandstone is most interesting for everywhere it appears to be gradational In the Upper two or three feet of the Hayfield, especially on the Allegheny River and on Oil Creek, there is an alteration of olivaceous shale and white sandstone layers which grade vertically into the base of the Corry sandstone. However, the Corry fauna does not occur in the gradational zone or below.

At times Caster appears to have equated the Cobham conglomerate and the Cussewago sandstone, both of which were assumed to underlie his Hayfield monothem. A frequently overlooked portion of Caster's work involves the correlation of the Bedford shale of Ohio which he (Caster, 1934, p. 165) postulated might possibly be represented by the Hayfield shale rather than the Kushequa in northwestern Pennsylvania.

De Witt (1951), studying the Berea sandstone in Ohio and Pennsylvania, concluded that the Cussewago sandstone and the "Riceville shale", which he depicted as underlying the Corry in Erie and Crawford Counties of Pennsylvania, were separate lithologic units. Curious as to his usage of the term "Riceville" the writer corresponded with de Witt who (1958, personal communication) indicated that the term was employed in the sense of the original definition of I. C. White (1881, p. 97-98) with the possibility that the designation "Knapp" might be applicable. Caster's separation (1934, p. 95) of the upper portion of the original Riceville as Knapp would indicate that the latter usage might be appropriate.

Pepper, *et. al.,* (1954) expanded de Witt's work of 1951. They denied the extent of Caster's Tidioute shale from Tidioute to Meadville to the Allegheny River stating (1954, p. 52):

> The writers conclude that White's Cussewago shale is synonymous with the Bedford shale and that, because the name Bedford has priority, the names Cussewago shale and Hayfield shale are invalid and may be dropped from the literature. Also, the names Cussewago limestone, Hayfield limestone, or Littles Corner limestone cannot be applied to definite rock units and may also be dropped from the literature.

Thus, contrary to the long standing dictum of Lesley (1895, p. 1779), Ohio stratigraphic terminology was once again introduced into the stratigraphic nomenclature of northwestern Pennsylvania. The work of Pepper, *et al.,* while adequate for the section in Ohio and the Berea sandstone, leaves many questions unanswered as to the formation or formations which underlie the Corry; particularly with respect to their correlation. Greiner (1957) chose to interpret Caster freely and designated the strata underlying the Corry from Warren to Meadville, Pennsylvania, simply as the Hayfield shale. The present writer feels that such oversimplifications are not acceptable. Rather than add to the uncertainty of the situation the writer chose to cite the opinions of many investigators on Text Fig. 4* in the hope that sound field and paleontological practice will ultimately solve the problem of the formations subjacent to the Corry sandstone.

THE FORMATION ABOVE

Regardless of the stage designation, the formation generally construed as overlying the Corry sandstone is the Orangeville shale of White (1880). Other than its constancy as a dark, fissile, olive shale its most outstanding characteristic, for the purposes of this

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*The draft of Figure 4 was made prior to changes of gender in the text.

report, is the presence of the Bartholomew siltstone member near the base, which de Witt (1951, p. 1368) considered, along with the Cussewago sandstone, " . . . the key to working out the stratigraphy of the lower Mississippian rocks in that area [northwestern Pennsylvania]."

THE CORRY SANDSTONE

Many generalizations have been written concerning various aspects of Corry stratigraphy. The theory of Caster (1934) and others that the Corry might be a tripartite formation is one with which the present writer is in accord. As such, it forms the framework of the discussion which follows. The descriptive terms used with reference to lithologic properties are mainly those of size and texture rather than chemical composition.

THE BASAL MEMBER

Caster's observations on the nature of the lower contact of the Corry appear to be well taken, for the unit herein designated as the *Lower Corry sandstone* appears to be universally gradational with the formation below.

The Lower Corry has a minimum thickness of a few inches at locations 14-S (Warren Quadrangle) and 19-S (Kane Quadrangle). It gradually increases in thickness southwesterly and attains a maximum thickness of 10 to 12 feet in the Tionesta (location 9-S) and Oil City (location 121-P) Quadrangles. North and northwest of this trend the Lower Corry appears to thin gradually and is last recognized in the vicinity of Riceville (location 94-P) in the Union City Quadrangle. From Riceville to Meadville and beyond, the Corry is apparently lost by grading into the Shellhammer Hollow formation of de Witt (1951).

Lithologically the Lower Corry has frequently been described as a grayish-white to buff, pure grit or sandstone with more or less constant characteristics throughout. However, this constancy is frequently interrupted (*e. g.* the massive nature of the lower member is not continuous throughout the entire area of outcrop). At outcrops 110-P (Titusville Quadrangle) and 94-P (Union City Quadrangle) the lower member is irregularly bedded in increments of 12 to 18 inches rather than massive. The lower contact of this member has several peculiarities worthy of note.

At many outcrops the base has either calcareous concretions at its contact with the formation below or irregularly disposed lenticular intervals which have high concentration of calcium carbonate. The concretions are nonfossiliferous and composed mainly of crystalline calcite. Upon preliminary microscopic examination the lenticular intervals proved to contain re-crystallized portions of still-recognizable shell material.

The concentration of the shell material as a constituent of the sample as a whole proved to approach 25% of the total weight when removed by treatment with hydrochloric acid. The resulting voids, which are actually artificially induced molds, when filled with latex, produced casts such as those made from the natural molds. This similarity suggests that the natural molds found in such profusion at many Lower Corry outcrops are the product of the removal of carbonate shell material by natural processes (*e. g.* solution by ground water).

That calcite concretions may have formed from calcium carbonate derived from such an internal source is proposed by Waldschmidt. He (1941, p. 1865) suggested that diagenetic factors such as application of increased pressure plus the decomposition of organic material resulting in the formation of carbonic acid, ammonium carbonate, and other solvents would result in the solution and redeposition of organic carbonates such as shell material. Pettijohn (1957, p. 297) made the same suggestion.

It thus appears that the carbonate concretions and the concentrations of shell material, inferred from the predominance of the molds in the Corry sandstone, have a direct relationship. The necessity of postulating an outside source to account for the concretions in the Lower Corry is, therefore, avoided. Unfortunately, the concretions cannot be used to demark the base of the Corry for they occur in similar positions in other sandstones in northwestern Pennsylvania (*e. g.* the Cussewago sandstone at location 11-S).

Angular fragments of shale or siltstone are frequently found surrounded by the sand grains of the basal portion of the Lower Corry.

Some appear remarkably fresh upon exposure and resemble the lithology of the strata immediately below the Corry. Twenhofel (1950, p. 301) attributed similar accumulations to the destruction of mudcrack polygons by the vigorous action of water.

At the eastern limit of Lower Corry exposures, in the Kane, Warren, and Youngsville Quadrangles, the contact with the Knapp and other beds cannot be distinctly placed and, in fact, appears to be gradational. In these quadrangles the Corry, like the Knapp, contains rounded pebbles of milky quartz measuring up to 3 cm. in length and 2 cm. in width. In addition, at locality 19-S (Kane Quadrangle) fragments of carbonized organic material were found along with the molds of brachiopods and other marine organisms.

Lithologically, aside from the features described above, the Lower Corry appears to represent an accumulation of detrital material, predominantly quartz, with few varietal minerals. The grains of quartz are in general angular to subangular, lenticular to equidimensional, and, as determined by a few preliminary measurements, vary in average diameter from 0.072 mm. at Sill Run (Warren Quadrangle) to 0.070 mm. at location 9-S (Tionesta Quadrangle). Grains of a single specimen taken at the type section (location 103-C) in the Corry Quadrangle have an average diameter of 0.057 mm. From these few measurements it appears that the average diameter of the quartz grains in the Lower Corry falls at the lowermost boundary of sand-sized particles as qualified by Wentworth (1922) and as such the member can be called a very fine-grained sandstone.

More precisely, this lower member can qualify as a very fine-grained orthoquartzite in the sense of Pettijohn (1957, p. 295-300) since it: (1) has at least 90% quartz; (2) contains "characteristic" molds and casts of fossils; (3) is well sorted; (4) has well-rounded quartz pebbles at the base of the bed; and (5) has a great areal extent in proportion to its thickness.

THE MIDDLE MEMBER

The Lower Corry grades upward, almost imperceptibly, into a lithologic interval herein designated as the *Middle Corry siltstone member*. This unit is best developed in the Tionesta and Oil City

Quadrangles where it attains a maximum thickness of ten feet. To the north and northeast of these quadrangles it is only sporadically developed. Its absence may be due to nondeposition or pre-Pennsylvanian erosion but positive evidence for either possibility is lacking. To the northwest, like the lower member it is not recognizable west of Riceville in the Union City Quadrangle.

The sequence is usually gray to greenish-gray in color on fresh exposure and contains appreciable quantities of small mica crystals oriented parallel to the bedding planes. While occasional thin sequences of shale may be present, in the main the member tends to be flaggy with certain more durable layers weathered in relief. It is this sequence that White (1881, p. 92) at the type section (location 103-C) characterized as being "shattered" and unfit for construction purposes.

The Middle siltstone has generally been considered to be unfossiliferous; in a broad sense this is apparently so. However, the writer has in his possession two small faunal collections from this member, one from locality 103-C (Corry Quadrangle) and the other from locality 121-P (Oil City Quadrangle). The former contains spiriferoid brachiopods and the latter productids. Other faunal assemblages may be located in the course of future collecting.

THE UPPER MEMBER

Like the sequence below it, the Middle Corry siltstone grades into the third and uppermost member herein assigned to the Corry—*the Upper sandstone member.* This unit is the least persistent of the three, particularly in the northern portion of the outcrop area where it is totally absent. The Upper sandstone finds its optimum development in the Tionesta, Oil City, and Titusville Quadrangles where it attains a maximum thickness of 10 feet. North, east, and west of these quadrangles it thins rapidly or is missing. The Upper Corry is lithologically similar to the Lower sandstone member. As far as is known at the present this unit has not yielded a fauna. Where developed, it grades into the sequence most generally agreed to overlie it—the Orangeville shale.

The lithologic units described above were deposited in a setting which has been called the Penn-York Embayment by Caster (1935b) or Corry Bay (Pepper, *et al.,* 1954). As reconstructed by

Pepper, *et al.,* (1954, pls. 13A-13I), the Bay existed as a coastal indentation of the Devono-Mississippian epicontinental sea. It was bordered to the north and west by the fluctuating red Bedford delta and on the southwest by the Cussewago-Murraysville delta.

The western or seaward entrance to Corry Bay is depicted as having been closed or restricted by sand bars during early Bedford and Berea times. Such a history would have created conditions which were alternately restrictive and nonrestrictive with respect to the free flowage of marine currents and must have affected both the deposition of sediments and the life of the marine organisms in the embayment.

STRATIGRAPHIC PALEONTOLOGY

COMPOSITION OF THE FAUNA

Caster (1934, p. 123-124) recorded more than 56 separate genera of invertebrates, based upon his own collections from the Corry sandstone, and stated (footnote, p. 123), "This list does not include all the forms known to exist in the Corry . . ." The writer's collection is somewhat less voluminous than Caster's list would indicate it might be, but a complete faunal accounting would be premature at this time. In the writer's collection, as in Caster's, the majority of the species represent the phylum Brachiopoda. The Gastropoda and Pelecypoda (as yet unstudied) form the next most important groups with the former more conspicuous by virtue of its representation by a greater number of individuals. The Porifera are a minor faunal element but an important one. The remainder of the writer's collection consists of a single conularid, a mold of a shark (?) spine, tracks and trails, and numerous problematical markings.

Of the Porifera, species of the following genera have been recognized by the writer:

1. *Clathrospongia* Hall, (1884)
2. *Ectenodictya* Hall (1884)
3. [?] *Phragmodictya* Hall (1882)

Genera of the Brachiopoda recognized thus far are:

1. *Paraphorhynchus* Weller (1905)
2. *Syringothyris* Winchell (1863)
3. [?] *Septosyringothyris* Vandercammen (1955)
4. *Cyrtospirifer* Nalivkin (*in* Fredericks, 1926)
5. *Camarotoechia* Hall and Clarke (1893)
6. *Rhipidomella* Oehlert (1890)
7. *Schuchertella* Girty (1904)
8. *Chonetes* de Koninck (1842)
9. *Lingula* Bruguière (1797)

The Gastropoda appear to be represented, in part, by the following genera:

1. *Platyceras* Conrad (1840)
2. *Euomphalus* Sowerby (1814)

Only the Porifera and species of the brachiopod genera *Paraphorhynchus, Syringothyris,* and [?] *Septosyringothyris* (in part) have been thoroughly investigated thus far and will constitute the basis for the discussion which follows. Their areal distribution is documented on Tables 3 and 4. Other genera are mentioned in the text to supplement the discussion but their specific identification is not to be construed as final.

DISTRIBUTION OF THE FAUNA

The base of the lower member of the Corry appears to represent the habitat of what was a thriving diversified invertebrate community. The distribution of the fauna within the member is sporadic and appears to have both areal and vertical limitations. Good faunal assemblages seem to be limited to the lower four feet of the member, with the most prolific accumulations within a foot of the lower contact.

PORIFERA

The sponges are few in number and rather widely dispersed; single specimens of each of three genera have been recorded from the Warren (location 116-C), Corry (103-C), and Oil City (location

TABLE 3

List of the faunal elements herein described and the localities from which they were collected. Localities arranged from easternmost (right) to westernmost (left). (*See* also fig. 4)

Species	*Locations*												
	767 CT	90 P	113 P	103 C	214 C	1565 CT	910 CT	140 C	112 C	116 C	14 S	123 C	19 S
Clathrospongia abacus Hall, 1884				x									
Ectenodictya carlli (Hall and Clarke) 1898										x			
Paraphorhynchus medialis (Simpson), 1889	x			x	x	x	x	x	x	x	x	x	
P. striatus (Simpson), 1889	x			x	x	x	x	x	x	x	x	x	x
P. girtyi Caster, 1930												x	
P. casteri, n. sp.										x			
Syringothryris angulata Simpson, 1890		x	x							x			
S. randalli Simpson, 1890								x		x		x	x

TABLE 4

Elements of the Corry fauna; arranged by quadrangle.

Quadrangle	*Locality*		
Kane	*19-S*		
Paraphorhynchus striatus (Simpson), 1889	x		
Syringothyris angulata Simpson, 1890	x		
Warren	*123-C*	*14-S*	*116-C*
Ectenodictya carlli (Hall and Clarke), 1898			x
Paraphorhynchus medialis (Simpson), 1889	x	x	x
Paraphorhynchus striatus (Simpson), 1889	x	x	x
Paraphorhynchus girtyi Caster, 1930	x		
Paraphorhynchus casteri, n.sp.			x
Syringothyris angulata Simpson, 1890			x
Syringothyris randalli Simpson, 1890	x		x
Youngsville	*112-C*		
Paraphorhynchus medialis (Simpson), 1889	x		
Paraphorhynchus striatus (Simpson), 1889	x		
Tidioute	*140-C*	*910-CT*	
Paraphorhynchus medialis (Simpson), 1889	x	x	
Paraphorhynchus striatus (Simpson), 1889	x	x	
Syringothyris randalli Simpson, 1890	x		

Corry	*103-C*		
Clathrospongia abacus Hall, 1884	x		
Paraphorhynchus medialis (Simpson), 1889	x		
Paraphorhynchus striatus (Simpson), 1889	x		
Titusville	*1565-CT*	*214-C*	*113-P*
Paraphorhynchus medialis (Simpson), 1889	x	x	
Paraphorhynchus striatus (Simpson), 1889	x	x	
Syringothyris angulata Simpson, 1890			x
Union City	*767-CT*		
Paraphorhynchus medialis (Simpson), 1889	x		
Paraphorhynchus striatus (Simpson), 1889	x		
Townville	*90-P*		
Syringothyris angulata	x		

68-C) Quadrangles. Only specimens from the first two locations have been positively identified. As will be shown, it is the paucity of numbers and morphological features rather than locality which contribute to the importance of the sponges in the Corry sandstone.

BRACHIOPODA

Four species of the genus *Paraphorhynchus* Weller (1905) and two of *Syringothyris* Winchell (1863) are discussed in detail in the section on systematic paleontology. Two of the four paraphorhynchoid species, *P. medialis* (Simpson) and *P. striatus* (Simpson), appear to have the same areal distribution, but the former was apparently the more prolific. *P. girtyi* Caster and *P. casteri*, n.sp. are not only severely limited in numbers, with only a total of four specimens of the two species recorded thus far, but also appear to have been restricted to the eastern portion of the area under investigation.

The syringothyroids exhibit an equally interesting distribution. The ranges of the species of *Syringothyris, sensu stricto,* overlap, but the species themselves exhibit differences other than morphological ones. Specimens of *S. randalli* Simpson far outnumber those of *S. angulata* Simpson, of which only four are in the writer's possession. *S. randalli* appears to be confined to the eastern portion of the area of investigation, while *S. angulata* is represented at both its eastern and western extremities.

Numerous specimens of syringothyroids, herein tentatively referred to the genus *Septosyringothyris* Vandercammen (1955), for reasons discussed under systematic paleontology, occur along with both *S. angulata* Simpson and *S. randalli* Simpson. It is quite possible that these syringothyroids, with a syrinx supported by a median septum, will prove to be of great stratigraphic value for correlative purposes.

GASTROPODA

The gastropods have yet to be studied by the writer. However, certain significant distribution patterns emerged when the locations of the specimens of this faunal element were being recorded. From the writer's observations certain genera seem to have flourished in limited areas. Species of the genus *Platyceras* Conrad (1840) appear to be the dominant representatives of the Gastropoda at locality 116-C (Warren Quadrangle), while the genus *Euomphalus* Sowerby (1814) is superior in numbers at locality 140-C (Tidioute Quadrangle). This differentiation may have ecological significance.

ECOLOGICAL IMPLICATIONS

PORIFERA

De Laubenfels (1936, p. 54) ended his discussion of factors involved in studying the paleoecology of sponges with the statement, "It appears that in the past Porifera occurred in much the same environments as at present, and led similar lives." Disregarding, for the moment, that our concept of environment criteria has been altered by modern oceanographic research, a few of De Laubenfels' predications may be helpful in understanding the interrelationships between the sponges and their environment during Corry time. Some of the criteria of De Laubenfels (1936, p. 44-54) and the relationships observed by the writer and other workers compare as follows:

De Laubenfels (1936, p. 44):

> . . . wherever fossil sponges occur there was probably a large island or continent within a few hundred kilometers.

It is the opinion of Caster (1934/1939) and others that the "Catskill Delta" was slowly building westward from a land mass to the east of the area under study, during Devono-Mississippian time.

De Laubenfels (1936, p. 46):

> . . . the finer the particles in question, the fewer are the sponges that occur [the inhalent openings become clogged].

The grains of the constituent minerals of the Lower Corry in which the sponges occur, have previously been cited as approaching silt size. This could account for the small number of sponges found in the lower member. The subsequent changes to the finer, true silts of the middle member might be responsible for their absence in the middle and upper members of the Corry.

De Laubenfels (1936, p. 49):

> . . . one may . . . state with considerable confidence that the occurrence of fossil hexactinellid sponges [which concern us here] indicates that their horizon had been characterized by darkness [and concomitantly great depth.]

The above statement is subject to a variance of opinion because some sponges exhibit remarkable adaptive capabilities. De Laubenfels (*op. cit.*, p. 48) cited the case of *Acarnus erithacus* (Demospongiae) which normally occurs in zones of good illumination but which has been reported from depths of 700 meters off the California coast. Clarke (1920, p. 36) cited the migration of the Dictyosponges, ". . . into the shallow and cool waters of the Chemung. . .", where he presumed they evolved further and subsequently migrated again into deeper waters during the Mississippian. Caster (1939,

p. 18, text fig. 7) effectively showed that the "glass sponges" not only could, but did thrive in near-shore environments.

In addition, certain sponges of the Corry were apparently capable of inducing morphological variation to cope with a changing environment. Such appears to be the case with *Ectenodictya carlli* Hall which was discovered to have developed, in addition to double rows of strands in the horizontal component of the primary reticulum, a series of diagonal strands in the constricted area below the mesial bulge. (See Pl. 28, fig. 3.) Such devices are construed by the writer as structural in nature, designed to support the distal portion of the cup, expanding to minimize the suffocating effects of the encroaching fine sediment; or possibly as bracing to combat the effects of strong currents. In essence, the sponges could have been: (1) limited in number by the nature of the sediment; (2) capable of morphological variation, within limits, to cope with environmental change; (3) inhabitants of relatively "shallow water"; (4) unable to cope with the silts after Lower Corry time and eliminated from the remainder of the sequence by extinction or migration.

BRACHIOPODA

Greiner (1957, p. 40-43), citing Cooper (1937) and others, listed the following morphological traits of brachiopods as possible representative adjustments to specific environmental conditions:

1. Heavy shells; suggest habitat as near-shore or sublittoral zone (characterized by coarse sandstones or conglomerates).
2. Median fold; facilitates ingress and egress of water currents that aerate the mantle and bring in food.
3. Plication; increases shell strength under arduous conditions.
4. Strong muscles; indicate a habitat characterized by strong wave and current action.

The species of *Paraphorhynchus* Weller (1905) share in common: (1) well-developed folds and sulci; (2) costellated plicae on the entire surface of both (?) valves; (3) evidence of relatively large pedicles, via a sizeable foramen in the pedicle valves; (4) large diductor muscle scars; and (5) the development of additional muscles of closure (the "posterior adductor process"). The development of such features can be interpreted as an attempt to compensate for the inability of weak dentition and fragile tissue to cope with arduous living conditions. If such is the case, it should be possible to discern the relative severity of such conditions, areally, by examining the distribution and characteristics of individual brachiopod species. (See Table 3.)

Paraphorhynchus medialis (Simpson) and *P. striatus* (Simpson) are widely dispersed sympatric species and exhibit only a modest development of surface ornamentation (see Pls. 31, 32). *P. girtyi* Caster and *P. casteri,* n. sp. appear to be ecotypic and restricted to the easternmost area of outcrop (Warren Quadrangle). They are characterized by the development of coarse plicae and carinae and crenulate diductor muscle scars in the pedicle valve. The heavy ornamentation and musculature must indicate an environment closer to the shore line and more violent than that occupied by species to the west. This relationship appears to be substantiated by similar phenomena in other genera.

Syringothyris angulata Simpson, while represented by a few specimens, is a widely dispersed form. *Syringothyris randalli,* represented by many individuals, is confined to the easternmost areas of outcrop (see Table 3); it has two sets of striae on the diductor muscle scar of the pedicle valve as opposed to the single set borne by *S. angulata.* Further, *S. randalli* has heavy deposits of secondary callist material in the delthyrium, rostral and lateral cavities, as though an attempt were made to achieve stability in a turbulent sea.

All these adjustments by brachiopod species, apparently confined to the easternmost area of outcrop, indicate that this area was probably within the zone of wave-base activity, frequently disrupted by storms, tides and strong currents; perhaps at the junction of the littoral and neritic zones.

GASTROPODA

While the easternmost area of outcrop may represent a tumultuous marine environment it seems to have been one which offered all the ingredients necessary for the propagation of vast populations. Location 116-C (Still Run, Warren Quadrangle) appears to have been a most favored location, reminiscent of a modern reef. With few exceptions, almost all of the genera and species (brachiopods in particular) in the writer's collection are represented here.

At this locality the genus *Platyceras* Conrad (1840) is the dominant representative of the Gastropoda. This association of brachiopods and gastropods was at first perplexing. However, the subsequent discovery of what appears to be a boring in a brachiopod mold made by a gastropod radula suggests that this relationship is not coincidental. It appears that the platycerids were carnivorous, perhaps preying on certain species of Brachiopoda.

The Corry may offer a unique opportunity for the study of the relationship between the organisms themselves as well as between the organisms and their environment.

POSSIBLE ORIGINS OF THE FAUNA

Girty (1905, p. 6) stated, "The supposed equivalent of the Berea grit in northwestern Pennsylvania contains a fauna which is without question of a Mississippian type . . .;" the source and nature of the fauna were not discussed. Weller (1905) differentiated a northern from a southern Kinderhookian fauna in the mid-continent region stating (*op. cit.*, p. 634):

> During earlier Kinderhookian time these two faunas were restricted, one to the more northern, the other to the more southern region, and the two provinces were separated by some barrier, doubtless a land barrier. Near the close of the Kinderhookian epoch, the barrier separating the two provinces was removed, and the fauna from the south migrated into the northern province. . . With the removal of the barrier, however, the northern fauna did not make any headway into the southern province.

It is interesting to note that both of Weller's faunas contain species of the brachiopod genera herein described (*e.g. Paraphorhynchus transversus* Weller and *Syringothyris extensa* Hall).

Schuchert (1910, p. 223-224) postulated a dual origin for the syringothyroids as follows:

> *Syringothyris* therefore originated in the Cordilleran sea during the later Devonian [?] and not in the Atlantic province as the writer heretofore held, but it was not a conspicuous member of any fauna until Mississippian time. The genus is then present in most of the formations from the early Kinderhook to the Keokuk, and it persists even into the Spergen of the Meramecian series. At no time, however, was there more than one species in a fauna and all these are very much alike[?].
>
> Another phylum [?] originated in the Atlantic realm of the Appalachian province in *Spirifer randalli* [= *Syringothyris randalli* Simpson],

> which also has a well developed syrinx, but differs from *Syringothyris* of the Mississippian sea in having a strongly plicated fold and sinus. This stock must be separated generically from those of the Mississippian sea because of its different phyletic derivation, . . .

Girty (1911) effectively refuted Schuchert's thesis of a separate derivation for syringothyroids with a plicate fold and sulcus but did not comment specifically on the Cordilleran origin of the mid-continental representatives of the group.

Williams (1943) suggested that the fauna of the Louisiana limestone of Missouri (which he considered to be Kinderhookian in age) resembles that of the Hamilton (Middle Devonian) of the eastern United States rather than the Upper Devonian faunas of the mid-continental region. To substantiate this contention he listed a number of Hamilton brachiopod genera which duplicate those previously listed above as Corry forms (*e.g. Rhipidomella, Schuchertella,* and *Camarotoechia*). Citing the fauna of the Cleveland and Bedford shales of Ohio as indicative of a migratory path from the east, Williams (1943, p. 49) remarked that, ". . . the presence of the rare genus *Paraphorhynchus* in the Berea (Corry) sandstone of Pennsylvania suggests either that there was communication between the Louisiana area and these areas [Ohio, Indiana, and Illinois] as late as in early Waverly time or that the faunas were derived from a common source."

The opinions above are too diverse to warrant further comment in a localized study such as that undertaken here. However, in the course of the preparation necessary for the descriptive text on systematic paleontology certain faunal distribution patterns emerged which may be significant for future work concerning the Corry. At present there appear to be three distinct faunal elements within the Lower Corry, each exhibiting a slightly different origin and/or evolutionary history.

The Dictyospongiidae represent a slowly evolving group, apparently indigenous to the Appalachian province, which reached its climax during the Upper Devonian; some species appear to have become extinct during Lower Corry time. Clarke (1920, p. 36-37) traced their evolution from the Silurian through the Mississippian and attributes their ultimate westward migration during the latter period to (*op. cit.*, p. 36), " . . . an incursion of fresh waters which flooded the Devonian province with gravel from eastern lands."

Caster (1939) recorded the facieological preferences of a number of species of the dictyosponges and depicted their migratory shifts with respect to the westward migration of magnafacies boundaries. Unfortunately the distribution and identification of the dictyosponges in the Mississippian strata west of Pennsylvania is not well recorded.

The Brachiopoda studied thus far appear to be divisible into two elements—one foreign and the other native to the Penn-York Embayment. The paraphorhynchoids represent the exotic element; they have not been reported in the Embayment either above or below the Lower Corry sandstone. Their total absence in the Knapp and sudden appearance in the Lower Corry would appear to discount the possibility that the genus is diphyletic.

Species of the genus *Paraphorhynchus* Weller (1905) are reported in North America, in addition to those of the Penn-York Embayment, from Lower Mississippian (Kinderhookian) strata of Illinois, Iowa, and Missouri. Some of the formations involved (*e.g.* the Louisiana limestone of Missouri) had formerly been placed in the Upper Devonian but subsequent workers established their age as Lower Mississippian. Consequently, *Paraphorhynchus* has become an index fossil of the Lower Mississippian where reported in North America.

Outside of North America this distinction does not hold. Nalivkin (1937) and Simorin (1956) described species of the genus from the Famennian (Upper Devonian) as well as the Lower Mississippian beds of Kazakhstan and the Karagandin Basin of south-central Asia. Although such far-flung occurrences are admittedly tenuous it appears that the paraphorhynchoids originated in south-central Asia and subsequently migrated into North America.

The syringothyroids appear to represent an element derived from antecedent spiriferoid stock in the Penn-York Embayment. They are reported by Holland (1958) from the Lower Mississippian Knapp but not from the underlying Upper Devonian Oswayo formation. Their initial appearance in the Lower Mississippian formations of North America marks the group as excellent guide fossils of Lower Mississippian time.

The reported initial occurrence of species of the genus *Syringothyris* in Upper Tournaisian beds of Australia by Maxwell (1954, p. 41) and in the Middle Tournaisian formations of the Karagandin Basin by Simorin (1956, Table 2) may lend credence to the North American origin and subsequent migration of the genus as supposed by Termier and Termier (1949).

Maxwell (1954, p. 7, Map 1) showed supposed late Paleozoic faunal migration routes affecting the Northern Hemisphere and Australia. By coincidence, these routes could mark the migratory path of the paraphorhychoids into North America during Devono-Mississippian time and the exit routes of the syringothyroids from North America during Mississippian time.

AGE AND CORRELATION

The Mississippian (Kinderhookian) age of the Corry sandstone has been reiterated many times since White first named the formation in 1881. The faunal elements studied herein affirm this assignment. It is the relationship of the Corry with beds of equivalent age to the west of Pennsylvania, not its age, which remains problematical.

Correlations to date have depended largely on lithology or stratigraphic position because the intended correlative, the Berea sandstone of Ohio, is markedly unfossiliferous. Rather than argue the merits of the relationships already suggested the writer prefers to hold the question of absolute correlation in abeyance and discuss instead the possible avenues of investigation.

CORRELATION A

This would involve a direct Berea-Corry relationship of variations between a single or tripartite Berea sandstone with a single or tripartite Corry. The relationships would, of necessity, be based on lithology and stratigraphic position. Such correlations have been discussed previously.

CORRELATION B

In 1951 de Witt suggested that the Bedford shale of Ohio and the Corry sandstone of northwestern Pennsylvania merged into a siltstone sequence called the Shellhammer Hollow formation in the vicinity of Meadville, Pennsylvania. A shallow strait was presumed to exist in the Meadville area during much of Corry time.

In discussing the paleogeography of late Bedford time Pepper, *et al.,* (1954, p. 104) stated, "In the eastern part of Corry Bay the lowest beds of the Corry sandstone were being deposited." In the subsequent chronology of Berea paleogeography the strait at the entrance to Corry Bay (*op. cit.,* pls. 13E-13H) is shown as being closed during early Berea time and open during middle and late Berea time. Such a series of events suggests that the lower fossiliferous member of the Corry could correlate with a portion of the Bedford shale. The Middle siltstone member would relate to the slight interruption between Bedford-Berea deposition, the closure of the strait during early Berea time, or both. The Upper Corry sandstone member and the Berea proper would then be temporal equivalents with the strait between the epicontinental sea and Corry Bay open. In this way the paleogeographic interpretations of Pepper, *et al.,* (1954) and the extant lithologic units might correspond, in that median siltstone of the Corry could relate to the gradual closure of the strait and the restriction of the waters in Corry Bay. The Upper and Lower Corry sandstones would represent times when the strait was open and Corry Bay swept by marine currents of the epicontinental sea to the west.

These relationships are admittedly arbitrary and must be substantiated by other means if their validity is to be ascertained. Further exploration of the problem must involve the biologic factors. This particular facet of the problem has always presented difficulties because of the relatively unfossiliferous nature of the Berea sandstone. In addition to plant fragments, de Witt (1958, personal communication) reported an assemblage of small pelecypods in the *upper* five feet of the Berea at Kinsman, Ohio. This distribution is what might be expected if the statement of Pepper, *et al.,* (1954, p. 1) that, "The Berea sandstone was deposited above the Bedford shale, at first subaerially as a delta and later as a marine pavement that formed as the sea inundated this delta," is to be accepted. Briefly, the circumstances of its deposition do not warrant any expectation of finding a large marine fauna in the Berea sandstone.

Caster (1943, p. 161-162), from various sources, listed the components of the Bedford fauna which he (Caster) believed to consist of a minor Hamilton (Middle Devonian) element and a major Mississipian element. The Mississippian aspect of the Bedford fauna, he believed, had a common heritage with the fauna of the Knapp. Caster (1934, p. 163) concluded:

> The Bedford *Syringothyris "carteri"* is very closely related to the forms occuring in the Knapp monothem, and quite indistinguishable from species occurring in the Corry sandstone. The Bedford forms seem clearly to be of the Mississippian type, and more specifically, of lower Kinderhookian age.

The study of the Lower Corry fauna initiated herein does not as yet provide a sufficient basis for definitive correlation. The Porifera, known to exist in the Bedford, are not adequately described for comparison with those of the Corry. Paraphorhynchoids are as yet unreported from the Bedford. The syringothyroids described herein compare favorably with those of the Knapp and will perhaps prove to be equally comparable with those of the Bedford, as Caster intimated. Other faunal elements of the Bedford and Corry must be studied and compared. This faunal comparison must be affected by the study of accurately zoned topotype material. It should be noted that the Bedford has a faunal zone not only at its base but also near its upper limit according to de Witt (1958, personal communication) who noted the zone in the vicinity of Kinsman, Ohio.

If the Lower Corry and comparable Bedford faunas are found to be intimately related the following theories would appear to supplement each other:

1. Williams' (1943) suggestion that the fauna of the Louisiana limestone of Missouri and the Corry sandstone of Pennsylvania either stemmed from a common source or were related by way of migratory routes represented by the Cleveland and Bedford shales of Ohio.

2. De Witt's (1951) proposed coalescence of the Bedford and the Corry into the Shellhammer Hollow formation.

3. The paleogeographic interpretations of Pepper, *et al.*, (1954) and their proposed simultaneous deposition of the Lower Corry and the Upper Bedford.

4. The similarity between Bedford and Lower Corry syringothyroids noted by Caster (1934) and his supposition that the Bedford represents a westerly subneritic zone of the Penn-York Embayment.

CORRELATION C

There are in the Lower Corry and the Knapp syringothyroids with a syrinx supported by a median septum; Holland (1958) referred the Knapp forms to the genus *Syringopleura* Schuchert (1910). Regardless of the difference of opinion on the genus to which the species belong, the specimens from the Knapp and Corry compare favorably.

Schuchert (1890, p. 11) erected the species *Syringothyris herricki* for specimens, described previously as *Syringothyris cuspidata* by Herrick in 1888, which exhibit a syrinx supported by a median septum. Hyde (1953, p. 277) suggested that the median septum in this species is a variable feature and not particularly diagnostic. All of the specimens described by the authors cited above appear to have come from the Byer sandstone member of the Logan formation which lies some 250 feet above the Berea. If the septate forms in the Byer should be found equivalent to those in the Knapp and Corry, it might be argued that the three formations were related—particularly if other faunal elements were also found to correspond. The Corry would thus correlate with beds younger than the Berea.

Of the three possible alternate correlations, the second (B) appears to be the most promising.

SUMMARY AND CONCLUSIONS

During the Lower Mississippian (Kinderhookian) epoch a portion of what is now northwestern Pennsylvania was apparently occupied by an embayment of the epicontinental sea which lay to the west. According to Pepper, *et al.*, (1954) this "Corry Bay" was bordered to the northwest by the Bedford-Berea delta and to the southwest by the Cussewago-Murrysville delta. At its westernmost extremity the embayment was intermittently cut-off from the sea beyond by the closure of an unnamed strait.

The sediments in the embayment subjacent to the Corry sandstone (Knapp, *et seq.*) reflect the westward encroachment of the magnafacies boundaries defined by Caster (1934) and re-affirmed by Holland (1958). For reasons not well understood, the Corry sediments do not reflect similar lateral facieological changes except at the extreme margins of the area of outcrop.

The gradational nature of the contact of the basal Corry sandstone with the subadjacent beds suggests that there was little, if any, interruption between the deposition of the sediments of underlying formations and those of the Corry. Pepper, *et al.*, (1954) proposed a northeastern source for the Corry sediments. The quartz grains of the basal Corry approach, but do not attain, particle sizes which are termed "silt." The small-sized grains may indicate a remote primary source of sediment or an adjacent secondary source reflecting more than one cycle of sedimentation.

The fauna is confined largely to the lower member of the Corry and appears to contain elements of at least three distinct origins.

The "glass sponges" represent a group which, according to Clarke (1920), had its origins in the early Paleozoic of the Appalachian province. Their limited representation in the Corry sandstone is probably due to unfavorable environmental factors. That some species did manage to adjust themselves is evidenced by the increased structural supports of the outer reticulum of *Ectenodictya carlli* Hall. The record of the westward (?) migration of the surviving forms is not well documented, but species of the genus *Ectenodictya* Hall have been reported from the Keokuk beds at Crawfordsville, Indiana.

The Brachiopoda are divisible into two distinct groups, one foreign and the other native to the Corry embayment. The paraphorhynchoids appear to have originated during the Famennian in south-central Asia and subsequently migrated to the eastern North American continent during Lower Kinderhookian time by way of the mid-continent area.

Two species, *Paraphorhynchus medialis* (Simpson) and *P. striatus* (Simpson), are equitably distributed within the Lower Corry wherever a distinct fauna can be recognized. Contrarily, *Paraphorhynchus girtyi* Caster and *P. casteri,* n. sp. were found only in the eastern area of outcrop. Their coarse plicae, strong concentric carinae and rugose muscle scars are interpreted as adjustments to a tumultuous existence in a near-shore environment. Since species of the genus are not reported from the Knapp and did not survive Lower Corry time they are considered good indices of the Corry. Whether the extinction of the genus was due to its inability to compete with others occupying the same ecological niche or some other cause is not apparent.

The syringothyroids represent the element indigenous to the embayment, for the Corry and Knapp species studied thus far are identical. The group is believed to have originated from Middle Devonian spiriferoids but their migratory history and evolution prior to Mississippian time is not well documented.

The species of *Syringothyris* Winchell, *s.s.,* are irregularly distributed in the Lower Corry. *Syringothyris randalli* Simpson is more prolific but appears to be restricted to the eastern area of outcrop. Several species of as yet unnamed septate syringothyroids coexist with both *S. angulata* and *S. randalli.*

The restriction of the more rugose brachiopod species to the eastern area of outcrop and the concomittant inclusion of rounded pebbles in the same sequence is interpreted as indicative of near-shore conditions. This environment appears to have been suited for the establishment of large populations for it is in this area (Warren Quadrangle and vicinity) that the largest faunal assemblages are found. The concentration of particular gastropod species in this well-populated area is considered to represent an association which existed in life.

The Lower Corry sandstone grades into the silts of the Middle Corry member. The change in the nature of the sediment may be associated with the gradual closure of the western strait postulated by Pepper, *et al.,* (1954); other explanations for this change are also possible. Whatever the mechanism, with the change, the fauna of the Lower Corry either perished (paraphorhynchoids) or migrated (syringothyroids) as the silts gradually accrued. A few productids and cyrtospirifers apparently survived in the new environment.

The Middle Corry siltstone grades into the sandstone of the Upper Corry member which has yet to yield a fauna. The upper member, in turn, grades in to the overlying Orangeville shale. The record of the Upper and Middle Cory members in the eastern area of outcrop has been obliterated by pre-Pennsylvanian or post-Paleozoic erosion.

It is suggested that the Lower Corry member may correlate, in part, with the upper portion of the Bedford shale of Ohio rather than with the Berea sandstone as has previously been supposed. Such a correlation appears to integrate the hitherto unrelated theories of other workers who have dealt with the formations in question. Only a careful systematic and stratigraphic study of the Corry and Bedford faunas will invalidate or support this suggestion.

SYSTEMATIC PALEONTOLOGY

SOURCE AND NATURE OF COLLECTION

The fauna here described was in part collected by the writer in northwestern Pennsylvania during the summers of 1957 and 1958. The remainder of the specimens were donated by Dr. K. E. Caster to the University of Cincinnati Museum.

With few exceptions, the specimens studied were natural internal and external molds presumably caused by the solution of the original or subsequently recrystallized carbonate shell material; all are from the Corry sandstone unless otherwise indicated.

PREPARATION OF SPECIMENS

It was determined that the nature of the finer morphological features of the fossils could be most readily discerned through the preparation of artificial casts. The casts were made from black, liquid, water soluble, pre-vulcanized, latex emulsion; commercially obtainable as "Permaweld" from the Polymer Chemical Company, Cincinnati 12, Ohio.

After some experimentations, the latex casts were successfully made in the following manner: The surface of the specimen was first dampened with a liquid detergent (Kodak photo-Flo) to serve as a wetting agent and facilitate the removal of the finished cast from the mold. Two initial coats of thin latex were applied to the surface of the dampened mold with a fine brush. After each application of the initial coats the latex, while still wet, was blown with compressed air. (This technique eliminated air bubbles and forced the latex into the deeper recesses of the mold.) Subsequent coats of increased viscosity were applied by brush, in 24 hour increments, until a total thickness of approximately 1/8 to 1/4 inch was achieved.

In some instances it was necessary to give the cast additional support. For the internal features of brachiopods (*e.g.*, syrinx or dental support plates) the depression in the mold was filled, in part, with thin slivers of balsa wood moistened in liquid latex. The "filler" was installed subsequent to the first two thin coats and prior to the application of the more viscous layers. The outside of the cast was occasionally reinforced by the application of latex-saturated medicinal cotton or gauze along with the final coat.

Prior to microscopic study or photographic reproduction both casts and molds were coated with a patina of sublimated ammonium chloride to further emphasize the details of the morphology.

PALEONTOLOGIC PLATES

All plates illustrating described or identified species were prepared in the conventional manner (*i.e.,* illuminated from the upper left side). The photographs are approximately natural size unless otherwise indicated.

LOCATIONS

The collecting site for each individual specimen used to describe or identify a species is designated by a numbering system previously defined (see Table 1).

TYPES

The types for each species described or identified herein are accessioned and stored with the collections of the University of Cincinnati Museum, Dept. of Geology, Cincinnati 21, Ohio. All accession numbers of the above named repository are preceded by the designation—UCM. Types, stored elsewhere, are so designated whenever practical.

TAXONOMY

All taxonomic decisions are made in accordance with the International Rules of Zoological Nomenclature—as emended and modified by the Fourteenth International Congress of Zoology at Copenhagen, Denmark in August, 1953. The term Regles will designate the above named authority when, for the purposes of this paper, reference is necessary for the clarification or explanation of a particular point of taxonomy.

PHYLUM PORIFERA

Recent publications and textbooks reflect the general disagreement among diverse authors with respect to the classification of both fossil and living Porifera. The lack of solidarity is particularly noticeable in the higher taxa where a division exists not only among paleontologists but also between paleontologists and neontologists. Despite the objections of King (1943) and others, the classification employed herein for the higher taxa is that of De Laubenfels (1955) which is well documented in a previous publication (see De Laubenfels, 1936).

Most of De Laubenfels' proposed changes, particularly with respect to the "glass sponges", appear to be in accord with the International Code of Zoological Nomenclature and are long-overdue applications of the Law of Priority. Further, De Laubenfels' subdivisions of the fossil Hyalospongia into orders which approximate those of living forms is a commendable effort to resolve the differences between paleontologist and neontologist.

The general accord of the present writer with the classification proposed by De Laubenfels (1955) extends to, but does not include, the subfamilial rank. The subdivision of the family Dictyospongiidae into subfamilies based upon the presence or absence of the prismatic form appears to be too artificial. Clarke (1918, p. 180) emphasized the gradational nature of external form in the "glass sponges." Citing the external structural features of *Hydnoceras walcotti* he (Clarke, *loc. cit.*) demonstrated the existence of all four basic structural patterns (obcone, prism, node, and ring) in a single individual. Until the nature of the relationships between the "glass sponges" is better understood it seems prudent to employ the subfamilial designations of Hall and Clarke (1898) for the purposes of this report.

Phylum PORIFERA Grant, 1872

Class HYALOSPONGEA Vosmaer, 1886

[*nom. correct.* de Laubenfels, 1955 (*ex* Hyalospongiae Vosmaer, 1886)] [= Hexactinellida Sollas, 1887]

Order LYASSAKIDA Zittel, 1877

[*nom. correct.* de Laubenfels, 1955 (*ex* Lyssakina Zittel, 1877)]

Family **Dictyospongiidae** Hall, 1882

[*nom. transl.* de Laubenfels, 1955 (*ex* Dictyospongidae Zittel—Eastman, 1913, *ex* Dictyospongiae Hall, 1882)]

Subfamily **Dictyospongiinae** Hall and Clarke, 1898

Genus **Clathrospongia** Hall, 1884

1863. *Dictyophyton* Hall, [*pars*], New York State Cab. Nat. Hist., 16th Ann. Rept., p. 87; p. 90, pl. 3, fig. 4 [*non* p. 90, pl. 5, fig. 3 *(Thysanodictya)*].
1883. *Clathrospongia* Hall, [*nomen nudum*], [title only], American Assoc. Adv. Sci., Proc., (1882), vol. 31, p. 419.
1884. *Dictyophyton (Clathrospongia)* Hall, New York State Mus. Nat. Hist., 35th Ann. Rept., p. 466; p. 474, pl. (18) 19, figs. 2-4.
1890. *Dictyophyton* Hall, New York State Geologist, 9th Ann. Rept., p. 57-88.
1898. *Clathrospongia* Hall and Clarke, New York State Mus., Mem. 2, p. 121-122.
1955. [*non*] *Clathrospongia* Hall and Clarke, de Laubenfels, Treatise on Invertebrate Paleontology, pt. E (Archaeocyatha and Porifera), p. E 74.

Type species. (By original monotypic designation), *Dictyophyton (Clathrospongia) abacus* Hall, New York State Mus. Nat. Hist., 35th Ann. Rept., p. 478, pl. (18) 19, figs. 2-4, 1884. Waverly group (Mississippian) at Warren, Pennsylvania (*i. e.* Knapp or Corry formation in modern terminology). (Beds of the Waverly group do not occur within the city limits of Warren but their remnants are found to the south and east of Warren).

The following remarks on the genus *Clathrospongia* are taken from Hall and Clarke (1898, p. 121-122):

> Remarks.—This term [*Clathrospongia*] was introduced without definition and was intended to cover, in a subgeneric sense, the species *Dictyophyton abacus,* Hall, which represents a strong development of the erect reticulating surface lamellae such as also occur in the genus *Thysanodictya.* Unlike the species of the latter genus, however, the form of the cup is regularly obconical, and it appears to terminate below in an acute point. There is still some uncertainty in regard to this character,

> but nevertheless the differences in the form of the cups, and the characters of their earlier growth are evident. It has been found necessary in consideration of a number of different species where imperfect preservation has precluded definite knowledge of the basal structure, to refer to this genus some forms which, when better known, may prove to belong in some other association. Indeed, in the type-species only are the generic features clearly defined, and hence the group must for the time being serve in a measure as a convenient receptacle for certain imperfectly known forms.

Clathrospongia abacus Hall, 1884 Pl. 28, figs. 1, 2

1883. *Clathrospongia abacus* Hall, [*nomen nudum*], [title only], American Assoc. Adv. Sci., Proc., (1882), vol. 31, p. 419.
1884. *Dictyophyton (Clathrospongia) abacus* Hall, New York State Mus. Nat Hist., 35th Ann. Rept., p. 474, pl. (18) 19, figs. 2-4.
1898. *Clathrospongia abacus* Hall and Clarke, New York State Mus., Mem. 2, p. 153, pl. 49, figs. 5-8.
1930. *Clathrospongia abacus* Caster, Bull. Amer. Paleont., vol. 15, No. 58, p. 238, pl. 73, figs. 1-3.
1934. *Clathrospongia abacus* de Laubenfels, Treatise on Invertebrate Paleontology, pt. E (Archaeocyatha and Porifera), p. E 74, fig. 56, 2.

Specimens.—The information which follows is based upon a single natural mold of the interior and a latex cast derived therefrom.

Description.—The sponge is medium-sized and turbinate in shape. From an acute (?) base, expansion to the aperture was probably rapid but weathering has destroyed those portions of the cup necessary for detailed description. The nature of the megalosceres is nowhere apparent and is presumed to have been modifications of triaxons characteristically assigned to this group. Dermal spicules and microscleres could not be distinguished.

The prominent longitudinal and transverse spicular strands of the primary reticulum intersect normally at regular intervals and form quadrules which consistently approximate 9 mm. in length and width. The bands themselves, in life, were extended outwardly into free horizontal and vertical projections giving the exterior a fenestrate appearance. According to Hall and Clarke (1898, p. 153) the fenestrations are subdivided into smaller areoles by subordinate reticulating bands but the weathered surface of the specimen under discussion does not show this characteristic.

Fortuitous preservation (see Pl. 28, fig. 2) reveals the existence of a thicker mesoglea than has heretofore been ascribed to this species; the flattened, slit filled, region approximate 3 mm. in thickness. Superimposed upon the interior of this region is the impression of a reasonably well-ordered paragastric reticulum with primary quadrules approximating 8 mm. in length and 5 mm. in width. The primary quadrules are subdivided into meres of the second order. Whether or not the subdivisions of the paragastric reticulum are directly responsible for the subdivisions of the primary reticulum reported by Hall and Clarke (1898) could not be determined.

Dimensions.—The length of the mold approximates 85 mm.; diameter of cup, at upper extremity, 47 mm.; diameter at base 18 mm.

Figured specimens and localities.—

UCM No.	*Type*	*Locality*
34548	Hypotype	103-C

Occurrence.—Collected by K. E. Caster from the basal Corry sandstone at location 103-C. This is the type section for the Corry sandstone.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—The fenestrate primary reticulum and the turbinate shape constitute the outstanding characteristics of the genus *Clathrospongia* Hall. The acute base and lack of a basal diaphragm permit differentiation from its generic homeomorph *Thysanodictya* Hall and Clarke. Species of the genus *Clathrospongia* Hall are apparently distinguished by the size of the cup and the nature of the reticulum. The specimen under discussion compares favorably with *C. abacus* Hall and is, therefore, assigned to that species.

Clathrospongia abacus Hall is readily distinguishable from the obscure Hamilton form *C. hamiltonensis* (Hall) which has irregularly developed primary quadrules measuring 12 mm. on a side (at the median portion of the cup) and distinct nodules at the intersection of the primary bands.

Of the Chemung species *C. fenestrata* (Hall) is subcylindrical, larger (138 mm. length), and nodular at the intersection of the primary bands of the reticulum. *C. vascella* (Hall) is much larger (260 mm. in length) and has primary quadrules measuring 26 × 30 mm. *C. tomacula* (Hall) is subcylindrical and longer than *C. abacus* Hall (135 mm.), the vertical fasicles of the primary reticulum are more strongly developed than the horizontal, and the primary quadrules measure 17 × 15 mm. *C. irregularis* (Hall), like *C. abacus*

Hall has primary quadrules measuring 9 mm. on each side but exhibits nodular development at the intersection of the primary reticular bands. *C. desmia* Hall and Clarke has rectangular quadrules with the horizontal bands of the primary reticulum twice as far apart as the vertical bands.

The Waverly species *C. caprondonta* Hall and Clarke is much longer than *C. abacus* Hall (185 mm. in length) with large primary quadrules measuring 13 mm. in width and 19 mm. in length.

Remarks.—Species of the genus *Clathrospongia* Hall have been reported from the Middle Devonian Hamilton group and the Upper Devonian Chemung group of New York as well as from the Lower Mississippian (Kinderhookian) series of Pennsylvania. The genus itself has never been adequately defined. Hall and Clarke (1898, p. 122), as seen above, considered it "a convenient receptacle for certain imperfectly known forms." Examination of the illustrations in Hall and Clarke (1898) appear to bear out this contention. The vicissitudes of preservation are such that the matter of the presence or absence of a basal disc, which differentiates *Clathrospongia* Hall from *Thysanodictya* Hall and Clarke, seems to be somewhat nebulous. A re-examination of the two genera appears to be in order.

Subfamily **CALATHOSPONGIINAE** Hall and Clarke, 1898

Genus **Ectenodictya** Hall, 1884

1863. *Dictyophyton* Hall, [*pars*], New York State Cab. Nat. Hist., 16th Ann. Rept., p. 87, pl. 4, fig. 6; pl. 5, fig. 1; pl. 5A, fig. 1 [*non* pl. 4, figs. 1-3 *(Thamnodictya)*].
1883. *Phragmodictya* ? Hall, [*nomen nudum*], [title only], American Assoc. Adv. Sci., Proc., (1882), vol. 31, p. 419.
1884. *Dictyophyton* Hall, [*pars*], New York State Mus. Nat. Hist., 35th Ann. Rept., p. 466, pl. (17) 18, fig. 9 [*non* pl. (18) 19, fig. 5 *(Tylodictya)*].
1884. *Ectenodictya* Hall [*pars*], *op. cit.*, pl. (18) 19, fig. 1 [*non* pl. (19) 20, fig. 1 *(Phragmodictya)*; fig. 10 *(Thysanodictya)*].
1888. [*non*] *Dictyophyton* Hinde, British Fossil Sponges, Palaeont. Soc., Mon., vol. 1, pt. 2, p. 126-127, pl. 2, fig. 4.
1898. *Calathospongia* Hall and Clarke, New York State Mus., Mem. 2, p. 155-156.
1898. (?) *Ectenodictya* Hall and Clarke, *op. cit.*, p. 164, pl. 54, figs. 3-4.
1913. *Calathospongia* Zittell, Textbook Palaeontology, vol. 1.
1939. *Calathospongia* Caster, Jour. Paleont., vol. 13, p. 10-12.
1955. *Ectenodictya* de Laubenfels, Treatise on Invertebrate Paleontology, pt. E (Archaeocyatha and Porifera), p. E 73.

Type species. (By subsequent monotypic designation, Hall and Clarke, 1898, p. 164), *Ectenodictya implexa* Hall, New York State Mus. Nat. Hist., 35th Ann. Rept., p. 475, pl. (18) 19, fig. 1, 1884. Waverly group (Mississippian) at Warren and Oil City, Pennsylvania.

The following description of the genus *Ectenodictya* is taken from Hall (1884, p. 466):

> DIAGNOSIS: Discoid, globose, ovoid or irregularly expanding or explanate forms, consisting of a reticulate frond or envelope.
>
> Several species referred to this genus are broadly spreading forms which are flattened, discoid or subovoid in form, sometimes apparently conforming to the sea-bottom and variously infolded or plicated. The reticulation is irregular, presenting radiating and concentric striae which are frequently interrupted and altered in their direction.

Remarks.—Hall (1884) assigned four species to his genus *Ectenodictya (E. implexa, E. expansa, E. burlingtonensis,* and *E. eccentrica)* but failed to designate a type species. Much of the material, by Hall's own admission, was fragmentary.

Hall and Clarke (1898, p. 164), upon re-examination of the original specimens and comparison with newly acquired material, reassigned all but one species of the genus *Ectenodictya* Hall *(E. implexa)* to other genera. The validity of the genus *Ectenodictya* itself was questioned by the co-authors who suggested (1898, p. 158, 165) that the fragments assigned earlier by Hall to *E. implexa* were probably fragments of *Calathospongia redfieldi* (Hall) or *C. carlli* Hall and Clarke. Such a decision would incorrectly render *Ectenodictya* Hall a junior subjective synonym of the genus *Calathospongia* Hall and Clarke, erected by Hall and Clarke (1898, p. 155). The single species *E. implexa* Hall was maintained (*op. cit.*, p. 306) as a dubious species.

De Laubenfels (1955, p. E 73) referred *Calathospongia* Hall and Clarke to synonomy under *Ectenodictya* Hall. It is not known whether the type species *(C. redfieldi* and *E. implexa)* of the two genera were examined before this decision was made.

Ectenodictya carlli (Hall and Clarke), 1898, emend. Pl. 28, fig. 3; Pl. 29, fig. 1; Pl. 30, figs. 1-3

1898. *Calathospongia carlli* Hall and Clarke, New York State Mus., Mem. 2, p. 158; p. 159, fig. 21, pl. 52, figs. 4-7.

1955. *Ectenodictya carlli* (Hall and Clarke), de Laubenfels, Treatise on Invertebrate Paleontology, (Archaeocyatha and Porifera), p. E 73.

Specimens.—The information which follows is based upon a single natural cast of the exterior and a latex mold derived therefrom.

Description.—The specimen is flattened and imperfectly preserved. In life the cup was apparently medium-sized and funnel-shaped with the upper half longitudinally fluted. The base, which is incomplete, appears to have been flat. The maximum diameter appears to have been that of the aperture.

Approximately one-third of the distance from the base, the cup developed a bulge which carries the linear flutings of the distal section. The cup expands rapidly beyond the bulge until what is presumed to be the aperture is attained. The aperture was probably fluted in life.

There is no evidence of nodes (unless the single bulge is so construed) or prismatic faces. The surface is smooth with a well-developed reticular pattern lacking all indication of the nature of the dermal spicules. The primary reticulum is composed of strongly developed transverse bands and thin vertical bands which are only sporadically preserved. The strands of the reticulum were presumably formed by bundles of modified triaxial megloscleres but this fact cannot be verified because of the coarseness of the preservation.

Photographic enlargement of a portion of the primary reticulum (see Pl. 28, fig. 3) reveals some interesting details of composition and distribution. The predominance of the transverse bands is due to their duplicate nature. The paired transverse bands are regularly spaced only near the aperture where the distance between them is about 3.5 mm. Toward the base the distance gradually diminishes and reaches a minimum of 1.3 mm. at the lowest measurable portion of the specimen.

In the concave constricted areas approaching the bulge and adjacent to the convex longitudinal fluting (partially destroyed) the primary reticular net appears to grow more complex by the addition of extra strands, irregularly but generally diagonally disposed with respect to the quadrules. The adventitious strands appear to have served as structural cross-bracing of the constricted and fluted portions of the cup. They are not unlike the diagonal fasicles seen in the skeletons of the extant genus *Euplectella* Owen (1841).

The dimensions of the primary quadrules themselves are difficult to ascertain—principally because of the apparently diffuse and weakly developed longitudinal strands. The quadrules vary in size dependent upon their relative position in the reticulum. Adjacent to the aperture they are approximately 4 mm. square, at the bulge 3 mm. and near the base 2 mm. The primary quadrules are themselves subdivided into meres of at least the fourth order. Whether this subdivision is created by the impression of a well-ordered inner reticulum or actual subsidiary fasicles of the primary net could not be determined.

Microscleres, presumably present in life, could not be found in the specimen under discussion. The spicular bands of the reticulum were probably somewhat fused in the living organism into a dictyine-like skeleton as in *Euplectella*. The regular nature of the fluting suggests that this shape was the normal one and not an accident of preservation as has been sometimes suggested with respect to this and other Paleozoic hexactinellids.

Dimensions.—The illustration shown on Plate 29, figure 1, is × 0.85 natural size. Height of the somewhat-incomplete hypotype about 166 mm.; diameter of the base, 72.7 mm.; diameter of aperture, restored, 125 mm.

Types.—Lectotype [herein designated], *Calathospongia carlli* Hall and Clarke, 1898, New York State Museum-Paleontology No. 58 (= New York State Mus., Mem. 2, pl. 52, figs. 4-5). Collected by J. F. Carll on the flats of Oil Creek near Pleasantville, Venango County, Pennsylvania. [?] Paratype: New York State Museum-Paleontology No. 59 (=New York State Mus., Mem. 2, pl. 52, fig. 6).

Figured specimens and localities.—

UCM No.	*Type*	*Locality*
34549	Hypotype	116-C
	Lectotype	Pleasantville, Pa.
	[?] Paratype	Pleasantville, Pa.

Occurrence.—Collected by K. E. Caster from the basal Corry sandstone at location 116-C.

Discussion.—The genus *Ectenodictya* Hall [= *Calathospongia* Hall and Clarke] is apparently indigenous to the Mississippian; all of the described species have been assigned to rocks of that age. The type species, *E. implexa* Hall, was inadequately described from fragmentary material and, if extant, its repository is unknown. There are, however, some elements of the original description of the genus and species by Hall (1884, p. 466, 475) which merit special attention. These described features include: (1) the irregular nature of the reticulum and the interruption of the concentric striae with accompanying alteration of direction; (2) the presence of protuberances, "not sufficiently elevated to be termed nodes." To the above Hall and Clarke (1898, p. 165) added (3), "the characteristic predominance of the horizontal spicular bands."

Hall and Clarke (1898) frequently referred to the irregularities on the surface of a number of species assigned to the genus as distortions due to crowding or compression. Yet, these irregularities appear to constitute a major characteristic of the genus *Ectenodictya* Hall, the species of which are differentiated on the degree of irregularity of the cup and the nature of the reticulum. Caster (1939, p. 11) suggested that there are two form tendencies in the genus *Ectenodictya* Hall [= *Calathospongia* Hall and Clarke], namely:

> . . . (1) those that have the characteristic form of the genotype *C. redfieldi,* with constricted basal attachment, expanded broadly nodose basal zone, constricted lower neck and broad mesial bulge followed by an upper constricted neck and expanded aperture; and (2) essentially all of the other species attributed to the form genus in which the hourglass shape apparently prevails, *i. e.,* those species with a broadly expanded basal attachment, constricted mesial part and broadly expanded aperture of about the same diameter as the base.

The specimen at hand is presumed to fall into the second category. It appears to have its closest affinities with *Ectenodictya carlli* (Hall and Clarke) [= *Calathospongia carlli* Hall and Clarke].

There is no single illustration given by Hall and Clarke (1898) which corresponds exactly to the specimen under discussion. Figure 21, page 159 (*op. cit.*) exhibits a remarkable resemblance to the gross shape, fluting, basal constriction, and reticulation of the specimen under discussion. Neither the original description (*op. cit.*, p. 158) nor the figures used for illustration delineate the double rows of horizontal strands of the primary reticulum or the diagonal strands so prominent in the specimen studied. These features have apparently been overlooked.

The Hall and Clarke specimens (New York State Museum-Paleontology Nos. 58 and 59) are both labelled "types." The two specimens prove to have less in common than one would be led to expect. No. 58 falls into Caster's second form category and has the characteristic accentuated horizontal reticular bands which Hall and Clarke (1898, p. 156) attribute to the form genus *Ectenodictya redfieldi* (Hall) [=*Calathospongia redfieldi* (Hall)] as well as the diagonal strands described above. No. 59 recalls Caster's first category but shows no size differentiation between the horizontal and vertical reticular bands of the primary reticulum and lacks the diagonal strands. It is much smaller than either the specimen under discussion or No. 58. Details of comparative measurements are given in Table 5 below.

TABLE 5

Comparative measurements of several specimens of the species *Ectenodictya carlli* (Hall and Clarke).

Location	*UCM No. 34549*	*NYSM No. 58*	*NYSM No. 59*
Length	166.0 mm	148.0 mm	86.2 mm
Width at base	72.7 mm	54.3 mm	37.6 mm
Width at top	125.0 mm	150.0 mm	53.8 mm
Width between horizontal reticular bands	3.5 mm	3.5 mm	2.0 mm

The specimen under discussion compares favorably with No. 58 and its identification as *Ectenodictya carlli* (Hall and Clarke) seems justified. Further, since a holotype has apparently never been designated for the species, NYSM No. 58 is so designated as the lectotype. NYSM No. 59 is provisionally named a paratype although further investigation will probably necessitate a change in its specific designation.

At first glance a portion of the specimen figured herein (see Pl. 29, fig. 1) appears to resemble *E. redfieldi* (Hall) but further examination proves this relationship to be an illusion. *E. carlli* (Hall and Clarke) differs from *E. redfieldi* in that it is somewhat broader, lacks the distinct bulge and accompanying sharp constrictions, has primary quadrules which vary in size, is distinctly fluted, and does not exhibit the development of prismatic faces. It lacks the prismatic form, large primary quadrules (10 × 12 mm.), and nodular intersections of the reticular bands of *E. tiffanyi* (Hall and Clarke). *E. carceralis* (Hall and Clarke) has too strongly developed vertical strands of the primary reticulum, a prismatic shape, and too large-sized quadrules (8 × 10 mm.) for a favorable comparison with E. *carlli. E. sacculum* (Hall) has weaker horizontal reticular strands than *E. carlli* and is itself a highly questionable species. *E. tidioutensis* (Caster) has larger primary quadrules (11 × 8 mm.), a bulge similar to that of *E. redfieldi,* and exhibits a stronger development of the vertical fasicles. *E. amphorina* (Hall and Clarke) and *E. magnifica* (Hall and Clarke) are both Keokuk species. The former differs from *E. carlli* by exhibiting prominent vertical spicular strands while the latter has primary quadrules which are far too large (24 × 24 mm.) for favorable comparison.

Remarks.—The question of the examination of the type specimens by De Laubenfels was posed previously. If this has been done and the genera *Ectenodictya* Hall and *Calathospongia* Hall and Clarke are one-and-the-same, it appears that the revival of the generic name *Ectenodictya* constitutes a burdensome nomenclatorial change. Despite its admitted priority the name has not been used since 1898, its type species poorly described, and the type specimen presumed to be lost. *Calathospongia,* to the contrary, has been employed by recent authors (*i.e.,* Caster, 1939) and has the added advantage of having well-documented and available types.

General observations on the "glass sponges."—The description of two specimens can hardly be construed as adequate for generalizations concerning an entire family. Yet, certain descrepancies have been noted in the writer's brief encounter with the Dictyospongiidae. It appears that many of the generic designations of Hall and Clarke (1898) were hastily conceived and based on fragmentary material. A re-working of the entire family would certainly be in order.

In such a project some care should be taken to explore the details of the reticulum more thoroughly. As indicated in the discussion above, reticular bands frequently described as "prominent" may actually consist of two or more bundles of fasicles. Further, it is rarely clear as to the exact meaning of the terms "secondary reticulation" or "subdivisions of the primary reticulum." It is entirely possible, although the walls of the fossil "glass sponges" are generally construed as having been thin, that distinctions can be made between the inner and outer reticula. Further, the so-called "subdivisions" of the primary reticulum, may be due to the impressions of well organized and fortuitously placed spicules of the inner reticulum. This appears to be the case in the brief study made here.

PHYLUM BRACHIOPODA

One has but to read the abbreviated history of the Brachiopoda in Muir-Wood (1955) to appreciate the existing uncertainty of its position in the world of invertebrates. Within the phylum the higher taxonomic categories of the earlier workers are, in the light of modern research, gradually being altered. At the moment, more questions are being asked than answered.

The preliminary classification outlined by Muir-Wood (1955) adequately reflects the present incomplete status of our knowledge with respect to the Brachiopoda. Until the promised revision of the phylum in the Treatise on Invertebrate Paleontology is available, Muir-Wood's classification will provide an interim opportunity for reconsideration; it is the classification used here.

Phylum **BRACHIOPODA** Dumeril, 1806

Class **ARTICULATA** Huxley, 1869

Suborder **RHYNCHONELLOIDEA** Moore, 1952
emend. Muir-Wood, 1955

Superfamily **RHYNCHONELLACEA** Schuchert, 1896

Family **CAMAROTOECHIIDAE** Schuchert and LeVene, 1929

Subfamily **CAMAROTOECHIINAE** Schuchert and LeVene, 1929

Genus **Paraphorhynchus*** Weller, 1905

1855. [*non*] *Rhynconella* Shumard, Missouri Geol. Surv., Ann. Rept. 1-2, pt. 2, p. 204, pl. C, figs. 5a-c [*(Shumardella) fide* Branson, 1938, p. 50]
1868. [?] *Rhynchonella* Meek and Worthen, Geol. Surv. Illinois, vol. 3, p. 450-452, pl. 14, figs. 7a-d [*fide* Weller, 1914, p. 189]

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*The ending *rhynchus* has usually been designated as neuter. The International Commission on Zoological Nomenclature, Declaration 39, 1958 ruled the ending is masculine.

1877. [*non*] *Rhynchonella* Gosselet, Ann. Soc. Geol. Nord., t. 4, p. 314, pl. 3, fig. 4; pl. 4, fig. 5 [*(Camarotoechia) fide* Sartenaer, 1958, p. 2].

1883. *Rhynchonella* Carll, 2d Pennsylvania Geol. Surv., Rept. I-4, p. 305 [footnote].

1887. [*non*] *Rhynchonella* Gosselet, Ann. Soc. Geol. Nord., t. 14, p. 218-221, pl. 3, figs. 14-18 [*(Camarotoechia)*].

1889. *Rhynchonella* Simpson, [*pars*], in Lesley, J. P., 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 892-893, 900-901 [*sc. R. striata* Simpson and *R. medialis* Simpson, 1889].

1889. *Rhynchonella* Rowley, American Geol., vol. 3, p. 116.

1890. *Rhynchonella* Simpson, [*pars*], American Phil. Soc., Trans., vol. 16, p. 444-445, text figs. 9-10 [*non* p. 443, text fig. 8 *(Stenoscisma)*].

1894. [*non*] *Rhynchonella* Keyes, Missouri Geol. Surv., vol. 5, p. 100, pl. 41, fig. 11 [*(Shumardella) fide* Weller, Stuart, 1914, p. 222].

1894. [?] *Rhynchonella (Pugnax)* Hall and Clarke, [pars], New York Geol. Surv., Nat. Hist. of New York, Palaeont., vol. 8, pt. 2, p. 204 [footnote], pl. 60, figs. 33-34 [*non* pl. 60, figs. 23-26 *(Pugnoides)*].

1900. *Pugnax* Weller, Iowa Geol. Surv., Ann. Rept., vol .10, p. 76.

1900. *Pugnax* Weller, Acad. Sci. St. Louis, Trans., vol. 10, p. 72, pl. 2, figs. 16-17.

1901. *Pugnax* Weller, Acad. Sci. St. Louis, Trans., vol. 11, p. 154-156, pl. 13, figs. 14-16.

1905. *Paraphorhynchus* Weller, Acad. Sci. St. Louis, Trans., vol. 15, p. 260-261, pl. 1, figs. 1-15, text figs. 1-7.

1910. [*non*] *Paraphorhynchus* Greger, American Jour. Sci., 4th ser., vol. 29 [p. 73, figs. 1-6 *(Rhynchotreta)*; p. 74, figs. 9-10 *(Rhynchotreta)*: *fide* Weller, 1914, p. 208, 211].

1914. *Paryphorhynchus* Weller, [*nom. correct.*], Illinois Geol. Surv., Mon. 1, pt. 1, p. 187, text fig. 8; pt. 2, pl. 26, figs. 10-28.

1925. *Paryphorhynchus* Van Tuyl, Iowa Geol. Surv., Repts. and Papers, vol. 30, p. 56, pl. 3, figs. 9-10.

1925. *Paraphorhynchus* Branson and Williams, Geol. Soc. America, Bull., vol. 36, p. 217.

1928. *Paraphorhynchus* Moore, Missouri Bur. Geol. and Mines, vol. 21, 2d ser., p. 21, 27, 49, 53, 59, 63, 98.

1929. *Paraphorhynchus* Schuchert and LeVene, Fossilium Catalogus, Animalia, pt. 42, p. 93.

1930. *Paraphorhynchus* Caster, Bull. Amer. Paleont., vol. 15, No. 58, p. 163, pl. 30, figs. 13-22; pl. 32, fig. 18.

1931. *Paraphorhynchus* Laudon, Iowa Geol. Surv., Repts. and Papers, vol. 35, p. 362, 363, 364, 368-369, 392.

1934. *Paraphorhynchus* Caster, Bull. Amer. Paleont., vol. 21, No. 71, p. 123.

1937. *Paryphorhynchus* Nalivkin, Central Geol. and Prospecting Inst., Trans., Fasc. 99, p. 78-82 (Russian), p. 134-162 (English), pls. 11-13.

1938. *Paraphorhynchus* Branson, Univ. Missouri Studies, vol. 13, No. 3, p. 46-48, 166-169, pl. 4, figs. 1-20; pl. 17, figs. 1-5, 15-20; pl. 19, figs. 12-14.

1943. *Paraphorhynchus* Williams, U. S. Geol. Surv., Prof. Paper 203, p. 83, pl. 8, fig. 32.

1944. *Paryphorhynchus* Cooper, *in* Shimer and Shrock, Index Fossils of North America, p. 311, pl. 119, figs. 1-3.

1944. *Paraphorhynchus* Branson, [*pars*], Univ. Missouri Studies, vol. 19 (No. 3), p. 185, 192, 213, pl. 31, figs. 1-5, 15-18, 20 [*non* pl. 31, fig. 19 *(Shumardella)*].

1948. *Paraphorhynchus* Weller, *et al.*, Geol. Soc. America, Bull., vol. 59, p. 113.
1952. *Paraphorhynchus* Roger, *in* Piveteau, Traite de Paleontologie, t. 2, p. 89.
1956. *Paryphorhynchus* Simorin, Akad. Nauk Kazakhstan, SSR, Inst. Geol. Nauk, Alma-Ata, p. 239-244 (Russian), pl. 21, figs. 26-54.

Type species. (By subsequent designation, Schuchert and LeVene, 1929, p. 93); *Paraphorhynchus elongatus* Weller, 1905, St. Louis Acad. Sci., Trans., vol. 15 (No. 4), p. 261-262, pl. 1, figs. 1-5. Kinderhook limestone (Mississippian) on the South Fabius River in the southeastern corner of Knox County, Missouri.

The original description of the genus *Paraphorhynchus* by Weller (1905, p. 260-261) reads as follows:

> DIAGNOSIS: Shell rostrate, or rather large size, coarsely plicate with usually simple plications which extend nearly to the beak, with a deep sinus in the pedicle valve and an elevated fold in the brachial valve of the mature shell. Surface of both valves marked by very fine longitudinal striae [costellae] which increase by bifurcation and intercalation. In the interior of the pedicle valve there is a pair of vertical dental lamellae which support the teeth and extend forward into the cavity of the valve and between which there is a narrow muscular scar. In the brachial valve a strong median septum supports posteriorly a hinge-plate with a cruralium-like cavity, anteriorly each lateral division of the hinge-plate is produced into the cavity of the shell as a crural process, and the median septum also continues forward towards the front of the shell beyond the cruralium-like hinge-plate. Cardinal process wanting. Shell structure fibrous, not punctate.
>
> The members of this genus differ exteriorly from *Pugnax* [Hall and Clarke, 1893] with which they have usually been placed, in the longitudinally striated shell surface, and in the more strongly plicated shell with the plications extending nearly to the beak. Internally the characters of the shell resemble *Camarotoechia* [Hall and Clarke, 1893] rather than *Pugnax*, the strong median septum of the brachial valve with its cruralium-like hinge-plate being absent in the typical forms of *Pugnax*.

Branson (1938, p. 167) included the following observations in his discussion of the genus *Paraphorhynchus* Weller, 1905, based on species from the Bushberg sandstone of Missouri.

> The genus was in process of rapid evolution and every feature of the shell excepting the striae displays numerous differences. The number of plications in the sinus ranges from three to seven. The number of plications on each lateral slope varies from four, two short and almost obsolete, to five long and well defined; from broad and low to sharp crested and high. The beak comes to an almost needle-like point which projects backward in the plane of the valve in some while in others it keeps almost the curve of the rest of the shell and is blunt. The posterior lateral margins range from an angle of 47 degrees from the median line to 90 degrees, from straight to strongly concave. The fold and sinus range greatly in width and height.
>
> The Chouteau specimens [*loc. cit.*, p. 47] vary greatly but the variations depend mainly on age.

Synonomy.—Some authors (*e.g.* Williams, 1943, p. 83) regard the assignment of certain Missouri brachiopods to the genus *Rhynchonella* Fisher de Waldheim (1809) by Meek and Worthen (1868) as the earliest acceptable synonym of the genus *Paraphorhynchus* Weller (1905). Meek and Worthen (*loc. cit.*) disclosed that the previous usage of the generic designation for the species *Rhynchonella missouriensis* by Shumard (1855, p. 204, pl. C, figs. 5a-c), actually represented two species—not various stages of growth as Shumard presumed.

Although favorably impressed with the comparison between Shumard's smaller specimen (*op. cit.*, fig. 5a) and the English species *Rhynchonella pugnus* (Martin), Meek and Worthen were hesitant to place the two in synonomy. They were somewhat confused by Davidson's personal assurance that *R. pugnus* was striated when they could not find the striae on the specimens he had sent them. They (Meek and Worthen, 1868, p. 452) stated:

> Should future comparisons of more extensive collections, however, bring to light good distinctions between the smaller, obscurely plicated and non-striated shell represented by Dr. Shumard's figure 5a, and *R. pugnus*, (Martin) (sp.), we would propose to restrict the name *Missouriensis* to that type, and to distinguish the larger, strongly plicated and distinctly striated shell we have figured, under the name *R. striato-costata.*

It is to be noted that the specific designations put forth in the quotation above were merely suggestions—not direct proposals.

In 1894 Hall and Clarke (p. 202) proposed the subgenus *Pugnax* for species of American rhynchonellids characterized by a trihedral shape and believed to be related to the type species *Rhynchonella loxia* Fisher de Waldheim. Included in the group were the striated species tentatively suggested by Meek and Worthen (1868). In a footnote Hall and Clarke (1894, p. 204) stated:

> The American Carboniferous shells representing the specific type of *R. pugnus*, namely, *R. striato-costata* Meek and Worthen, *R. missouriensis* Shumard, bear a fine radiate-lineate ornamentation, and what might be interpreted as a similar character is apparent in many of Davidson's [1863] figures of the Carboniferous species (Carboniferous Brachiopoda, pl. 22), though this feature is not mentioned in his descriptions.

(Examination of the plate cited above failed to reveal to the present writer the striae which Hall and Clarke presumed to be present.)

The professional stature of Hall and Clarke was such that for many years their assignment of the species of Shumard and Meek and Worthen to the subgenus *Pugnax* was accepted without question. Subsequent authors accorded the subgenus full generic status (*see* synonomy above). This usage, particularly in synonomy with the genus *Paraphorhynchus* Weller (1905), was probably in error since the genus *Pugnax* Hall and Clarke lacks a distinct median septum in the brachial valve and is a rarity in American faunas.

In 1914 Weller (p. 222) placed the species *Rhynconella* [*sic*] *missouriensis* Shumard (1855) in synonomy with his newly created species *Shumardella missouriensis* (Shumard). Shumard's controversial figures 5a-c, discussed above, were cited as examples of the new species. In the same publication Weller (1914, p. 224) erred by again citing Shumard's figure 5a as representative of the species *Shumardella obsolens* (Hall). The duplication was not immediately detected for it remained uncorrected in Schuchert and LeVene (1929, p. 113). Branson (1938, p. 50-51) appears to have rectified the discrepancy by assigning only Shumard's figures 5b-c to the species *Shumardella missouriensis* (Shumard) Weller (1914).

With the assignment of Shumard's figures 5a-c to the genus *Shumardella* Weller (1910), the decision of some authors to relate the same specimens to the genus *Paraphorhynchus* Weller (1905) via the genera *Rhynchonella* Fisher de Waldheim (1809) and *Pugnax* Hall and Clarke (1894) appears to be somewhat questionable; as the synonomy of Williams (1943, p. 83) suggests.

Until 1937 the genus *Paraphorynchus* Weller (1905) was presumed to be limited to specific outcrops of Lower Mississippian strata in the continental United States. In that year Nalivkin (1937, p. 78-82 described nine species of the genus from the Upper Devonian Fammenian sequence of Kazakhstan, S. S. R. Two of these species, *P. triaequalis* (Gosselet) and *P. gonthieri* (Gosselet), were considered to be synonymous with species from the Fammenian of the Ardenne region of France and Belgium which Gosselet (1877/1887) had previously assigned to the genus *Rhynchonella*. Simorin (1956) recognized five of Nalivkin's species, including the two cited above, also in the Fammenian sequence of the Karagandin basin, U.S.S.R.

Examination of the original descriptions and illustrations of Gosselet failed to reveal any justification for the synonomy proposed by Nalivkin and repeated by Simorin. Gosselet (1877, p. 314, pl. 3, fig. 4; pl. 4, fig. 5) neither described or illustrated any characteristics which would lead one to believe that *Rhynchonella triaequalis* Gosselet and *Paryphorhynchus triaequalis* (Gosselet) Nalivkin are comparable. The same can be said for the inferred relationship between *Rhynchonella gonthieri* (Gosselet) Nalivkin (*see* Gosselet, 1887, p. 218-221, pl. 3, figs. 14-18).

The writer's conclusions with respect to the species cited above have been substantiated by the studies of Mallieux (1933) and Sartenar (1958). These authors placed many of Gosselet's species assigned to the genus *Rhynchonella* in synonomy with species they assigned to the genus *Camarotoechia* Hall and Clarke. Sartenar (1958, p. 12-16) is particularly emphatic in noting that Gosselet himself used the species *triaequalis* interchangeably between *Camarotoechia* and *Rhynchonella*. Sartenar's 1958 study resulted in the erection of several new subspecies (*e.g. Camarotoechia nux praenux* Sartenar) with which all or portions of Gosselet's species *Rhynchonella triaequalis* were declared to be synonymous.

While the weight of the evidence may, at present, deny the occurrence of the genus *Paraphorhynchus* in the Upper Devonian Fammenian sequence of France and Belgium, there can be little doubt as to its identification in strata of comparable age in Kazakhstan and the Karagandin basin. In conformance with the criteria presently regarded as valid for the recognition of the genus *Paraphorhynchus* Weller (1905), the identification of the Asiatic species by Nalivkin (1937) and Simorin (1956) is acceptable to the writer. Thus, the genus not only occurs outside of the United States but also in strata older (Upper Devonian) than had previously been supposed.

Orthography.—Between 1905 and 1914 Weller, without explanation, changed the spelling of the genus from *Paraphorhynchus* (1905) to *Paryphorhynchus* (1914). Williams (1943, p. 83) investigated the change and stated:

> G. H. Girty states that he imperfectly remembers that Weller wrote him that he made the change because he had discovered an error in transliteration. The changing of the spelling of generic names on that

basis has been upheld in Opinion 36 of the International Commission of Zoological Nomenclature. However, as *para* is a common combining form and *pary* is not, it seems best to return to the original spelling.

Nalivkin (1937), Cooper (1944), and Simorin (1956) preferred the usage of the prefix *pary*. Caster (1930), Branson (1938), and Williams (1943) employed the prefix *para*. The latter usage is preferred in this paper.

Generic distinctions.—Weller (1905, p. 259) originally established the genus *Paraphorhynchus* for rhynchonelloid shells of large size, with simple coarse plications, having the external surface covered with fine radiating "striae" [=costellae]. The internal structures were presumed to resemble those of the genus *Camarotoechia* Hall and Clarke (1893). These characteristics, Weller believed, were deserving of the generic rank which he accorded them. Such external distinctions are difficult to establish in all but perfectly preserved specimens. Variations in shape concomitant with age, as described by Branson (1938) and cited above, could add to the difficulty of positive identification.

Weller (1905/1914) thought that the rostral portions of both valves of *Paraphorhynchus* were homeomorphic (in internal characteristics) with those of other rhynchonellid genera. In gross aspect he was perhaps correct. However, as will be shown, the genus *Paraphorhynchus* does possess distinct internal morphological features which permit its positive identification to the exclusion of similar appearing genera.

Species of the genus *Camarotoechia* Hall and Clarke (1893), which frequently occur in the same stratigraphic sequence, are most likely to be confused with *Paraphorhynchus* in the absence of well-preserved interiors and exteriors. Hall and Clarke (1894, p. 190) cited crenulations on the dental sockets as a distinguishing internal characteristic of *Camarotoechia*. Holland (1958, p. 171) noted the presence of corresponding serrations on the surface of the teeth of some species of *Camarotoechia,* in addition to those on the dental sockets.

Weller (1914, p. 175), without reference to the crenulations on the teeth and sockets, distinguished *Camarotoechia* from *Paraphorhynchus* and other rhynchonellids as follows:

> The essential generic characters of *Camarotoechia* are found in a combination of the internal and external features of the shell. The median septum of the brachial valve supporting the v-shaped crural cavity [= septalium] and the divided hinge-plate are identical in all essential respects with the rostral characters of *Wilsonia, Liorhynchus, Paryphorhynchus* and *Pugnoides,* the five genera being differentiated one from another by constant external characters. In *Wilsonia* the shell is subcubical in form with plications flattened anteriorly and longitudinally grooved, especially in the fold and sinus. *Liorhynchus* is a larger shell with the plications usually nearly obsolete upon the lateral slopes of the valves. *Paryphorhynchus* also is a much larger shell with the entire external surface of the valves marked by fine radiating striae in addition to the plications, and *Pugnoides* has plications becoming obsolete towards the beak.

Table 6 which follows documents the distinguishing characteristics of *Paraphorhynchus* and other similar appearing, impunctate, rhynchonellids, as currently recognized.

Generic characteristics.—The inverted syrinxlike structure on the floor of the pedicle valve has been previously noted by Weller (1905, p. 260) and Caster (1930, p. 166). Neither author emphasized the importance of the structure as a distinguishing feature of the genus. Its presence in the pedicle valves of all four known species in the Corry sandstone, below, is considered to be significant.

Proof of the existence of such a structure in the mid-continent species and those described in Russia cannot be offered at this time. The descriptions of Branson (1938), Nalivkin (1937), Williams (1943), and Simorin (1956) are chiefly concerned with external characteristics. A single illustration of Branson's (1938, pl. 17, fig. 1) for *Paraphorhynchus transversus* Weller suggests that such a supposed muscle attachment may be present in species other than those described here.

Holland (1958) coined a term, *adductor process,* for a similar structure attached to the delthyrial plate in some cyrtospiriferids. Holland's terminology is herein adopted but modified by the usage of quotation marks to signify that the "adductor process" in paraphorhynchoids lacks attachment to a delthyrial plate.

The "adductor process" thus becomes an important generic characteristic of *Paraphorhynchus* Weller (1905) which distinguishes the genus from all others assigned to the Camarotoechiidae. It is

TABLE 6

Distinguishing characteristics of the genus *Paraphorhynchus* and other plicated rhynchonellid brachiopods [according to Weller (1914) and Roger (1952.)]

Genus	*Characteristics & Range*
Camarotoechia Hall and Clarke (1893).	Contour triangular; angular plicae reaching the dentate frontal margin; dorsal median septum, divided posteriorly to form a septalium the branches of which support a divided hinge-plate; brachial fold and pedicle sinus. Range—Silurian to Lower Permian.
Paraphorhynchus Weller (1905)	Internal characters similar to *Camarotoechia;* mesial fold and sinus well developed; both valves with rounded broad plicae; surface of valves marked by fine, radiating striae. Range—Upper Devonian to Lower Mississippian.
Leiorhynchus Hall (1860)	Internal characters as in *Camarotoechia;* mesial fold and sinus well developed; plicae obsolete on lateral slopes of valves and well developed on fold and sinus. Range—Upper Silurian to Permian.
Pugnoides Weller (1910)	Internal characters as in *Camarotoechia;* rounded or subangular plicae which are obsolete in the posterior portion of the shell. Range—Upper Devonian to Mississippian.
Allorhynchus Weller (1910)	Externally like *Camarotoechia;* brachial valve with divided hinge-plate but no median septum and no septalium. Range—Lower Carboniferous.
Pugnax Hall and Clarke (1893)	Mesial fold and sinus well developed; strong anterior plicae becoming obsolete posteriorly; brachial valve with unsupported divided hinge-plate, no median septum or cardinal process. Range—Devonian to Permian.
Rhynchotetra Weller (1910)	Median septum in each valve; spondylium in the pedicle valve; septalium lacking in the brachial valve; surface with fine radiating striae as in *Paraphorhynchus.* Range—Mississippian to Permian.
Shumardella Weller (1910)	Mesial fold and sinus well developed anteriorly; anterior margin of the sinus linguloid; plicae may be obsolete, strongest development on the fold and sinus; brachial valve with a strong median septum forming a septalium which is short in an antero-posterior direction and entirely closed on the cardinal side; exterior may be marked by coarse radiate striae. Range—Mississippian.

particularly useful in differentiating *Paraphorhynchus* from *Camarotoechia* Hall and Clarke (1893), which Weller (1914, p. 187) declared to be replicas of each other internally.

Internal morphology and preservation.—From the almost complete absence of the brachial valve and the presence of the "adductor process" the writer has reached some tentative conclusions which are admittedly speculative.

Unlike *Camarotoechia,* for which both valves are usually found and which had strong dentition supplemented by crenulations on both teeth and sockets, the teeth and sockets of *Paraphorhynchus* probably served as fulcral points for opening and closing the shell rather than as structures for keeping the valves together. The "adductor process" could have evolved to supplement the other muscular attachments in containing the valves as well as manipulating them.

In life the pedicle valve was apparently partially buried in the sea bottom with its stability augmented by a sizeable pedicle. Upon death the soft parts, presumed to have been delicate, must have disintegrated rapidly permitting the removal of the brachial valve by the action of currents. The disintegration of the soft parts combined with the partial burial of the shell allowed rapid filling of the pedicle valve with sediment. That some sediment entered via the pedicle foramen is substantiated by the merging of the enclosing matrix and the material filling the valve (see Pl. 33, fig. 1).

The subsequent activity of groundwater in the porous sandstone matrix of the Corry is presumed to have removed the carbonate material of the original shell, leaving only the molds of the interior and occasionally the exterior of the pedicle valve. The missing brachial valves could have been carried shoreward and abraded by wave action; their subsequent representation could be in the numerous indistinguishable cavities which occur in eroded fragments of the basal Corry sandstone.

Ecology.—From the representation of the genus studied here and the distribution of species studied elsewhere in North America certain generalizations with respect to the ecological preference of the genus *Paraphorhynchus* Weller (1905), can be made.

Williams (1943, p. 83) reported a single internal mold of a specimen of *P. striatocostatus* (Meek and Worthen) Weller from, "the yellow-brown calcareous mudstone of the [base] of the Louisiana limestone," at Clarksville, Missouri. Weller (1914, p. 189) believed the species *P. transversus* Weller to be, ". . . restricted in its distribution to some of the fine yellow sandstone formations in the Kinderhook at Burlington, Iowa; Washington County, Iowa; and Kinderhook, Illinois." Branson (1938, p. 46-47) records 335 specimens of *P. elongatus* Weller and a few of *P. crenulatus* Branson from the Chouteau limestone near Columbia, Missouri; at other localities the same horizon was apparently barren. From the Bushberg sandstone, between the Louisiana and Chouteau limestones, of Montgomery County, Missouri, Branson also reported numerous specimens of *P. striatocostatus* (Meek and Worthen) Weller, *P. transversus* Weller and *P. bushbergensis* Branson.

Within the limits of the areal distribution of the genus in northwestern Pennsylvania (see Table 3) similar observations were made by the writer. The largest concentrations of individuals of a species are found in the basal Corry sandstone coincidental with the presence of carbonate lentils or heavy concentrations of carbonate cement. Fewer individuals are found in conglomeritic phases or where calcium carbonate is not in evidence in the matrix of the sandstone. The genus has yet to be reported from the medial micaceous siltstone or the upper sandstone members of the Corry.

From the above, the organisms appear to have preferred bottoms characterized by carbonate deposition, been tolerant of sandy or silty environments (providing enough carbonate was locally available) and abhorred pure silts and clays.

Distribution.—Nalivkin (1937) recorded eight definite species of the genus (see Table 7) from northeastern Kazakhstan; seven of these are restricted to the Upper Devonian (Fammenian) Meister and Sulcifer beds. The eighth species, a single specimen of *P. striatocostatus* (Meek and Worthen) Weller, is assigned to the Lower Carboniferous (Tournaisian) Kassin beds which are considered to be Kinderhookian in age. Simorin (1956) describes four of Nalivkin's species from the Karagandin basin; *P. triaequalis* (Gosselet) Nalivkin, *P. gonthieri* (Gosselet) Nalivkin, *P. zobeida* Nalivkin, and *P. fatima* Nalivkin, all from beds of Upper Devonian age equivalent to the Meister and Sulcifer beds.

The lowermost representation of the genus in the mid-continent region is the above mentioned presence of the species *P. striatoco-*

status (Meek and Worthen) Weller, in the basal Louisiana limestone of Missouri. Branson (1938, p. 5) referred the formation to the Devonian but Weller, *et al.* (1948), assigned it as the uppermost member of the Kinderhook Fabius group considered to be Devono-Mississippian in age. The genus is not included in Holland's (1958) study of the brachiopods of the Knapp formation of northwestern Pennsylvania which he (Holland) regards as Lower Mississippian in age. As far as the writer can determine the genus makes its initial appearance in the area of northwestern Pennsylvania in the basal Corry sandstone.

Pending further study, the present distribution indicates the possibility that the genus originated in south-central Asia in the Upper Devonian and subsequently reached North America via routes discussed in the preceding sections. If this presumption is to be ultimately substantiated paraphorhynchoids must be found in the Devono-Mississippian sequences of the western United States and Canada.

Evolutionary trends.—Without detailed study of the types, only general statements concerning the evolution of the genus appear to be in order.

The genus could have evolved from either camarotoechoid or leiorhynchoid stock; the internal and external characteristics of the two groups are similar enough to elicit such comparisons. Details of the distribution known at present, indicate that initial evolutionary changes took place in Asia but the possibility of the independent homeomorphic development of geographically isolated groups cannot be overlooked.

Once established in a particular environment, each group apparently evolved rapidly as Branson (1938, p. 167) indicated. In the species described above some specific modes of change are indicated. *P. girtyi* Caster and *P. casteri*, n. sp., appear to have been near-shore species. As such, living in an environment subject to wave and current action, they exhibit a more rugose external appearance and concomitant changes in the nature of the diductor muscle attachment. The variations in the total number of plicae on each valve (*e.g. P. striatus,* 11-16) may indicate attempts to adjust the water vascular system to changing conditions of sedimentation as suggested for certain spiriferoids by Termier and Termier (1949).

Regardless of the accuracy of the suppositions above, species of the genus were apparently unable to cope with their changing environment and neither in northwestern Pennsylvania or elsewhere survived the end of the Lower Mississippian (Kinderhookian) epoch.

Species differentiation.—No author concerned with the genus *Paraphorhynchus* Weller (1905) has enumerated the principles of specific differentiation. The most commonly used criteria appear to be:

1. Relative size as defined by;
   a. Maximum length of the valves measured as both straight line distance and distance along the curvature of the valve.
   b. Maximum width and its position relative to the mid-point of the line of maximum length.
   c. Ratio of length to width (=shell index).
2. Origin of the sulcus of the pedicle valve with respect to the umbo.
3. External ornamentation, including;
   a. Total number of plicae on each valve.
   b. Number and disposition of plicae on fold, sinus, and lateral margins.
   c. Number of costellae (striae, *auct.*) per mm.
   d. Presence or absence and position of concentric rugosities or growth lines.
4. Internal characteristics;
   a. Generally not well preserved but where present are discussed in terms of the disposition of the pallial sinuses, muscle scars, and ovarian markings.

Table 7 which follows is, in effect, a catalogue of measurements taken from the more lucid descriptions of each of the known species of the genus *Paraphorhynchus* Weller (1905). Measurements of the pedicle valve are emphasized since, with one exception, only this valve is known for the species found in the Corry sandstone.

The information for the Russian species is somewhat limited by the nature of the original descriptions of Nalivkin (1937) and subsequent re-descriptions of Simorin (1956). In many of Nalivkin's descriptions actual linear measurements are omitted. Since the photographic plates carry no mention of scale it was impossible to estimate size from the photographs.

Paraphorhynchus medialis (Simpson), 1889 emend. Pl. 31, figs. 1-10; Pl. 33, figs. 1,2

1883. *Rhynchonella missouriensis* Meek and Worthen, Carll, 2d Pennsylvania Geol. Sur., Rept. I4, p. 305 [*fide* Lesley, 1889, p. 893].
1889. *Rhynchonella medialis* Simpson, [*nomen nudum*], [title only], 2d Pennsylvania Geol. Sur., Rept. O3, p. 257.
1889. *Rhynchonella medialis* Simpson, *in* Lesley, 2d Pennsylvania Geol. Sur., Rept. P4, vol. 2, p. 892-893.
1890. *Rhynchonella medialis* Simpson, American Phil. Soc., Trans., vol. 16, p. 444, text-fig. 9.
1892. *Rhynchonella medialis* Lesley, 2d Pennsylvania Geol. Sur., Final Rept., vol. 2, p. 1494.
1897. *Rhynchonella medialis* Schuchert, U.S. Geol. Sur., Bull. 87, p. 360.
1898. *Rhynchonella medialis* Weller, U.S. Geol. Sur., Bull. 153, p. 534.
1905. *Paraphorhynchus medialis* (Simpson), Weller, Acad. Sci. St. Louis, Trans., vol. 16, p. 259.
1930. *Paraphorhynchus medialis* (Simpson). Caster, Bull. Amer. Paleont., vol. 15, No. 58, p. 163-164, pl. 32, fig. 18; pl. 30, figs. 14, 21.
1934. *Paraphorhynchus mediale* (Simpson), Caster, Bull. Amer., Paleont., vol. 21, No. 71, p. 124.

Specimens.—The description below is based upon 11 natural molds of the interior and two molds of the exterior of the pedicle valve only. The brachial valve is, as yet, unknown. The molds of the exteriors were discovered only after the examination of hundreds of samples collected in the field; they appear to be a rarity. Latex casts of the better specimens were of great value in accentuating morphological details which might have otherwise gone unobserved. All measurements are of necessity "straight line" distances since the molds do not readily lend themselves to measurements along curved planes.

Description.—

Exterior.—The pedicle valve is rostrate and of medium size in comparison with other elements of the brachiopod fauna (*e.g.* *Chonetes vs. Cyrtospirifer*). The maximum width of the valve is always greater than the length and achieves its greatest dimension

TABLE 7

Characteristics of the pedicle valve of typical specimens of known species of the genus *Paraphorhynchus* Weller (1905). (All linear measurements are given in mm.)

Species	*Length*	*Width*	*L/W*	*Origin of Sulcus*	*Plicae in Sulcus*	*Tot. Plicae*
P. elongatus Weller	37.0	28.8	1.3	At mid-valve	4-5	10-14
P. striatocostatus (Meek and Worthen)	25.0	26.0	0.96	At umbo	3-5	9-12
P. transversus Weller	25.0	31.0	0.81	At umbo	4	12
P. striatus (Simpson)	35.0	35.0	1.0	At umbo	5	11-16
P. medialis (Simpson)	25.0	30.0	0.83	At umbo	11	20
P. crenulatus Branson	23.0	25.0	0.92	Anterior of mid-valve	5-7	9-13
P. bushbergensis Branson	18.0	32.0	0.56	Anterior of mid-valve	4-6	10-14
P. girtyi Caster	26.0	29.0	0.89	Anterior of mid-valve	4	10-12
P. triaequalis [?] (Gosselet)	15.5	16.5	0.94	At umbo	2-3	10-11
P. gonthieri [?] (Gosselet)	13.0	14.0	0.93	At umbo	4-5	12-13
P. fatima Nalivkin	10.0	14.0	0.72	At mid-valve	2-5	10-15
P. zobieda Nalivkin	12.0	13.5	0.89	At umbo	1	9
P. zuleika Nalivkin					2-4	8-16
P. badura Nalivkin					3-4	9-12
P. celak Nalivkin					3-6	10-20

anterior of the mid-point of the distance from the beak to the anterior commissure. The shell index (L/W) has an arithmetic mean of 0.82 for the eleven specimens studied.

The valve is generally convex in profile with the greatest convexity near the umbo. In planar view the valve is generally subtriangular. The beak ridges are straight and at the apex of the valve join in an angle which varies from 100° to 120°. The lateral margins are rounded and do not appear to have been extended anteriorly into the marked lingual extension characteristic of other species of the genus (*e.g., P. elongatus* Weller).

The beak is suberect and perforated by a sizeable mesothyrid foramen which, in one specimen, measures 2 mm. in diameter. The umbo is slightly flattened; its entire central portion is occupied by the sulcus which begins at the edge of the foramen. From the umbo the sulcus widens rapidly and occupies at least half of the width of the commissure upon attainment of the anterior portion of the shell. The sulcus is consistently shallow for its entire length.

The surface of the valve is marked by approximately 20 rounded plicae, from 9 to 11 of which occupy the sulcus. The plicae vary in width according to position. The two bounding the sulcus are the largest—measuring 1 mm. in width at the base; the plicae on the lateral margins measure approximately 0.75 mm. and those in the sulcus 0.5 mm. Four of the plicae in the sulcus originate posterior to the umbo, the remainder are intercalated between the others just anterior of the umbo; all are distinct for the entire length of the sulcus. The plicae on the lateral slopes also originate at the foramen but have a tendency to become obsolete anteriorly.

The entire surface of the valve is covered with fine radiating costellae (striae, *auct.*) five of which occupy the space of 1 mm. In addition, angular, elevated, concentric carinae (probably representing growth stages) mark the surface of the valve; they are best developed at the lateral margins of the shell and cross the plicae in the sulcus without loss of definition. The carinae originate at the beak and exhibit a mixoperipheral habit which results in a constriction of the beak.

Interior.—The palintrope is small and interrupted medially by a large, open, triangular, delthyrium the posterior end of which is enlarged by the foramen. Deltidial plates appear to be absent. The sides of the delthyrium are lined by stout, slightly convergent, complete, dental lamellae which form umbonal cavities between themselves and the postero-lateral sides of the umbo. The nature of the dentition could not be determined.

The dental lamellae do not extend beyond the hinge line but elevated, ridgelike, callosities, which appear to originate at their bases, are joined anteriorly of the mid-point of the valve producing a lenticular ridge which surrounds the diductor muscle scar. The diductor scar is deeply incised in the floor of the valve and has a short sulcus at its anterior end which marks the pedicle attachment of the anterior adductor muscle.

Lying between the dental lamellae on the floor of the diductor muscle scar, extending from the rear of the umbo and not quite attaining the anterior limit of the diductor scar, is a sulcate ridge which Caster (1930, p. 166) considered to represent the pedicle attachment for the posterior adductor muscles. (See Pl. 33, figs. 1-2.) The ridge can best be described as resembling an inverted, flattened, syrinx with the seam of the tube depressed to form a sulcus. An analogous structure has recently been described by Holland (1958 thesis) from the pedicle valve of a subspecies of *Cyrtospirifer* he (Holland, 1958, thesis) termed the structure an *adductor process*. However, the adductor process is buttressed against a delthyrial plate—a structure which does not exist in the genus *Paraphorhynchus* Weller (1905).

Ovarian markings are prominent on and adjacent to the elevated ridge surrounding the diductor muscle scar. The vascular sinuses are distinct with one main trunk on either side of the umbo. Each trunk bifurcates anterior to the base of the dental lamellae; if further divisions of the main trunks are effected, the details are not sufficiently clear in the specimens at hand. However, repeated branching does take place with the branches extending toward the lateral margins in what Caster (1930, p. 164) termed as a "pectinate manner."

Dimensions.—Given for figured specimens only. All measurements were taken at their maxima as straight line distances.

Characteristic	*UCM 34554*	*UCM 34555*
Length	24.2 mm	22.3 mm
Width	33.9 mm	27.5 mm
Shell index (L/W)	0.72	0.81
Apical angle	120°	116°
Plicae in sulcus	9	11
Width between bases of dent. lamellae	5.0 mm	6.0 mm

Types.—Holotype [by monotypic designation], *Rhynchonella medialis* Simpson, 1889, Pennsylvania Geol. Surv. No. 9509 (=2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 892, fig. viii-x [?]) deposited at Philadelphia Acad. Nat. Sci. Collected by F. A. Randall from "the Waverly group [Corry] at Warren, Pennsylvania." [Probably either from east of Warren or the hills south of Warren, because no known Corry occurs at Warren, Pennsylvania.]

Figured specimens and localities.—

UCM No.	*Type*	*Locality*
34554	Hypotype	112-C
34555	Hypotype	116-C

Occurrence.—Specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 103-C, 112-C, 116-C, 123-C, 140-C, 214-C, 767-CT, 910-CT, 1565-CT, and 14-S.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—General size, shape, costellation of the surface, and the presence of the "adductor process" mark the figured specimens and others in the writer's collection as paraphorhynchoids. The total number of plicae (20), the number of plicae in the sulcus (9-11), the general configuration of the diductor muscle scar, the character of the vascular system, and general dimensions agree sufficiently with previously described specimens to permit the assignment of the specimens in question to the species *Paraphorhynchus medialis* (Simpson).

With reference to all described American species of the genus, *Paraphorhynchus medalis* (Simpson) appears to have dimensions which compare most favorably with *P. transversus* Weller, but the latter species has only four plicae in the sulcus of a total complement of twelve. *P. girtyi* Caster, despite its favorable shell index (0.89), is a more rugose form with four angular plicae in a sulcus which originates at mid-valve rather than at the foramen. *P. striatus* (Simpson) is generally equidimensional and has only five plicae in the sulcus. The remaining American species differ significantly in one or more external features (see Table 7). All of the Russian species appear to be smaller; none have as many plicae in the sulcus.

Until more detailed descriptions of the internal features of other species are presented the uniqueness of *Paraphorhynchus medialis* (Simpson) will lie in the great number of plicae (9-11) in the sulcus of the pedicle valve. Because this is in keeping with the form criteria originally established by Weller (1905), it appears to suffice for the present.

Remarks.—In the synonomy given above, the reader may have noted the assignment of the date 1889 as the initial date of publication for the species *Paraphorhynchus medialis* (Simpson). Several dates have been used in the literature including, 1888, 1889, and 1890; only 1889 is correct. Simpson originally presented his paper before the American Philosophical Society on December 21, 1888. The paper was not published until 1890 in the Trans. American Phil. Soc., n.s., vol. 16, p. 435-460. On page 440 of the aforementioned volume of the journal, Simpson described and figured his new species *Rhynchonella medialis*. The preceding year (1889) Lesley described and figured *Rhychonella medialis* Simpson, on pages 892-893 of P4 of the Second Geological Survey of Pennsylvania. The description and illustration of Lesley are duplicates of Simpson's published report of 1890. Because the work is obviously that of Simpson he, not Lesley, is credited with the initial publication of the species *Paraphorhynchus medalis* (Simpson) as of 1889.

Paraphorhynchus striatus (Simpson), 1889 emend. Pl. 32, figs. 1-5; Pl. 33, fig. 3

1883. *Rhynchonella missouriensis* Meek and Worthen, Carll, 2d Pennsylvania Geol. Surv., Rept. I4, p. 305 [*fide* Lesley, 1889, p. 893].

1889. *Rhynchonella striata* Simpson, [*nomen nudum*], [title only], 2d Pennsylvania Geol. Surv., Rept. O3, p. 257.

1889. *Rhynchonella striata* Simpson, *in* Lesley, 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 900-901.

1890. *Rhynchonella striata* Simpson, American Phil. Soc., Trans., vol. 16, p. 444-445, text fig. 10.

1892. *Rhynchonella striata* Lesley, 2d Pennsylvania Geol. Surv., Final Rept., vol. 2, p. 1494.

1895. *Rhynchonella striata* Lesley, *et al.,* 2d Pennsylvania Geol. Surv., Final Rept., vol. 3, pt. 1, p. 1688, pl. 125.
1897. *Rhynchonella* (?) *striata* Schuchert, U. S. Geol. Surv., Bull. 87, p. 364.
1898. *Rhynchonella striata* Weller, U. S. Geol. Surv., Bull. 153 p. 535.
1905. *Paraphorhynchus striata* (Simpson), Weller, Acad. Sci. St. Louis, Trans., vol. 16, p. 259.
1930. *Paraphorhynchus striata* (Simpson), Caster, Bull. Amer. Paleont., vol. 15, No. 58, p. 166, pl. 30, figs. 16, 20.
1934. *Paraphorhynchus striatum* (Simpson), Caster, Bull. Amer. Paleont., vol. 21, No. 71, p. 124.

Specimens.—The following description is based upon a collection of twenty natural molds of the interior, a portion of a single mold of the exterior, and latex casts made from the molds. All specimens are of the pedicle valve; the brachial valve is, as yet, unknown. The limitations of measurable dimensions are the same as those which apply to the preceding species *P. medialis* (Simpson).

Description.—

Exterior.—The valve is rostrate, broadly triangular and of medium size (in accordance with the standard previously set). The greatest width of the shell is anterior of the mid-point of the valve and is usually greater than the length. The difference between the two dimensions can vary from 11 mm. to less than 0.1 mm. The shell index (L/W) has an arithmetic mean of 0.76 for the 20 specimens studied.

In profile the valve is convex posteriorly, flattening toward the anterior as the sulcus deepens; the lateral margins retain their convexity. In planar view many specimens are broadly triangular. The beak ridges are generally straight and join at the apex in an angle which varies from 100° to 130°. Anterior of the cardinal extremities, the lateral margins are gently rounded. The beak is suberect and somewhat pointed; the foramen is submesothyrid. The sulcus originates at the umbo widening and deepening gradually as the anterior margin is attained; details of its conformation cannot be further ascertained from the material at hand. Five to six rounded plicae, which originate at the umbo, occupy the sulcus for its entire length. Three plicae are found on each side of the sulcus the largest of which defines the sulcus proper. The extreme lateral sides of the valve are smooth. Fine radiating costellae (striae, *auct.*) originate at the beak and cover the entire surface of the shell. Indistinct, concentric growth lines are also present.

Interior.—The palintrope is small with rounded postero-lateral margins. The delthyrium is triangular and open; there is no evidence of closure by deltidial plates. The deltidium is demarked ventrally by a pair of slightly convergent dental lamellae which are joined to the floor of the valve just anterior of the hinge line, producing a central rostral cavity and two narrow lateral umbonal cavities. Details of the dentition are not apparent.

Between the dental lamellae, extending anteriorly for approximately one-half the length of the valve, an oblong depression marks the site of attachment of the diductor muscles. The scar is bounded by a ridge which originates at the base of the dental lamellae. The anterior portion of the diductor scar is breached by an elongate depression which probably marks the pedicle attachment of the anterior adductor muscles. Posterior to the aforementioned depression, occupying the median portion of the floor of the diductor muscle scar, is an elongate process similar to that described in the pedicle valve of *P. medialis* (Simpson). It lies between the dental lamellae and appears to have attained the posterior wall of the umbo where additional support was provided by the deposition of adventitious shell material. (See Pl. 33, fig. 3.) As in the case of *P. medialis* (Simpson), the resemblance of this process to an inverted syrinx is striking; Holland's term "adductor process", as modified, appears to describe it adequately. As suggested, it probably represents the pedicle attachment for the posterior adductor muscles.

Distinct ovarian markings occupy the lateral slopes of the umbo. Dendritic pallial markings are observed at the lateral margins of the shell but details of their origin are obscure.

Dimensions.—Given for figured specimens only. All linear measurements were taken at their maxima as straight line distances. (The accidental destruction of a portion of UCM 34557 prohibits the citation of exact measurements.)

Characteristic	*UCM 34556*	*UCM 34557*	*UCM 34558*
Length	20.8 mm	?	25.5 mm
Width	21.1 mm	?	30.5 mm
Shell index (L/W)	0.98	?	0.86
Apical angle	120°	110°	120°
Plicae in sulcus	5	5	5
Width between bases of dent. lamellae	4.0 mm	5.5 mm	6.0 mm

Types.—Syntypes, *Rhynchonella striata* Simpson, 1889, Pennsylvania Geol. Surv., Nos. 9,506, 9,507, 9,508 (= 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 900-901, fig. x). Collected by F. A. Randall from the Waverly group [Corry] in the vicinity of Warren, Pennsylvania.

Figured specimens and localities.—

UCM No.	*Type*	*Locality*
34556	Hypotype	116-C
34557	Hypotype	116-C
34558	Hypotype	123-C

Occurrence.—The specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 103-C, 112-C, 116-C, 123-C, 140-C, 214-C, 767-CT, 910-CT, 1565-CT, 14-S, and 19-S.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—The costellate exterior, general shape, size, and the presence of the "adductor process" permit assignment of these specimens to the genus *Paraphorhynchus* Weller (1905). The number of plicae in the sulcus (5-6), general dimensions, and characteristics of the muscle scars compare favorably with the species *P. striatus* (Simpson) as described by Caster (1930, p. 166).

P. striatus (Simpson) has fewer plicae in the sulcus than does *P. medialis* (Simpson); 5-6 *vs* 9-11. It differs from *P. girtyi* Caster by the possession of rounded rather than angular plicae, being less rugose, the conformation of the pedicle attachment of the diductor muscle scar, and in having the sulcus originate at the umbo. Of the mid-continent species *P. striatus* (Simpson) appears to have its closest affinities with *P. striatocostatus* (Meek and Worthen) or *P. transversus* Weller both of which display variations of the exterior ornamentation and measurement that warrant favorable comparison. (See Table 7.) Unfortunately, the details of the muscular impressions of these forms have not been adequately described. Branson (1938, p. 202, pl. 17, fig. 1) did illustrate a pedicle valve of *P. transversus* Weller which suggests that this species also possesses an "adductor process."

P. elongatus Weller, unlike *P. striatus* (Simpson), is always longer than wide. *P. bushbergensis* Branson and *P. crenulatus* Branson, in addition to other distinguishing characteristics, differ from *P. striatus* (Simpson) in that their sulci originate anterior of the mid-portion of the valve. The Russian species described by Nalivkin and Simorin (see Table 7) are all smaller forms; the characteristics of the muscle scars of these species is unknown.

Remarks.—As in the case of *P. medialis* (Simpson), the first published account of *P. striatus* (Simpson) appeared in Report P4 of the Second Geological Survey of Pennsylvania on pages 900-901. The description is a duplicate of the published version of Simpson's original address which did not appear until 1890 on pages 444-445 of the Transactions of the American Philosophical Society, n.s., vol. 16. The date of original publication is, therefore, credited to Simpson as of 1889.

Paraphorhynchus girtyi Caster, 1930 Pl. 32, figs. 6-10, 12; Pl. 33, fig. 4

1930. *Paraphorhynchus girtyi* Caster, Bull. Amer. Paleont., vol. 15, No. 58, p. 165, pl. 30, figs. 15, 17-19, 22.
1934. *Paraphorhynchus girtyi* Caster, Bull. Amer. Paleont., vol. 21, No. 71, p. 124.

Specimens.—The descriptive material below is based upon two specimens: (1) the holotype, a natural internal mold of both valves, (2) a single internal mold of the pedicle valve which compares favorably with the holotype. The exterior of the species is, as yet, unknown. Latex casts were made of both specimens.

Description.—

General appearance.—The shell is rostrate, medium to large, and subquadrate to subtriangular in outline. The form in profile is biconvex with the brachial valve the smaller and more gibbous than the pedicle valve. The cardinal margin is subterabratulid; the anterior commissure uniplicate. As inferred from the molds, the external appearance is presumed to be rugose with heavy plicae and concentric ribbing marked by radiating costellae (striae, *auct.*).

Interior—pedicle valve.—The beak is erect, the valve moderately convex. The greatest convexity occurs at the umbo anterior of which the central portion of the valve flattens to accommodate the sulcus while the lateral slopes retain their convexity to the shell margins. The maximum width occurs anterior of the midpoint and always exceeds the length. The postero-lateral margins are straight and form an angle of 100° at the apex.

The sulcus originates anterior of the umbo and is relatively shallow for its entire length. From its inception it widens rapidly and occupies one-half of the width of the anterior commissure. Four angular plicae are present in the sulcus for its entire length. The lateral margins each have three to four plicae, the largest of which delimits the lateral extent of the sulcus. The posterior and extreme lateral expressions of the plicae are not distinctly preserved.

The palintrope is small with rounded lateral margins; its mesial portion is occupied by a large triangular delthyrium which has a small submesothyrid foramen at its apex. The sides of the delthyrium appear to be moderately restricted by a pair of discrete deltidial plates the details of which are indistinct. Narrow, complete, dental lamellae demark the delthyrium ventrally; the junction of their bases with the pedicle valve does not exceed the margin of the hingeline and effects the formation of two narrow umbonal cavities between their sides and the lateral extremities of the umbo. Details of the dentition are not apparent.

An elevated ridge, originating at the bases of the lamellae and extending anteriorly for one-third of the total length of the valve, surrounds a deeply incised subtrapezoidal diductor muscle scar. Irregular, concentric varices mark the anterior portion of the muscle scar recording, perhaps, stages in the development of the muscles. In the middle of the diductor scar, extending from the posterior portion of the umbo to a position just anterior of the hinge line, lies a syrinxlike "adductor process"; presumed to be the attachment for the posterior adductor muscles.

Ovarian markings are nowhere apparent. The dendritic development of the vascular system is well shown on the lateral portions of the valve but the origin of the system cannot be discerned.

Interior—brachial valve.—The brachial valve is smaller and more inflated than the pedicle valve. The fold originates anterior of the umbo and is distinctive only at the anterior margin of the shell. The surface of the fold has five angular plicae which are deeply marked on the mold of the interior under study. The plicae apparently originate at the umbo and gradually widen as the anterior margin is reached. The lateral portions of the valve each have three well-developed plicae which, like those of the fold originate at the umbo. Observations of the umbonal portions of the valve indicate that the surface was covered with radial costellae. The mold (see Pl. 32, fig. 8) has heavy concentric carinae which give the valve a rugose appearance. At the anterior end, the junction of the carinae and the plicae form a series of chevron-like patterns on the fold.

The beak is recurved ventrally, and protrudes into the delthyrium of the pedicle valve. A well-developed median septum extends from the beak to the center of the valve. The posterior portion of the septum is split and joined to the inner margins of a divided hinge plate forming a triangular cavity (= septalium). (See Pl. 32, fig. 9; Pl. 33, fig. 4.) The hinge plates lie between the dental sockets and the crural bases but the detail of their structure is obscure in the material at hand.

Dimensions.—For figured specimens only.

Characteristic	*Repository Number*	
(Pedicle Valve)	*UCM 34560*	*Paleo. Res. Inst. 5145*
Length	27.0 mm	23.0 mm
Width	30.0 mm	27.0 mm
Shell index (L/W)	0.9	0.86
Apical angle	90°	100°
Plicae in sulcus	4	4
Width between dental lamellae	6.0 mm	6.0 mm
(Brachial Valve)		
Length		21.0 mm
Width		28.0 mm
Shell index (L/W)		0.75
Plicae on fold		5
Length of median septum		13.0 mm

Types.—Holotype. *Paraphorhynchus girtyi* Caster, 1930, Paleontological Research Institute No. 5154 (= Bull. Amer. Paleont. vol. 15, No. 58, p. 165, pl. 30, figs. 15, 17-19, 22). Collected by K. E. Caster from the Corry sandstone at Cobham, Pennsylvania.

Figured specimens and localities.—

Repository No.	*Type*	*Locality*
PRI 5154	Holotype (Mold)	123-C
UCM 34559 (= PRI 5154)	Plastoholotype (Cast)	123-C
UCM 34560	Hypotype	123-C

Occurrence.—The specimens studied were collected by K. E. Caster and the writer from the basal Corry sandstone at locality 123-C.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—The septalium, divided hinge plate, brachial median septum, general size and shape of No. 5154 attest to its camarotoechid affinities. The inferred costellation of the mold and the presence of the "adductor process" in the pedicle valve permit its assignment to the genus *Paraphorhynchus* Weller (1905). The single pedicle valve (No. 34560) compares favorably with the pedicle valve of No. 5154 in the nature of its subtrapezoidal diductor scar, the presence of an "adductor process", the number of plicae in the sulcus (4), and its comparable shell index. No. 34560 is, therefore, assigned to the species *Paraphorhynchus girtyi* Caster (1930).

Paraphorhynchus girtyi Caster differs from *P. medialis* (Simpson) and *P. striatus* (Simpson) by virtue of its excessive rugosity, lesser number of plicae in the sulcus (4), origin of the sulcus at mid-valve, and subtrapezoidal diductor muscle scar. *P. elongatus* Weller, sometimes has four plicae in the sulcus but has a greater length than width. *P. transversus* Weller also has four sulcal plicae but its sulcus, unlike that of *P. girtyi,* originates at the umbo; it is also a less rugose form. *P. crenulatus* Branson is also a rugose form but its rugosity is confined to the postero-lateral margins and it has five to seven plicae in the sulcus.

The Russian species all appear to be smaller forms. In general, both exteriors and interiors are inadequately described. (See Table 7.)

Remarks.—The presence of the "adductor process" (described also for the two preceding species) and the unique form of the diductor muscle scar emphasize the importance of internal morphology in the study of brachiopods. The subtrapezoidal muscle scar which, in part, separates *P. girtyi* Caster from all other species of the genus may exist in the mid-continent or Russian species but thus far has not been documented.

Paraphorhynchus casteri, n. sp. Pl. 32, figs. 11, 13, 14; Pl. 33, fig. 5

Specimens.—The description which follows is based upon the molds of the interior of the pedicle valve of two separate individuals. A latex cast made from a deep mold of the holotype contained, on the reverse side, a portion of the exterior of the valve; thus permitting a descriptive reconstruction of the exterior. Only the holotype is figured.

Description.—

Exterior.—The valve is large, broadly triangular, and rostrate. The maximum width occurs anterior of the mid-point of the valve and is greater than the length. The two dimensions differ from 5 mm. to 8 mm. in the specimens studied. In profile the valve is convex with the greatest convexity occurring at the antero-lateral margins. The beak ridges are straight, converging at the apex at angles which vary from 90° to 100°. From the cardinal margin the lateral extremities are gently curved and form a suberect lingual extension at the anterior commissure.

The beak is erect; the foramen mesothyrid. The sulcus originates at the umbo and is already broad and shallow at its inception. It remains relatively shallow but widens perceptibly as the anterior margin is approached and occupies one-half the linear distance across the anterior commissure. Six to eight large, sharply angular plicae, which originate at the umbo, occupy the sulcus for its entire length, increasing in width toward the anterior of the sulcus. The lateral margins each possess three large, angular, plicae which originate anterior of the umbo. The largest and innermost of the three define the margin of the sulcus. The extreme lateral and postero-lateral margins appear to be nonplicate.

Fine radiating costellae (striae, *auct.*), which originate at the beak (see Pl. 32, fig. 11), cover the shell surface. Coarse, concentric carinae appear at the anterior margin of the shell and disrupt the plicae when crossing the sulcus.

Interior.—The palintrope is small with rounded lateral margins. The delthyrium is triangular with a broad base; it appears to be partially closed by discrete deltidial plates. Details of the structure are lacking. The teeth are supported by weak, thin, dental lamellae which also form small cavities along the lateral margins of the umbo. The lamellae are recessive and do not reach the hinge line of the shell.

A modestly elevated ridge, originating at the base of the dental lamellae, surrounds a weakly impressed ovoid diductor muscle scar, the anterior portion of which does not attain one-quarter of the total shell length. At the posterior end of the diductor scar a weak "adductor process" is present but its structure is obscured by the deeply incised plicae in the sulcus. Details of the reproductive and vascular systems are obscure.

Dimensions.—All linear measurements are straight line distances.

Characteristic	*UCM 34561*	*UCM 34562*
Length	35.0 mm	33.0 mm
Width	43.0 mm	37.0 mm
Shell index (L/W)	0.81	0.89
Apical angle	100°	90°
Plicae in sulcus	6	8
Width between bases of dental lamellae	4.0 mm	5.0 mm

Types.—Holotype, *Paraphorhynchus casteri*, n. sp. 1959, UCM No. 34561 (=herein Pl. 32, figs. 11, 13-14; Pl. 33, fig. 5). Paratype: UCM No. 34562 (not figured). Collected by the writer from the basal Corry sandstone at Sill Run, two and one-half miles southwest of Warren, Pennsylvania.

Figured specimens and localities.—

UCM No.	*Type*	*Locality*
34561	Holotype	116-C

Occurrence.—The specimens studied were collected by the writer from the basal Corry sandstone at locality 116-C.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—The general shape, surface costellation and "adductor process" compare favorably with similar features of the paraphorhynchoids described above. *P. casteri* differs from all previously described species by virtue of its excessive rugosity, number of plicae in the sulcus (6-8), and weakly developed, oval, diductor muscle scar. Its closest affinities are probably with *P. girtyi* Caster which is also a rugose form, but the latter species is smaller, has a subtrapezoidal diductor muscle scar, only four plicae in the sulcus which originates anterior to the mid-point of the valve. (See Table 7 for further comparisons.)

Remarks.—The species is named for K. E. Caster in recognition of his paleontological studies in northwestern Pensnylvania.

Suborder SPIRIFEROIDEA Allen, 1940 emend. Muir-Wood, 1955

Superfamily **Punctospiracea** Cooper, 1944

Family **Spiriferinidae** Davidson, 1884

Subfamily **Syringothyrinae** Schuchert and LeVene, 1929

Genus **Syringothyris** Winchell, 1863

1857. *Spirifer* Hall, [pars], New York State Cab. Nat. Hist., 10th Ann. Rept., Appendix C, p. 170 [*sc. S. carteri* Hall, 1857].
1863. *Syringothyris* Winchell, Philadelphia Acad. Nat. Sci., Proc., vol. 15, p. 6-8.
1867. *Syringothyris* Davidson, Geol. Mag., vol. 4, p. 311-313, pl. 14, figs. 1-11.
1867. *Syringothyris* Meek, Geol. Mag., vol. 4, p. 315-316.
1867. *Syringothyris* Carpenter, Ann. and Mag. Nat. Hist., vol. 20, 3d ser., p. 68-73, figs. 1-3.
1871. *Syringothyris* Winchell, Philadelphia Acad. Sci., Procl., vol. 11, p. 69, f. n.
1871. *Syringothyris* Winchell, Philadelphia Acad. Sci., Procl., vol. 11, p. 252-253.
1888. *Syringothyris* Herrick, Denison Univ. Sci. Lab., Bull., vol. 3, pt. 1, p. 41-42, pl. 1, fig. 7; pl. 2, fig. 17; pl. 5, figs. 4-7.
1890. *Syringothyris* Schuchert, New York State Geologist, 9th Ann. Rept., p. 28-37.
1894. *Syringothyris* Hall and Clarke, New York State Geologist, 13th Ann. Rept., p. 760, pl. 30, figs. 1-11.
1894. *Syringothyris* Hall and Clarke, New York Geol. Surv., Nat. Hist. of New York, Paleont., vol. 8, pt. 2, p. 47-51, pl. 25, figs. 33-35; pl. 26, figs. 6-12; pl. 27, figs. 1-18.
1911. *Syringothyris* Girty, Jour. Geol., vol. 1, No. 6, p. 548-554.
1914. *Syringothyris* Weller, Illinois Geol. Surv., Mon. 1, pt. 1, p. 384-386; pt. 2, pl. 68, figs. 1-15; pl. 69, figs. 1-9; pl. 70, figs. 1-15; pl. 71, figs. 1-7; pl. 72, figs. 1-23; pl. 73, figs. 8-10.
1920. *Syringothyris* North, Geol. Soc. London, Quart. Jour., vol. 76, p. 162-190, pls. 11, 12.
1930. *Syringothyris* Caster, Bull. Amer. Paleont., vol. 15, No. 58, p. 32-35, pl. 26, figs. 2-5; pl. 27, figs. 1-8; pl. 28, figs. 1-12; pl. 29, figs. 1-10.
1937. *Syringothyris* Nalivkin, Central Geol. and Prospecting Inst., Trans., fasc. 99, p. 109-110 (Russian), pl. 33, figs. 1-2.
1938. *Syringothyris* Branson, Univ. Missouri Studies, vol. 13, No. 3, p. 67-68, 174, pl. 6, figs. 5-7; pl. 8, figs. 6-11; pl. 19, figs. 3, 4, 6.
1943. *Syringothyris* Williams, U. S. Geol. Surv., Prof. Paper 203, p. 86-88, pl. 8, figs. 51-58.
1949. *Syringothyris* Termier, H. and Termier, G., Serv. Geol. Maroc, Notes and Mem., No. 74, p. 103-104, text fig. 10.
1953. *Syringothyris* Hyde, Ohio Geol. Surv., Bull. 51, p. 263-280, pls. 27-35.
1955. *Syringothyris* Glenister, Royal Soc. Western Australia, Jour., vol. 39, p. 70-71, pl. 7, fig. 15; pl. 8, fig. 9; text fig. 7.
1956. *Syringothyris* Simorin, Akad. Nauk. Kazakhstan, S.S.R., Inst. Geol. Nauk, Alma-Ata, p. 203-206 (Russian), pl. 18, figs. 5-11.

1957. *Syringothyris* Amos, Jour. Paleont., vol. 31, p. 103-104, pl. 18, figs. 1-7; text figs. 2, 3.
1958. *Syringothyris* Holland, Thesis, Doctor of Philosophy, Univ. of Cincinnati, p. 275-294, pl. 13; pl. 14; figs. 1-11; pl. 15, figs. 8-9.

Type species. By subsequent designation, International Commission on Zoological Nomenclature, Opinion 100, 1928), *Syringothyris typa* Winchell, 1863, Philadelphia Acad. Nat. Sci., Proceedings, vol. 15, p. 6-7. [Not illustrated; first illustrations, loaned by Winchell, appear in Davidson, Thomas, 1867, pl. 14, figs. 1-5] Burlington limestone, Misissippian; Burlington, Iowa.

The often cited, but seldom quoted, original description of the genus *Syringothyris* by Winchell (1863, p. 6-8) reads, in part, as follows:

> DIAGNOSIS: Shell with an elongated hinge-line. Ventral valve with a mesial sinus, a very broad area, and a narrow triangular fissure closed toward the apex by an external, convex pseudo-deltidium, beneath which, and diverging from it, is another transverse plate connecting the vertical dental lamellae, arched above, and beneath giving off a couple of median parallel lamellae, which are incurved so as to nearly join their inferior edges—thus forming a slit-bearing tube, which projects beyond the limits of the plate, from which it originates into the interior of the shell. A low median ridge extends from the beak to the anterior part of the valve. Dorsal valve depressed, without area, with a distinct mesial fold. Shell structure fibrous.
>
> . . . The shell substance is impunctate in all conditions and under high powers.

Synonomy.—Only monographic treatment would accord the genus *Syringothyris* Winchell (1863) the consideration that is its due. Such a study is beyond the scope of this paper. The immediate objective is to accurately describe the species of *Syringothyris, sensu stricto,* in the Corry sandstone and compare them with those recently documented from the Knapp by Holland (1958).

The entries above, which record only a portion of the available literature on this genus, were deliberately selected to: (1) denote the work of authors whose studies on *Syringothyris* will receive further consideration in the text which follows and, (2) demonstrate the world-wide distribution of this genus. With the exception of the work of Hall (1857), all synonomous reference prior to Winchell's designation of the genus *Syringothyris* in 1863, which are largely of historic interest, have been omitted. For accounts of references prior to 1863 the reader is referred to North (1920), Muir-Wood (1951), and Holland (1958).

Winchell's original description of *Syringothyris,* is admittedly inadequate by modern standards. His failure to familiarize himself with the published work of others and to designate a type species for his genus set in motion a controversy which was not settled until 1928 when the International Commission on Zoological Nomenclature (Opinion 100) suspended the rules and declared the type species of *Syringothyris* Winchell to be *Syringothyris typa* Winchell (1863).

Generic distinctions.—Weller (1914, p. 385) summarized the essential generic features of *Syringothyris* Winchell (1863) as: (1) a punctate shell structure [contrary to Winchell's opinion], except in the perideltidial region of the interarea; (2) the absence of plicae on the fold and sulcus; (3) the development of a syrinx attached to the "delthyrial plate" and presumed (herein) to be unsupported by a median septum; (4) the textile-like ornamentation of the external surface; and (5) the high cardinal area (= interarea). He (Weller, *loc. cit.*) remarked, " . . . the distinguishing characters are confined to the pedicle valve, indeed, from the brachial valves alone not even the species can be successfully identified."

Criterion number one, above, had become a cause célèbre much earlier when Winchell (1863, p. 7) said categorically that, "The shell substance [of *Syringothyris*] is impunctate . . ." The issue of the presence or absence of punctae in the shell of *Syringothyris,* reached a heated climax in a series of sharp literary exchanges between King, Carpenter, Meek, and Davidson in 1867. Some unanimity in the affirmative appeared to have been attained in 1867 when Carpenter (the sole dissenter other than Winchell), who had earlier denied the presence of punctae, upon re-examination of shell material sent by Winchell, declared (1867, p. 70) that *S. typa* Winchell (1863) had "perforations" 1/3000 of an inch in diameter set 1/3000 of an inch from each other. Hall and Clarke (1894, p. 47), North (1920, p. 221), and Amos (1957, p. 103) concluded that the presence of punctae constitutes an essential characteristic of the genus; as did Vandercammen (1955, p. 391, *fide* Holland, 1958, p. 281).

The issue, however, is not a simple one, despite the assurances of the authors cited above. Williams, describing *Syringothyris hannibalensis* (Swallow), declared (1943, p. 87), "Punctate shell structure was not seen on any of the specimens examined . . ." Glenister, describing a new species of *Syringothyris, S. spissa,* declared flatly (1955, p. 70), "The shells are impunctate." He (Glenister) refuted the argument that punctae could have been destroyed by silicification in citing the presence of punctae in other genera from the same horizon and stated (*op. cit.*, p. 71),

> It is difficult to believe that a complex structure such as a syrinx could appear simultaneously in two fundamentally different spiriferiod groups (punctate and impunctate). The fact that both punctate and impunctate syrinx-bearing forms do appear simultaneously shows clearly the inadequacy of a classification which accepts the presence or absence of punctae as of primary taxonomic importance. As indicated earlier in this paper, the author is of the opinion that the presence or absence of punctae in the spiriferids is of secondary importance. For this reason it is proposed that the species under discussion [*Syringothyris spissus* Glenister] be assigned to *Syringothyris* and that this genus be expanded to include impunctate forms.

Glenister assigned the genus *Syringothyris* Winchell (1863) to the superfamily Spiriferacea rather than the informally proposed Punctospiracea as Cooper (1944) and Muir-Wood (1955, p. 92) did. Glenister's removal of the genus from the superfamily Punctospiracea was anticipated by Roger (1952, p. 110) who likewise assigned *Syringothyris* to the superfamily Spiriferacea. The writer working only with molds and latex casts, is unable to pursue the matter further. For reasons stated above, the genus is, for the present, left in the superfamily Punctospiracea.

Weller's criterion number two, above, had been anticipated much earlier by Winchell. He (Winchell, 1863, p. 8), speaking of *Syringothyris halli,* declared that the mesial fold and sinus, were "destitute of ribs [plicae]." Hall and Clarke, aware of Simpson's description "of the plicae on the fold and sulcus of *Syringothyris randalli* Simpson (1890), declared (1894, p. 47) that the fold and sulcus of *Syringothyris* were "generally non-plicate."

Schuchert (1910) apparently sided with Winchell and, removing those species of *Syringothyris* with supposedly plicate folds and sulcae from the genus, (*op. cit.*, p. 222) erected the genus *Syringopleura* Schuchert, designating *Syringothyris randalli* Simpson as the type species. The following year Girty (1911, p. 548-553), who examined Simpson's types at the Philadelphia Academy of Science, rejected Schuchert's new genus *Syringopleura* on the grounds that: (1) the plicae were highly imaginative in Simpson's original drawings (1890, p. 441, text fig. 6); and (2) Simpson had confused the valves of *Syringothyris randalli* with those of *Spirifera disjuncta* Hall [=*Cyrtospirifer* sp. Nalivkin, *in* Fredericks, 1926], which do have plicate folds and sulci. Yet Girty (1911, p. 549) did mention "obscure radial markings" in the sulcus of *S. randalli* Simpson.

Weller 1914, p. 384), despite his denial of the existence of plicae on the fold and sulcus, cited above, apparently contradicted himself somewhat when he described *Syringothyris* as having " . . . the fold and sinus well developed and *usually* non-plicate." North (1920, p. 170), Caster (1930, p. 174), Branson (1938, p. 67), and Stainbrook (1943, p. 432) all consider the genus *Syringothyris* Winchell (1863) to be devoid of plicae on the fold and sulcus. More recently Glenister (1955, p. 70), speaking of the pedicle valve of *S. spissa* Glenister, observed:

> A deep, uniformly-rounded sinus is present in the pedicle valve, extending from the beak anteriorly. The sinus is smooth, . . .

Through the courtesy of K. E. Caster the writer was able to obtain photographs of Simpson's types of *Syringothyris randalli* and *S. angulata*. Examination of these illustrations and rubber casts and molds of the writer's own specimens are figured herein (see Pl. 34, figs. 1, 6; Pl. 35, fig. 1). In certain respects it even appears that the fold of the brachial valve of *S. angulata* Simpson may have been faintly costellate. For the remainder of this section of the present work the writer accepts the view that the sulcus and possibly the fold of syringothyroids may be faintly plicate or costellate.

Weller's criterion number three, the presence of the syrinx, received universal recognition even prior to Winchell's formal proposal of the genus *Syringothyris*. However, its manner of growth, form, and function are still uncertain.

Winchell (1863, p. 7-8) considered the syrinx and the "transverse plate" to which it was attached to be modifications of a "false inner deltidium." He did not speculate as to its use. Schuchert (1890, p. 29) recorded the presence of a split tube and a median supporting septum for the species *Syringothyris herricki* Schuchert.

Hall and Clarke (1894, p. 49) proposed that the syrinx may have served to enclose a functionless pedicle rather than serve as the base of attachment for the pedicle muscles as suggested previously by King (1868, p. 18). North (1920, p. 168-170) sagaciously noted that the form of the syrinx was related to the growth stage of the individual and that its earlier formed portion was frequently masked by the deposition of adventitious shell material. Hyde (1953, p. 264) suggested that the presence of a median septum or the partial development of the syrinx represented respectively phylogerontic and phyloneantic stages of growth. He (Hyde, 1953, p. 265) remarked further, that the syrinx remained constant, within limits, for a particular species and that it probably served as an attachment for the adductor muscles rather than the pedicle.

With such a diversity both of opinion and form it is not surprising that the nature and function of the syrinx have remained enigmatic. The writer's study has revealed that while the syrinx, *s.l.*, is significant generically, it is equally important as a specific trait.

The presence of the remaining generic features, the textile-like external ornamentation and the high cardinal area, have always received universal acceptance; it is their function which has been questioned.

The "twilled-cloth" external appearance of *Syringothyris* is distinctive, but the purpose of such ornamentation is unknown. The "twilled-cloth" texture is created by elongate pustules arranged in a chevron-shaped pattern on the crest of each plica.

As for the interarea (= cardinal area, *auct.*), it too displays characteristics of uncertain origin and function. Weller observed, in *Syringothyris,* the tripartite nature of the interarea and stated (1914, p. 384):

> The pedicle valve subsemipyramidal in form, the high cardinal area either flat, concave or convex, differentiated into three regions, a central including the delthyrium, and two lateral . . . .; The central region is distinctly marked by vertical striae, while the lateral regions are marked only by horizontal lines of growth; . . .

This differentiation of the interarea was subsequently noted in other taxa. Dunbar and Condra reported a similar phenomenon in the Orthotetinae and called the vertically striated region (1932, p. 67, text fig. 1) the *perideltidal area.* After duly reporting that the shell lamellae passed unbroken from the perideltidial area to the lateral regions they (Dunbar and Condra, 1932, p. 68) concluded, "The reason for this specialization of the cardinal area is an enigma." Holland (1958, p. 284-286) came to the same conclusion.

From the preceding discussion it appears that the distinctive features of the genus *Syringothyris* Winchell (1863), *s.s.*, should be:

1. Shell structure punctate or impunctate; except in the perideltidial region which is never punctate. (No one has thus far, noted whether punctate forms are endopunctate or exopunctate.)
2. The fold and sulcus *may* display faint plicae, particularly along their lateral margins. This distinction is apparently more common in the sulcus.
3. An unsupported syrinx developed from a transverse subdelthyrial plate, modifications of which take place concomitant with increasing age and the correlated disposition of adventitious shell material.
4. Textile-like ornamentation of the lateral plicae on both valves.
5. High interarea with a vertically striated perideltidial region.

The presence of only part of these features, or modifications thereof have correctly or incorrectly been the bases for the erection of a number of genera. (See Table 8.)

Generic relationships.—With the exception of the syrinx, many of the internal morphological features of the pedicle valve of *Syringothyris* Winchell, *sensu stricto,* are shared by *Cyrtospirifer* Nalivkin (*in* Fredricks, 1926). Comparison of Greiner's plate 7,

TABLE 8

Status of proposed syringothyroid genera.
(Modified from Holland, 1958, p. 294, Table 10, thesis)

Genus	*Distinguishing Features*
Syringothyris Winchell (1863)	Large, high area, textile-like exterior, punctate and impunctate, syrinx unsupported.
Syringopleura Schuchert (1910)	Punctate and impunctate, dental pl. short and thick, syrinx supported [?].
Pseudosyringothyris Fredericks (1916)	Subdelthyrial plate with roller-like callosity with longitudinal furrow.
Prosyringothyris Fredericks (1916)	Bilobed extensions of the subdelthyrial plate lacks 1/2 to 1/3 of a circle of meeting on the underside.
Plicatosyrinx Minato	Impunctate, plicate fold and sulcus, no (?) dental plates or median septum.
Pseudosyrinx Weller (1914)	Punctate and impunctate, without syrinx or subdelthyrial plate.
Asyrinxia Campbell (1957)	Punctate, "textile" surface, high area, alate, 4-6 weak costae in sulcus, perideltidium, no transverse plate or sulcus.
Eosyringothyris Stainbrook (1943)	Impunctate, high area, perideltidium, pustulose exterior, small subdelthyrial plate ends in a short sharp spine.
Septosyringothyris Vandercammen (1955)	Punctate, dental plates short and thick, long syrinx supported by a median septum.
Syringospira Kindle (1904)	Impunctate, high area, granulose surface, fold and sulcus costate, frill on area, blister-like plates in the posterior of pedicle valve, short dental plates, transverse plate without syrinx or delthyrial tube, stegidium.

figures 16-19 (*Cyrtospirifer nucalis* Greiner) with the writer's Plate 35, figures 8-11 (*Syringothyris randalli* Simpson) demonstrates that the two species share in common:

1. Callists, originating on the dental lamellae which seal the delthyrium, in varying degrees, from below.

2. Thick, stout, divergent dental lamellae encircling the muscle field.
3. High cardinal areas (=interarea).
4. Well-defined sulci.
5. *Transverse subdelthyrial plates* [*fide* Holland, 1958, thesis, p. 456 whose usage of the term is herein adopted].
6. Flanges at the lateral margins of the delthyrium.
7. Posterior adductor muscle attachments which Greiner (1957, p. 30) calls, "a spear-like apical boss or callus of secondary growth." [Holland (1958, thesis) calls this process the *posterior adductor process;* his terminology is herein adopted, but modified by quotation marks to differentiate between its attachment to the subdelthyrial plate in cyrtospiriferids as opposed to such a union in *Syringothyris*].

Syringothyris Winchell (1863) can be differentiated from *Cyrtospirifer* Nalivkin (*in* Fredericks, 1926), as follows:

1. *Syringothyris, s.s.,* has a syrinx in the pedicle valve while *Cyrtospirifer* does not.
2. The fold and sulcus of *Cyrtospirifer* are plicate; those of *Syringothyris* only faintly plicate—if at all.
3. The exterior of *Syringothyris* is characterized by plicae which exhibit a "twilled-cloth" texture and do not bifurcate or intercalate; those of *Cyrtospirifer* have spinose micro-ornament and do bifurcate and intercalate.
4. *Cyrtospirifer* has greater total number of plicae on each valve than does *Syringothyris.*

It is the similarities between syringothyroids and other spiriferoids that have prompted a number of writers to postulate the derivation of *Syringothyris* from spiriferoid (*sensu lato*) stock. Hall and Clarke (1894, p. 48) declared, " . . . it is quite safe to assume that this peculiar group of forms [*Syringothyris*] is an outcome from normal development with variation along that [*Spirifer plenus* Hall] spiriferoid line." North (1920, p. 187) re-emphasized this inferred relationship stating:

> In the Devonian rocks of North America there seems to be clear evidence of the evolution of the syrinx. American palaeontologists have

> described a number of species of *Spirifer* in which the fold and sinus are non-plicate, and in which a well-developed apical callosity and transverse plate are seen; as, for example, *Sp. granulosus* Conrad and *Sp. asper* Hall, both from the Hamilton group (Middle Devonian).

Termier and Termier (1949, p. 103) are somewhat more specific, stating [in translation]:

> One places *Syringothyris* in a special family because of the existence of the syrinx . . . Perhaps as Girty thought, according to North (1913), this group had its origin in North America through *Syringospira* [Kindle, 1909] of the Upper Famennien (Conewango). This imperforate form [*Syringospira*] reminds one of *Cyrtospirifer* but it has lost the ribs of the fold; its brachial valve has the same characteristics as *Syringothyris* and further a transverse plate (sub-delthyrial) which bears a median fold which is the forerunner of the syrinx.

Internal morphology and preservation.—In the Corry sandstone conjunct brachial and pedicle valves of the species of *Syringothyris* are seldom found. Apparently this condition does not pertain to all instances of the occurrence of the genus in the Penn-York Embayment, for Holland (1958) has reported locations in the Knapp where complete specimens were collected.

Unlike *Paraphorhynchus* Weller (1905), the brachial valves of which are seldom in evidence, numerous molds of the brachial exterior of *Syringothyris* are found in the Corry in close proximity to molds of the pedicle valves. Attempts to match pairs of valves were unsuccessful. Since there is no way at present of differentiating between the brachial valves of various Corry species, descriptions of complete specimens has not been attempted herein except in the nature of quotations.

The association of separated brachial and pedicle valves of *Syringothyris,* in contrast to the wide dispersal of the two valves of *Paraphorhynchus* for example, is probably attributable to their larger size and weight and similar hydrodynamic quality, hence they were but little moved by currents. As in the case of paraphorhynchoids, it appears that the dentition of *Syringothyris* was weak; the teeth and sockets serving as fulcral points rather than instruments of closure. The universal presence of the heavily striated and deeply incised muscle scars may indicate that these structures, rather than the ineffectual teeth and sockets, were instrumental in keeping the valves together as well as opening and closing them. Whether or not the syrinx played a part in these activities remains a mystery.

The origin of the molds themselves was probably the same as that of the paraphorhynchoids—discussed above.

Ecology.—From accounts of the occurrence of *Syringothyris* in various areas, in addition to that under discussion, certain generalizations relevant to the environmental preference of the genus can be made. Species of *Syringothyris* have been found in almost all of the ordinary sedimentary lithic types:

1. Conglomerate:
   - a. Cobham conglomerate (L. Miss.), northwestern Pennsylvania. (Holland, 1958, thesis, p. 302: *S. angulata* Simpson.)
2. Coquinoid:
   - a. Marvin Creek coquinoid zone of the Knapp (L. Miss.), northwestern Pennsylvania. (Holland, 1958, thesis, p. 301: *S. angulata* Simpson.)
3. Sandstone:
   - a. Bushberg sandstone (L. Miss.), Missouri. (Branson, 1938, p. 174; *S. bushbergensis* Weller.)
   - b. Sistema del Imperial (L. Carb.), Mendoza, Argentina. (Amos, 1957, p. 104: *S. fergulioi* Amos.)
4. Shale:
   - a. Salverton shale (L. Miss. ?), northeastern Missouri. (Williams, 1943, p. 87: *S. hannibalensis* (Swallow).)
   - b. Bedford shale (L. Miss.), Ohio. (Hyde, 1953, p. 268: *S. bedfordensis* Hyde.)
5. Limestone:
   - a. Moogooree limestone (Devono-Miss.), western Australia. (Glenister, 1955, p. 71: *S. spissa* Glenister.)

It would thus appear that species of *Syringothyris* were capable of adapting themselves to a variety of bottom conditions.

Close examination of bulk lithologic specimens reveals that some species of *Syringothyris* are represented by individuals of all but the youngest growth stages. Furthermore, gastropods are frequently found in the same faunule in great numbers and various growth stages, particularly at localities 116-C and 1565-CT. Greiner (1958, p. 58) also noted a similar association at lower stratigraphic levels in the Embayment.

Finally, the occurrences of S. *randalli* Simpson within the basal Corry appear to be limited to the eastern half of the area of investigation (see Table 3 and text fig. 4). This may reflect near shore conditions or even inter-co-tidal association, for the basal Corry member becomes evanescent eastward.

Distribution.—From all accounts the genus *Syringothyris* Winchell (1863), *s.s.*, exhibits a world-wide post-Devonian distribution. Its first appearance appears to be a reliable criterion of Lower Mississippian (Tournaisian) age.

North (1920, p. 221) said of the genus:

> It was initiated in Middle Devonian times, and reached its acme early in the Carboniferous Period. Our knowledge of the pre-Carboniferous history of the genus, is, up to the present, derived entirely from its North American representatives.

More recently Termier and Termier (1949, p. 110) commented [in translation]:

> It is clear that several genera originated in North America and subsequently migrated from this source (*Mucrospirifer* and *Syringothyris* among others).

The remarks above are interpreted as indicating that the authors regard the ancestral stock of *Syringothyris*, not *Syringothyris*, *s.s.*, itself, to have evolved in pre-Mississippian times. There are no unquestioned occurrences of *Syringothyris* in beds of pre-Mississippian age.

Glenister (1955, p. 47) discounts occurrences of the genus from the Permian of India, Spitzbergen, and Australia which are reported by Maxwell (1954, p. 41-42).

Evolutionary trends.—The syrinx, which characterizes the genus, is a useful tool for specific differentiation. Although North (1920, p. 206) said in commenting on *Syringothyris*, "The two structures, a median septum and a syrinx-bearing transverse plate, could not coexist in the same shell, since they would mutually interfere one with the other," the fact remains that in the Corry sandstone syringothyrids with and without a median septum supporting the syrinx do occur side-by-side. Whether one form evolved from the other is difficult to determine because of our lack of knowledge of the function of the syrinx. The possibility exists that the syringothyroids as a group may be diphyletic, with coeval and coetaneous septate and nonseptate forms evolving from different stocks.

There are, in addition to modifications of the syrinx, two other factors which may have evolutionary significance. These apparently related factors are: (1) the modification of the dental lamellae, and (2) the deposition of callist shell material in the posterior of the pedicle valve.

Through the medium of secondary deposition on and around the dental lamellae, they become thick and stout. Additional callists from the lamellae, more or less restrict the delthyrial opening and augment and change the shape of the subdelthyrial plate and its syrinx. In like manner, perhaps for better balance, callist deposits fuse portions of the syrinx and the "posterior adductor process." The posterior wall of the lateral cavities bear callists which could also have been deposited as "ballast" in forms with an ineffectual pedicle and no apparent substitute mode of attachment.

Specific distinctions.—If the features enumerated above characterize the genus, how then, are species of *Syringothyris* Winchell to be distinguished from one another? Weller (1914, p. 385-386) discussed this problem as follows:

> The essential specific characters are found in the pedicle valve and consist in the proportional height of the cardinal area, its degree of curvature, whether flat, concave, or convex, and especially in the size of the angle between the flatter portions of the area and the plane of the valve, this angle varying among different species from 25 to 110 degrees or more, but being fairly constant among different individuals of the same species. Another set of characters which seem to be of prime importance in specific differentiation are the characters of the delthyrial plate [= syringal plate = subdelthyrial plate = transverse plate, *auct.*] and syrinx. In all those species where a sufficient number of individuals have been observed showing these characters, they seem to be constant within reasonably narrow limits of variation, and they have been assumed to be of good specific value in other forms in which they have been observed sometimes in but a single individual; the different characteristics of this plate are shown in its transverse contour externally, whether flat, concave or longitudinally keeled, and in the length and width of the free extension of the syrinx.

No other writer has attempted such a summary, although others have incorporated its essence in their own descriptions of syringothyroid species. While these factors are important, there are others, occasionally touched upon in the literature, which may prove to be of great value in making specific determinations: (1) the disposition of secondarily deposited shell material in and around the posterior portion of the pedicle valve; (2) the nature of the closure of the delthyrium; (3) the development of the dental lamellae throughout progressive stages of growth; and (4) the nature of the "ovarian markings."

North (1920) remarked that the amount of callist material in the apical portion of the pedicle valve of syringothyroids increased in proportion to the age of the individual. Hyde (1953) demonstrated that "testaceous deposits" could and did mask various features of the internal morphology of *Syringothyris*. Neither author pursued the matter any further. It has been found that callist or "testaceous" material is deposited in a manner indigenous to a particular species and may be employed in specific taxonomy.

The closure of the delthyrium and the nature of the dental lamellae appear to have a direct relationship. The delthyrium is commonly described as being restricted by the growth of a structure variously called the "pseudodeltidium," stegidium, or xenidium. Whatever the terminology used, the structure usually occurs on the dorsal side of the delthyrium. The writer's observations have revealed that partial closure of the delthyrium is also effected on the ventral side by the development of callist material related, as is the subdelthyrial plate and the syrinx, to the dental lamellae. (See Pl. 34, figs. 3-4; Pl. 35, figs. 8-10.) Like other "testaceous" material, this *ventral delthyrial plug* appears to have value in specific determinations. Greiner (1957, p. 20) noted a similar structure in the cyrtospiriferids but referred to it simply as a "secondary growth." (See Greiner, 1957, pl. 7, figs. 16, 17, 19.)

"Ovarian markings" also appear to have patterns of value in making specific determinations. (*Compare* Pl. 34, fig. 4 and Pl. 35, fig. 9.)

Syringothyris angulata Simpson, 1890 emend. Pl. 34, figs. 1-8

1889. *Syringothyris angulata* Simpson, [*nomen nudum*], [title only], 2d Pennsylvania Geol. Surv., Rept. 03, p. 258.

1890. *Syringothyris angulatus* Simpson, Lesley, 2d Pennsylvania Geol. Surv., Rept. P4, vol. 3, p. 1150, figs. numbered 1-3.
1890. *Syringothyris angulata* Simpson, American Phil. Soc., Trans., vol. 16, p. 440, fig. 5 [figs. numbered 1-3].
1890. *Syringothyris angulata* Schuchert, New York State Geologist, 9th Ann. Rept., p. 32.
1894. *Syringothyris angulata* Hall, and Clarke, Nat. Hist. New York, Paleont., vol. 8, pt. 2, p. 50, pl. 27, figs. 14-15.
1898. *Syringothyris angulatus* Weller, United States Geol. Surv., Bull. 153, p. 619.
1930. *Syringothyris angulata* Caster, [*pars*], Bull. Amer. Paleont., vol. 15, No. 58, p. 32-35, pl. 26, figs. 2, 4-5; pl. 27, figs. 1-3; pl. 28, fig. 9; pl. 29, figs. 1-8 [*non* pl. 27, figs. 4, 6-7; pl. 28, figs. 1-8, 10-12; pl. 29, figs. 9-10 (*Syringothyris randalli* Simpson)].

Specimens.—The information which follows is based mainly upon six natural molds of the interior of the pedicle valve and the latex casts derived therefrom. Descriptive reconstruction of the exterior of the brachial and pedicle valves are based upon illustrations of Simpson's types. Examination of hundreds of rock specimens failed to disclose a single example of *S. angulata* Simpson with the two valves attached. Separate brachial valves could not be identified as to specific affiliation. As mentioned above, Weller (1914, p. 385) denied the importance of the brachial valve in the identification of species and describes the interior simply as "essentially as in *Spirifer*." Measurements are given only for the interarea since the extremities of the molds are frequently masked by the enclosing matrix.

Description.—

General appearance.—The shell is generally medium to large-sized and spiriferiod in shape. The form in profile is biconvex. The interarea of the pedicle valve is large and that of the brachial valve insignificant. In planar view the cardinal margin is megathyrid; the anterior commissure uniplicate. The lateral margins of both valves possess radial plicae which exhibit a "twilled-cloth" texture. The fold and sulcus may possess faint plicae, particularly at their lateral extremities.

The brachial exterior.—(See Pl. 34, fig. 6.) The cardinal margin is straight and equal to the greatest width of the shell. The greatest convexity occurs along the median line of the valve and is accentuated at the umbo. The fold appears to originate at or posterior to the umbo and increases in both breadth and height anteriorly.

From the mold the crown of the sulcus appears to bear faint radiating costellae. The lateral slopes of the valve each bear 18-20 radiating subangular plicae which originate at the beak and neither bifurcate or intercalate. The plicae appear to be narrower and less distinct toward the posterior margin.

The surface of the valve bears irregularly disposed concentric carinae which are faint near the posterior margin of the shell and deeply incised at the anterior margin. It is assumed that the exterior exhibited the "twilled-cloth" appearance.

The brachial interior.—For this description the writer is indebted to Holland (1958, thesis, p. 299) who said:

> The cardinalia are strong and spiriferiod. Wide sockets, which narrow posteriorly, are excavated in the strong, pendant socket plates and bounded by high heavy inner socket ridges. The cardinal process is a low vertically striate area nearly flush against the posterior wall of the valve. Below this is commonly developed a low, broad, nearly vertical median ridge or buttress at the posterior of the valve. Lateral branches of this ridge may connect with the socket plates or these plates may hang free. In some specimens this vertical posterior buttress is produced anteriorly as a short low median septum. Interior markings obscure. Details of the spiralia not known.

The pedicle exterior.—The valve has a high interarea which may be orthocline to apsacline and slightly recurved at its apex. The greatest width of the shell is at the cardinal margin which is coincident with the hinge line.

In profile the valve is generally convex, flattening somewhat anteriorly; the lateral margins retain their convexity. The beak ridges are gently curved and join at the apex at an angle which approximates 120°. Anterior of the cardinal extremities, the lateral margins are gently rounded.

The sulcus apparently originates at or near the umbo and gradually widens anteriorly but always remains shallow and somewhat indistinct. Although generally considered to be nonplicate, impressions on the molds of the interior show a few faint plicae at the lateral and anterior margins of the sulcus. (See Pl. 34, figs. 1, 8.) The plicae on the lateral slopes of the valve are indistinct in the specimens at hand but apparently are similar in conformation and distribution to those of the brachial valve.

Pedicle interior.—The interarea is large and gently concave; it is interrupted mesially by a large triangular delthyrium the length of which is greater than its maximum width. There is no indication, on either mold or latex cast, of a perideltidial area. The lateral margins of the delthyrium are marked by elongate narrow flanges for their entire length. From the apex to approximately 2/3 of its length the delthyrium is covered by what appears to be a single convex plate, the edges of which are welded to the bordering flanges. This is probably the "pseudodeltidium" of various authors but neither mold nor cast exhibit sufficient detail for further comment here. The "deltidial plate" frequently shows on molds of the interior as a narrow horizontal slit just below the mold of the upper surface of the delthyrium. The posterior portion of the deltyrium appears to have been plugged with callist deposits.

The lateral margins of the delthyrium are delimited ventrally by stout, complete, divergent dental plates which, in joining the floor of the valve, divide the posterior margin of the pedicle valve into a central rostral cavity and two lateral cavities. The bases of the dental lamellae extend beyond the hinge line as a pair of elevated sinuous ridges which join near the anterior margin of the shell forming an oval-shaped arena which surrounds the muscle scars. (See Pl. 34, figs. 3-4.)

A pair of striated diductor muscle scars occupy most of the floor of the oval-shaped arena and exhibit a curious serration at their lateral extremities. A long, thin, bilobed anterior adductor scar occupies the central-anterior portion of the muscle scar area. Its postero-central region has a thick, bilobed, "posterior adductor process" the median sulcus of which displays elongate striae. The "posterior adductor process" appears as an elongate "wrinkly" area in the midst of the triangularly shaped mold of the posterior wall of the rostral cavity; it *never* attains the summit of the mold. (See Pl. 34, figs. 1, 2, 5, 7, 8.)

A number of structures, critical for syringothyroid identification, are derived from the upper extremities of the dental lamellae. At the juncture of the dental lamellae and the lateral margins of the delthyrium, callist deposits develop which grow inward and partially restrict the delthyrial opening from below (see Pl. 34, figs.

3, 4). These deposits are genetically related to the dental lamellae, fused to the edges of the delthyrium but are not conjunct, and appear to have value in making specific determinations, as indicated previously.

Slightly below the cardinal margin an inverted "shoehorn-like" process (=*subdelthyrial plate*) is suspended between the dental lamellae. It is dorsally convex or flattened dorso-ventrally, and projects slightly anterior of the cardinal margin and the dental lamellae. If it is formed by conjunct lateral plates the suture is not apparent on mold or cast. On the underside of the projected area two processes, originating at its lateral margins, curl inward and form an open tube or syrinx. The open portion of the syrinx bears elongate striae; there is no evidence of a median septum contributing to its support.

On the underside of the interarea, in the lateral cavities, the latex casts show elevated, elongate regions adjacent to the delthyrium. Upon examination of the molds they proved to be elongate "tear-drop" impressions, more deeply incised than the casts would indicate. They may represent callists in the living organism. Scattered ovarian markings are also faintly represented in the posterior extremities of the lateral cavities.

Due to the nature of preservation of the material at hand the nature of the dentition, vascular system, and the presence or absence of punctae could not be determined.

Dimension.—Given for only those figured specimens in possession of the writer and taken largely from latex casts.

Characteristic	*UCM 34563*	*UCM 34564*
Apical angle	120°	120°
Delthyrial angle	40°	40°
Height of delthyrium	16 mm	14 mm
Width of delthyrium	7 mm	7.5 mm
Length of cardinal margin	39.5 mm	37.5 mm

Type.—Lectotype [herein designated, Holland and Sass], *Syringothyris angulata* Simpson, 1890, Academy of Natural Sciences of Philadelphia. No. 3535 (=American Phil. Soc., Trans., n.s., vol. 16, p. 440, fig. 5, specimen number 3). Collected by F. A. Randall from the Pocono (Waverly) formation X. at Warren, Pennsylvania. [Probably from the Kushequa shale, *fide Holland,* 1958, thesis, p. 299.]

Figured specimens and localities.—

Repository No.	*Type*	*Locality*
UCM		
34563	Hypotype	116-C
34564	Hypotype	116-C
Phil. Acad. Sci.		
9535	Lectotype	Warren, Pa.
9533	Paratype	Warren, Pa.
9538	Paratype	Warren, Pa.

Occurrence.—Specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 116-C, 113-P, and 90-P.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—The presence of an unsupported syrinx, the faintly plicate fold and sulcus, the "twilled-cloth" appearance of plicae which neither bifurcate or intercalate, and the high cardinal area all mark the specimens on hand as species of the genus *Syringothyris* Winchell (1863), *sensu stricto.* General shape, character and position of the impression of the "posterior adductor process" on the mold of the posterior wall of the rostral cavity (*cf.* figs. 1-2, Pl. 34 and figs. 5, 8, Pl. 34), and the mold of the subdelthyrial plate and syrinx, permit assignment of these specimens to the species *Syringothyris angulata* Simpson. The presence of the dorsally convex "shoehorn-like" subdelthyrial plate and its subtended syrinx mark this species as unique among American syringothyroids. The question of its supposed synonymous relationship with *S. randalli* Simpson will be considered in the discussion of that species.

Remarks.—The exact date of publication of *S. angulata* Simpson is difficult to establish. The species, originally presented orally in 1888, appears in 1890 in two different publications as noted in the specific synonomy above. Lesley (2d Pennsylvania Geol. Surv., Rept. P 4, p. 1150) used Simpson's wording in his description. Since Simpson was no doubt responsible for the original description he is awarded authorship of *S. angulata* as of 1890.

Syringothyris randalli Simpson, 1890 emend. Pl. 35, figs. 1-11

1889. *Syringothyris randalli* Simpson, [*nomen nudum*], [title only], 2d Pennsylvania Geol. Surv., Rept. 03, p. 258.

1890. *Syringothyris randalli* Simpson, *in* Lesley, 2d Pennsylvania Geol. Surv., Rept. P4, vol. 3, p. 1150-1152, fig. 6 [illustrations numbered 1-2].

1890. *Syringothyris randalli* Simpson, American Phil. Soc., Trans., vol. 16, p. 441-442, fig. 6 [illustrations numbered 1-2].
1890. *Syringothyris randalli* Schuchert, New York State Geologist, 9th Ann. Rept., p. 36.
1894. *Syringothyris randalli* Hall, and Clarke, New York State Geologist, 13th Ann. Rept., pl. 30, figs. 10-11.
1894. *Syringothyris randalli* Hall, and Clarke, [*pars*], New York Geol. Surv., Nat. Hist. New York, Palaeont., vol. 8, pt. 2, p. 50, pl. 27, figs. 13, 16-17 [*non* pl. 27, figs. 14-15 (*Syringothyris angulata*).]
1898. *Syringothyris randalli* Weller, U. S. Geol. Surv., Bull. 153, p. 621.
1910. *Syringopleura randalli* Schuchert, American Jour. Sci., vol. 30, 4th ser., p. 224.
1911. *Syringothyris randalli* Girty, Jour. Geology, vol. 19, No. 6, p. 548-554.
1920. *Syringothyris randalli* (Simpson) [?], North, Geol. Soc. London, Quart. Jour., vol. 76, p. 190.
1934. *Syringothyris randalli* Caster, Bull. Amer. Paleont., vol. 21, No. 71, p. 71.
1939. *Syringothyris texta* (Hall), Willard, Pennsylvania Geol. Surv., ser. 4, Bull. G 19, pl. 22, fig. 8.
1953. *Syringothyris randalli* Hyde, Ohio Geol. Surv., Bull. 51, p. 277-278.

Specimens.—The morphological descriptions which follow are based primarily upon five accessioned specimens in the writer's possession. With a single exception (a mold of the exterior of the pedicle valve), all are molds of the interior of the pedicle valve. In addition, dozens of poorly preserved specimens were observed in the course of the preparation of material collected in the field. Comparisons were also made with photographs of Simpson's type, furnished by K. E. Caster.

Although numerous examples of "apparent" syringothyroid brachial valve molds were found, none were joined to an undoubted pedicle valve of *Syringothyris randalli* Simpson. For this reason, and the fact that Simpson's (1890, p. 441) description of the brachial valve may have been based upon a crytospiriferid valve (*fide* Girty, 1911, p. 550), no attempt is made herein to give a descriptive reconstruction of the brachial valve of this species.

Because the matrix surrounding the molds masks the extremities of the valve, measurements are given for the interarea only.

Description.—

The pedicle exterior.—The valve has an interarea which is generally apsacline and gently concave. Its greatest width is at the cardinal margin which is coincident with the hinge line.

The profile is convex, both longitudinally and transversely with the maximum convexity centered at the umbo. The beak ridges curve gently and join at the apex of the valve at an angle which approximates 120°. Anterior of the cardinal extremities the lateral margins are gently rounded.

The sulcus originates at the beak, gradually widening and deepening as the anterior margin of the valve is attained. While the single cast of the exterior on hand does not exhibit plicae in the sulcus; the photograph of Simpson's holotype does (see Pl. 35, fig. 1). The lateral slopes of the valve are each occupied by 15 plicae which originate at the posterior margin of the valve. The plicae tend to be less distinct near the cardinal extremities; all exhibit the characteristic "twilled-cloth" texture.

Pedicle interior.—The concave interarea is divided mesially by a large triangular delthyrium, the length of which exceeds its maximum width. The perideltidial area is not apparent on either mold or cast. The lateral margins of the delthyrium are sculptured by elongate narrow flanges for their entire length. There is no direct evidence for closure of the delthyrium by deltidial plates of any kind. Occasionally, certain molds suggest the existence of such closure near the apex of the delthyrium but this feature, if existent, defies reproduction by the method of making casts herein employed.

The edges of the delthyrium are sutured to thick, complete, divergent dental plates which in joining the floor of the pedicle valve create a central rostral and two lateral cavities at the posterior extremity of the valve. The bases of the dental lamellae extend anteriorly in a lingual pattern to the mid-point of the valve, falling short of complete coalescence (see Pl. 35, figs. 10-11). The area so defined encloses the muscle scars.

The central portion of the muscle field is characterized by an elongate "anticlinal ridge" which marks the position of the deep median sulcus. The diductor muscle scars occupy all of the lateral portions of the muscle field and transgress the sides of the median ridge. They (the diductor muscle scars) bear overlapping striae of two kinds: (1) curved, elongate striae parallel to the sides of the muscle field; and (2) striae at the posterior portion of the muscle field, diagonally disposed to its sides, converging towards the center of the elongate ridge—but not attaining it. (See Pl. 35, figs. 6-7.) A long bilobed, "posterior adductor process" with a median sinus occupies the postero-central portion of the muscle field at the summit of the elongate ridge demarking the sulcus (see Pl. 35, figs. 9-11). At its posterior margin the "adductor process" frequently appears to be thickened by secondary deposition of shell material. Its impression on the mold of the posterior portion of the rostral cavity is extremely deep and all but intersects the mold of the syrinx (see Pl. 35, figs. 2, 3, 5-7).

As in the case of *S. angulata* Simpson, a number of structures appear to be derived from the deposition of callist material at the upper extremities of the dental lamellae. Accretion of such material at the juncture of the dental lamellae and the lateral margins of the delthyrium completely closes the delthyrium from its apex for about 2/3 of the total length, leaving no evidence of a pedicle opening of any kind. Viewed from above the callists have the appearance of conjunct triangular deltidial plates. However, the mold of the dorsal surface of the delthyrium exhibits sutures which leave no doubt as to their relationship to the dental lamellae (see Pl. 35, fig. 7-9). It is quite possible that these conjunct callists are responsible for the frequent reference to the "pseudo-deltidium" supposedly closing delthyrium.

Below the callists mentioned above, the dental lamellae are connected by a thin transverse subdelthyrial plate which gives no indication of having formed from the fusion of two separate lamellae. The mesial portion of the underside of the subdelthyrial plate gives rise to a pair of processes which curl ventrally while simultaneously extending forward slightly beyond the hinge line and create an elongate tubelike process or syrinx. The two lateral processes are not fused mesially, for the ventral side of the syrinx bears an elongate, striated slit. The syrinx is unsupported for 9/10 of its length (see Pl. 35, fig. 9). At its posterior margin the syrinx is thickened by a callist deposit which fuses it to the posterior margin of the "posterior adductor process." In mature individuals the anterior face of the fused callists joining the posterior portions of the syrinx and the "posterior adductor process" is marked by a slender sinus connecting the mesial sinus of the adductor process to the slit on the underside of the syrinx. This connective sinus frequently occupies a slender vertical ridge which faintly resembles a weak median septum. The slender, sinus-bearing ridge however, is not found in individuals at the neanic growth stage. In fact, there is some indication, from a few poorly preserved molds, that the syrinx may form initially even without the support of the subdelthyrial plate. This observation cannot be adequately substantiated at the moment.

In the molds of the interior of specimens on hand, the posterior margins of the lateral cavities are marked by peculiar "tear-drop" depressions which lie with their blunt ends adjacent to the margins of the rostral cavity. These positive representations of the depressions are not readily discernible in casts made from the molds. The depressions appear to be characteristic of this genus for they are represented in the holotype as well as the writer's specimens. (*Compare* Pl. 35, figs. 2-3 with Pl. 35, figs. 5-6.) They probably represent the impressions of callist deposits.

The posterior half of the valve, from the underside of the interarea to the anterior edge of the muscle scar, bears markings of two types (see Pl. 35, figs. 8-9). The first type is expressed as a series of concentrically disposed pits which have frequently been interpreted as "ovarian markings." The second type appears as a series of *en échelon* grooves not unlike the cuts a housewife would make in the crust of a pie. The writer has no intimation of their origin, but they may represent impressions of the spirialia of the brachial valve. The vascular system, usually preserved in this portion of the shell, is not represented on the writer's specimens.

The preservation of the material at hand prohibits any investigation of the presence or absence of punctae. For the same reason the nature of the dentition is not apparent.

Dimensions.—Given for only those figured specimens in possession of the writer and taken mainly from latex casts.

Characteristic	*UCM 34565*	*UCM 34566*
Apical angle	120°	120°
Delthyrial angle	40°	40°
Height of delthyrium	15 mm	7 mm
Width of delthyrium	12 mm	6 mm
Length of cardinal margin	46 mm	32 mm

Type.—Holotype [by monotypy], *Syringothyris randalli* Simpson, 1890, Academy of Natural Sciences of Philadelphia No. 3532

(=American Phil. Soc. Trans., n.s., vol. 16, p. 441-442, fig. 6, specimens numbered 1, 2). Collected by F. A. Randall from the "Chemung" [=Corry] near Warren and at Union City, Erie County, Pennsylvania.

Figured specimens and localities.—

Repository No.	*Type*	*Locality*
UCM 34565	Hypoype	116-C
UCM 34566	Hypotype	116-C
Phil. Acad. Sci. 3532	Hypotype	Warren, Pa.

Occurrence.—Specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 116-C, 123-C, 140-C, and 19-S.

Geologic age.—Lower Mississippian, Kinderhookian.

Discussion.—That the specimens described above belong to a species of the genus *Syringothyris* Winchell (1863), *sensu stricto,* is evidenced by the universal presence of unsupported syringes, the faintly plicate sulci, the "textile-cloth" appearance of the exteriors, and the high interareas. The specimens are further assigned to the species *Syringothyris randalli* Simpson because they share with the holotype the possession of prominent "tear-drop" impressions, conformity of general shape in posterior view, and molds of the interior which show almost conjunct impressions of the syringes and the "posteerior adductor processes." (See Pl. 35, figs. 1-7.)

Syringothyris randalli Simpson differs from *Syringothyris angulata* Simpson principally in the characteristics of the interior of the pedicle valve. Briefly summarized these differences are:

1. The delthyrium of S. *randalli* is closed for 2/3 of its length by conjunct callists which originate on the dental lamellae; callists from the same source restrict, but do not close, the delthyrium of S. *angulata.*
2. The subdelthyrial plate of S. *randalli* is flat; that of S. *angulata* convex or "shoehorn-like."
3. The syrinx of S. *randalli* is pointed; that of S. *angulata* flat.
4. The diductor muscle scars of S. *randalli* bear two sets of striae; those of S. *angulata* only one discernible set of striae.
5. The expression of the sulcus is much more prominent in the muscle field of S. *randalli* than that of S. *angulata.*

6. In the posterior portions of the molds of the rostral cavity, the impressions of the syrinx and the posterior adductor muscles of S. *randalli* almost intersect; in S. *angulata* the two are not proximate.

These differences appear to be of sufficient magnitude to warrant separation of the two species. For this reason, the synonymous relationship between *Syringothyris randalli* Simpson and *Syringothyris angulata* Simpson postulated by Caster (1930, p. 174) is rejected and the individuality of the two species re-established.

Schuchert (1910, p. 224) established the genus *Syringopleura* Schuchert citing *Syringothyris randalli* Simpson as the type species for the genus. Girty's (1911) rejection of the genus appears to be substantiated by the facts enumerated above.

The writer has in his possession a number of as yet unidentified syringothyroid specimens the molds and casts of which exhibit a syrinx supported by a true median septum in the pedicle valve. These specimens bear a descriptive resemblance to *Syringothyris herricki* Schuchert (1910) but the species was not illustrated by Schuchert, although he does refer to drawings of *Syringothyris cuspidatus,* Herrick (1888, pl. 5, figs. 4-7) which are eminently unsatisfactory. The problem of septate syringothyroids will not be solved until the types of *Syringothyris herricki* Schuchert and *Septosyringothyris* Vandercammen (1955) are examined. Such action is anticipated in the near future.

Remarks.—The species *Syringothyris randalli* Simpson appears in legally acceptable published form simultaneously in Lesley (1890, p. 1150-1152) and Simpson (1890, p. 441-442). It is impossible to determine which reference has priority. However, since Lesley's description is obviously borrowed from Simpson, as was the case with species described above, the authorship of *Syringothyris randalli* is awarded to Simpson as of 1890.

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PLATES

Explanation of Plate 28

Figure — Page

1,2. **Clathrospongia abacus** Hall 300

Specimen from the basal Corry sandstone.

1. Mold of the interior showing the natural cast of a remnant of the paragastric reticulum near the aperature, enlarged x 1.1. Location 103-C, UCM No. 34548; 2. Enlargement of the same, x 1.7, showing detail of the subdivisions of the primary quadrules of the paragastric reticulum.

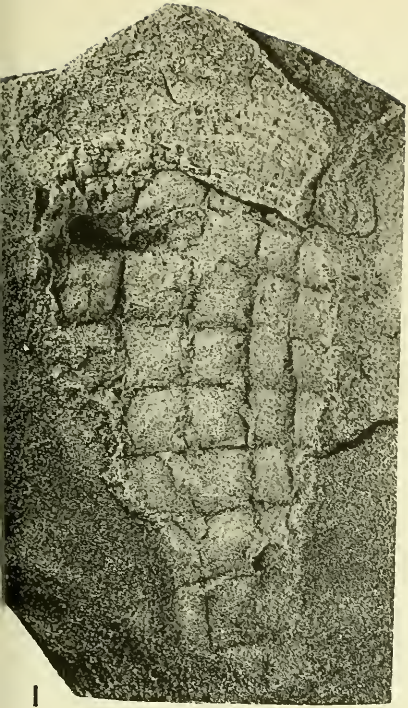
3. **Ectenodictya carlli** (Hall and Clarke) 303

3. Enlargement of a portion of a natural cast of the exterior of a specimen collected at location 116-C (*see* Pl. 29, fig. 1) The double rows of the horizontal strands of the primary reticulum and the diagonal strands of the same are well shown, enlarged x 1.4, UCM, No. 34549.

4,5. [?] **Phragmodictya** sp. Hall 278

4. Natural mold of an undescribed specimen collected at location 68-C and questionably assigned to the genus *Phragmodictya*, UCM, No. 34551; 5. Enlargement of the same, x 3.0, showing bean-shaped diactine microscleres (*see* Hall and Clarke, 1898, p. 175, fig. 30).

6. Fragment of an undescribed reticulate sponge, UCM, No. 34550.



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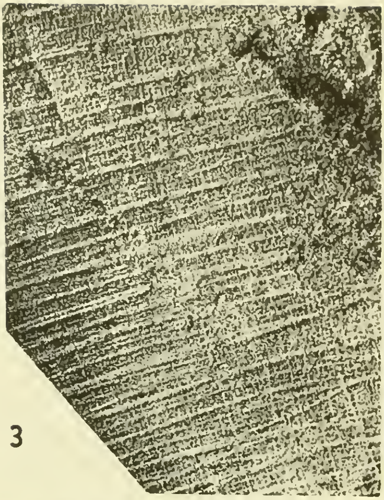

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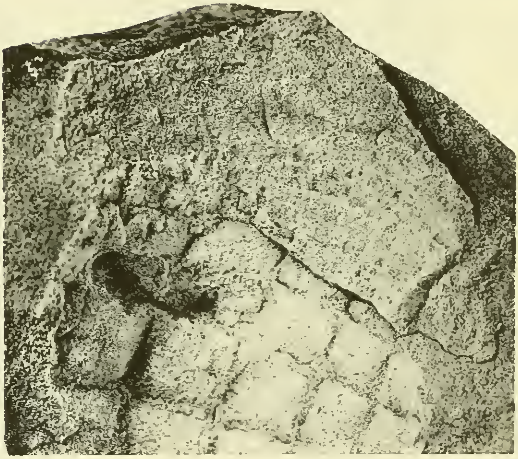

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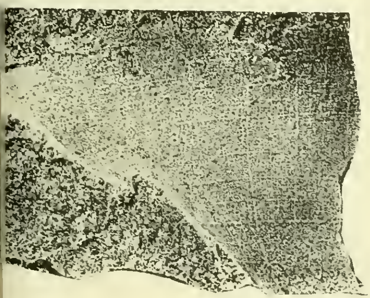

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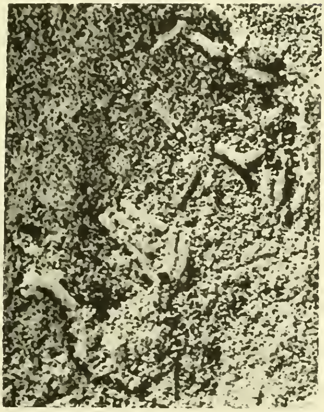

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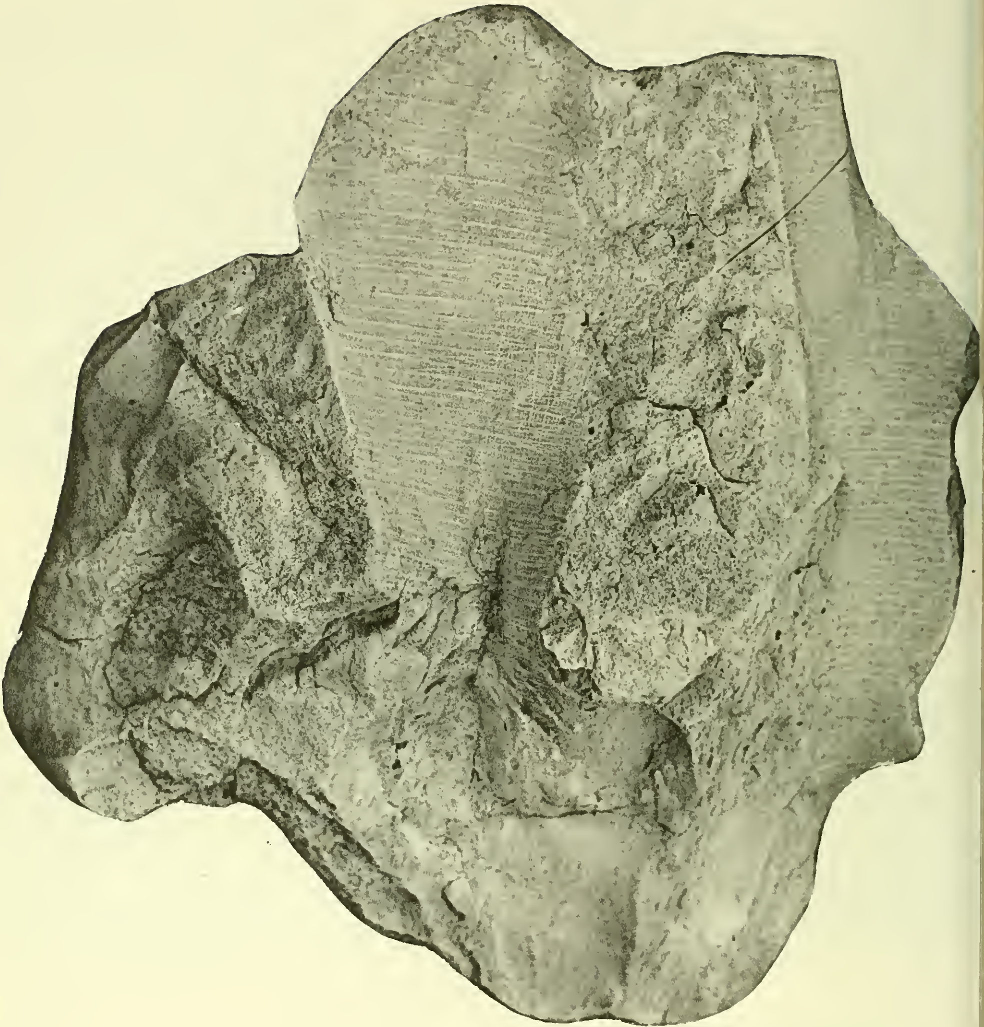

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Explanation of Plate 29

Figure		Page
1.	**Ectenodictya carlli** (Hall and Clarke)	303

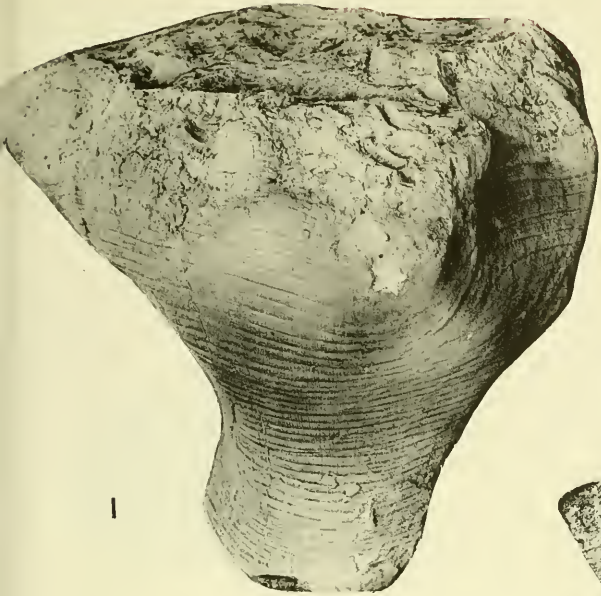
Specimen from the basal Corry sandstone.

Natural cast of the exterior, x 0.85, location 116-C, UCM, No. 34549.

Explanation of Plate 30

Figure Page

1-3. **Ectenodictya carlli** (Hall and Clarke) 303
Specimens collected by J. F. Carll at Pleasantville, Pa.; on loan to the writer through the courtesy of the New York State Museum. 1. Large specimen showing the characteristic shape, fluting, and mesial bulge, x 0.53, lectotype, New York State Museum—Paleontology, No. 58; 2. Enlargement of the same showing the double bands of the horizontal components of the primary reticulum as well as the diagonal strands (compare to Pl. 28, fig. 3), x 1.55; 3. Smaller specimen showing stronger vertical bands and completely lacking double bands or diagonal strands in the horizontal components of the primary reticulum paratype, New York State Museum—Paleontology, No. 59. Both specimens are natural molds of the exterior.



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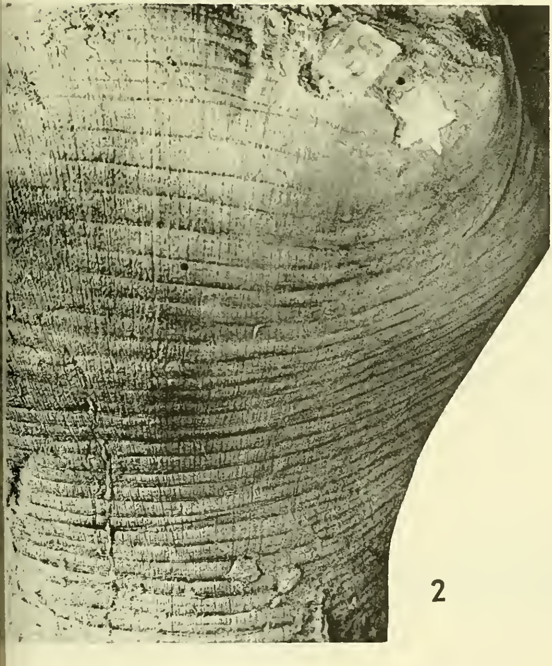

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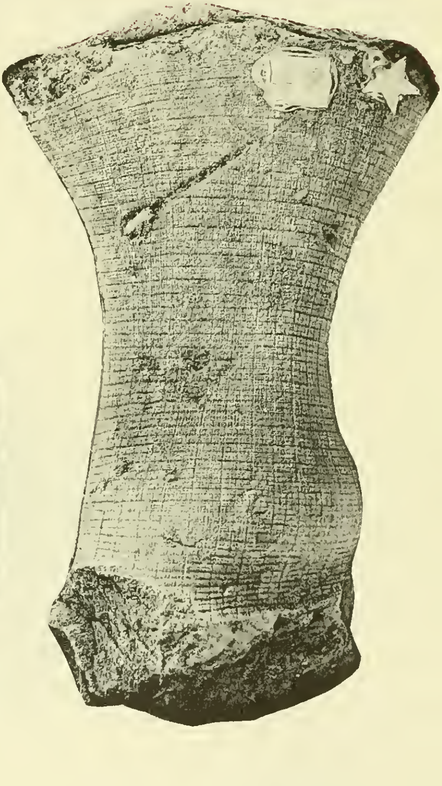

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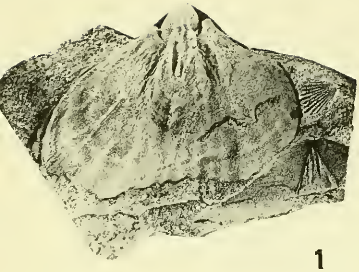
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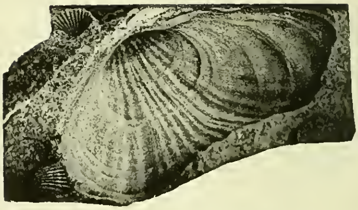
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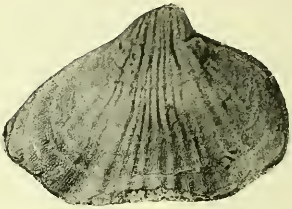
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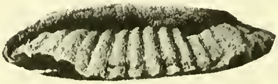
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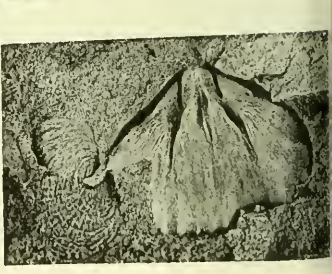
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Explanation of Plate 31

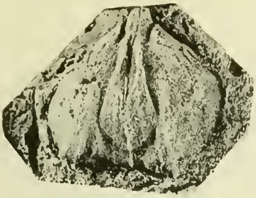
Figure		Page
1-10.	**Paraphorhynchus medialis** (Simpson)	322

Specimens from the basal Corry sandstone.

1. Natural mold of the interior of the pedicle valve showing the "adductor process", diductor muscle scar, and concentric carinae, locality 112-C, UCM. No. 34554; 2. Natural mold of the exterior of the pedicle valve showing plicae and concentric carinae, location 112-C, UCM, No. 34554; 3. Latex cast of fig. 1 showing dental lamellae, diductor muscle scar, "adductor process", umbonal cavities and ovarian markings, UCM No. 34544a; 4. Slightly distorted latex cast of fig. 2 showing sulcus and plicae, UCM No. 34554a; 5. View of the anterior of fig. 4 showing plicae in the sulcus; 6. View of the posterior of fig. 4 showing mesothyrid foramen and constriction of the beak; 7. Enlargement of fig. 5 showing costellae, x 2.66; 8. Latex cast of the interior of the pedicle valve made from fig. 10 and showing dental lamellae, umbonal cavities, "adductor process", and ovarian markings, locality 116-C, UCM, No. 34555a; 9. Anterior view of latex cast of exterior of pedicle valve showing sulcus and plicae, locality 116-C, UCM, No. 34555a; 10. Natural mold of the interior of the pedicle valve showing "adductor process", dental lamellae, and ovarian markings, locality 116-C, UCM, No. 34555.

Explanation of Plate 32

Figure		Page
1-5.	**Paraphorhynchus striatus** (Simpson) Specimens from the basal Corry sandstone. 1. Natural mold of the interior of the pedicle valve showing the "adductor process", diductor muscle scar and dental lamellae, location 116-C, UCM, No. 34556; 2. Latex cast of a portion of the exterior of fig. 1 showing plicae in sulcus and on lateral margins of the valve; UCM, No. 34556a; 3. Latex cast of fig. 1 showing the delthyrium, "adductor process", and teeth, UCM, No. 345556a; 4. Latex cast of an imperfect specimen showing delthyrium and palintrope, location 116-C, UCM No. 34557a; 5. Latex cast of a specimen with a gibbous pedicle valve, location 123-C, UCM, No. 34558a.	327
6-10.	**Paraphorhynchus girtyi** Caster Specimens from the basal Corry sandstone. 6. Natural mold of the interior of both valves of the holotype, inverted to show the erect beak and flattened umbo, location 123-C, PRI No. 5154; 7. View of the mold of the pedicle valve showing the plicae in the sulcus, location 123-C, PRI, No. 5154; 8. View of the mold of the brachial valve showing the plicated fold and median septum, location 123-C, PRI, No. 5154; 9. Latex cast of the posterior portion of PRI, No. 5154 showing "adductor process", diductor muscle scar, dental lamellae, and septalium, location 123-C, plastoholotype, UCM, No. 34559; 10. Natural mold of the interior showing depression for "adductor process", and diductor muscle scar, location 123-C, UCM, No. 34560.	331
11.	**Paraphorhynchus casteri**, n. sp. Specimen from the basal Corry sandstone. Latex cast of the posterior portion of the exterior of the pedicle valve of the holotype showing the foramen and costellae, location 116-C, UCM, No. 34561a.	334
12.	**Paraphorhynchus girtyi** Caster Latex cast of the interior of fig. 10 showing diductor muscle scar, "adductor process", and deltidial plates, location 123-C, UCM No. 34560a.	
13,14.	**Paraphorhynchus casteri** n. sp. Specimens from the basal Corry sandstone. 13. Latex cast of the interior of the pedicle valve of the holotype showing sulcus and plicae, location 123-C, UCM No. 34561a; 14. Natural mold of the interior of the pedicle valve of the holotype showing the plicae in the sulcus and on the lateral slopes (arrow points to the "adductor process"), location 123-C, UCM No. 34561.	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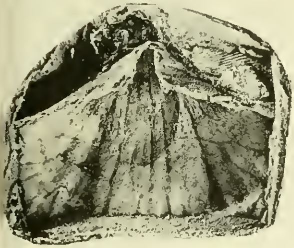
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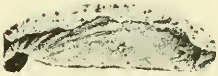
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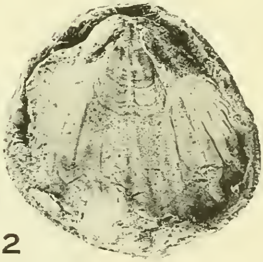
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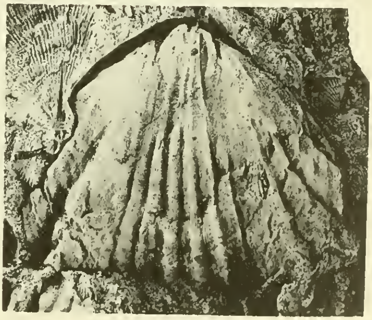
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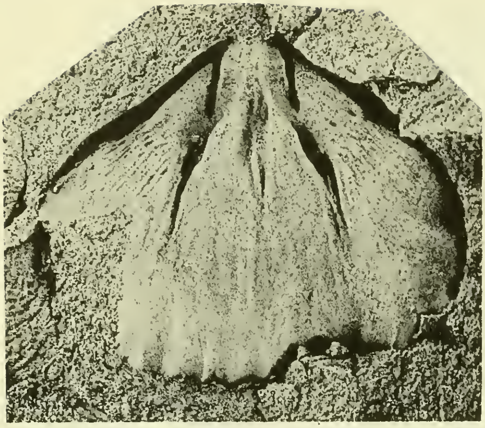

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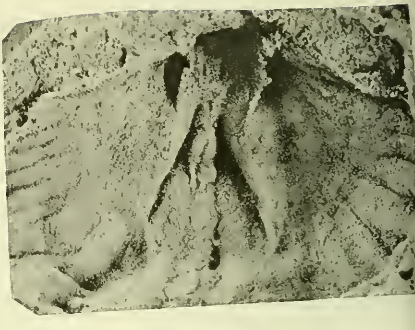

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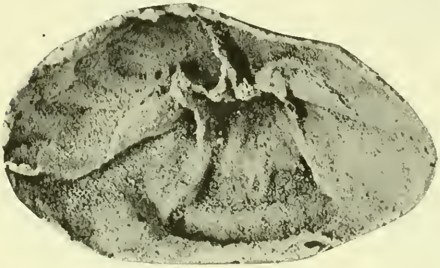

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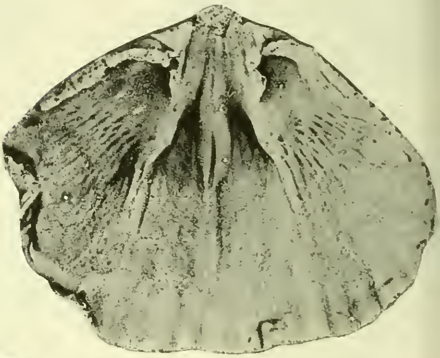

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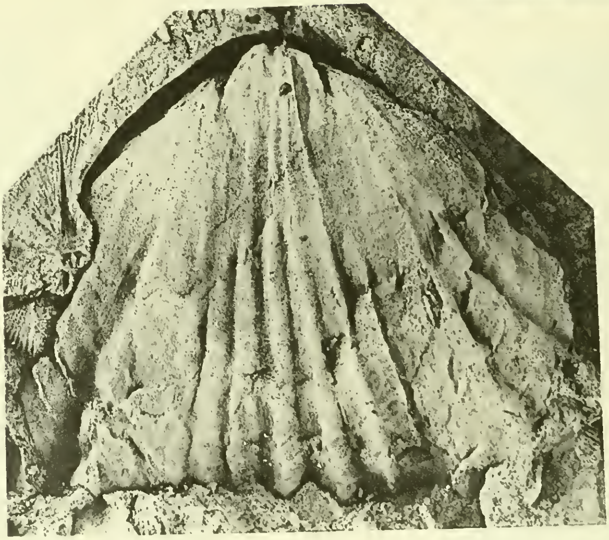

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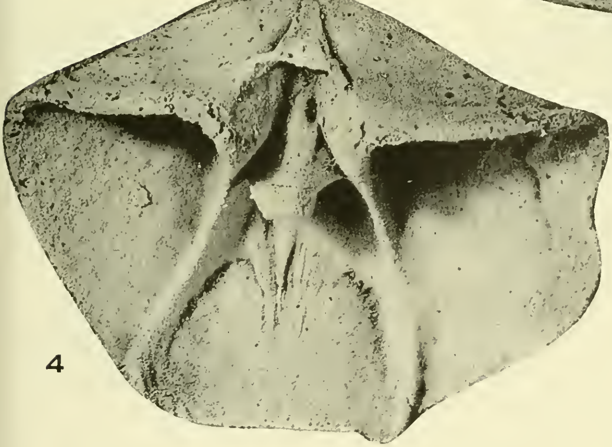

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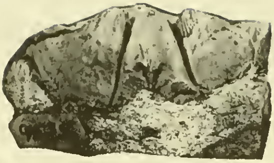

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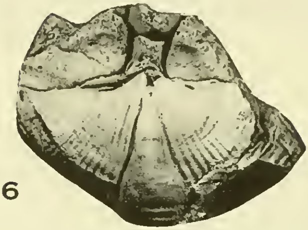

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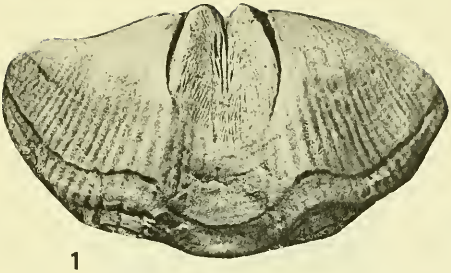
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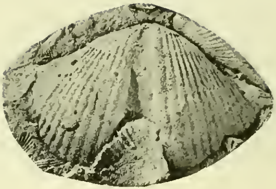
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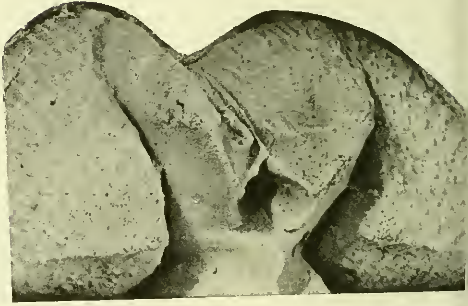
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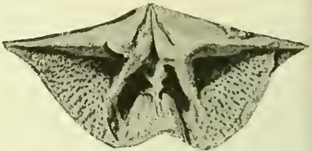
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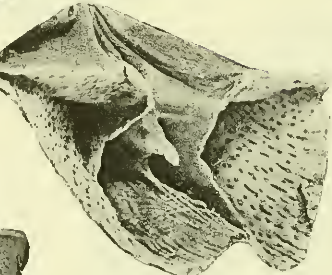
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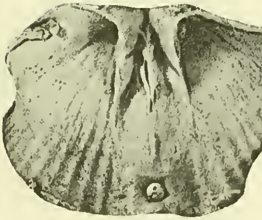
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1-11 **Syringothyris randalli** Simpson 355

Specimens from the basal Corry sandstone.

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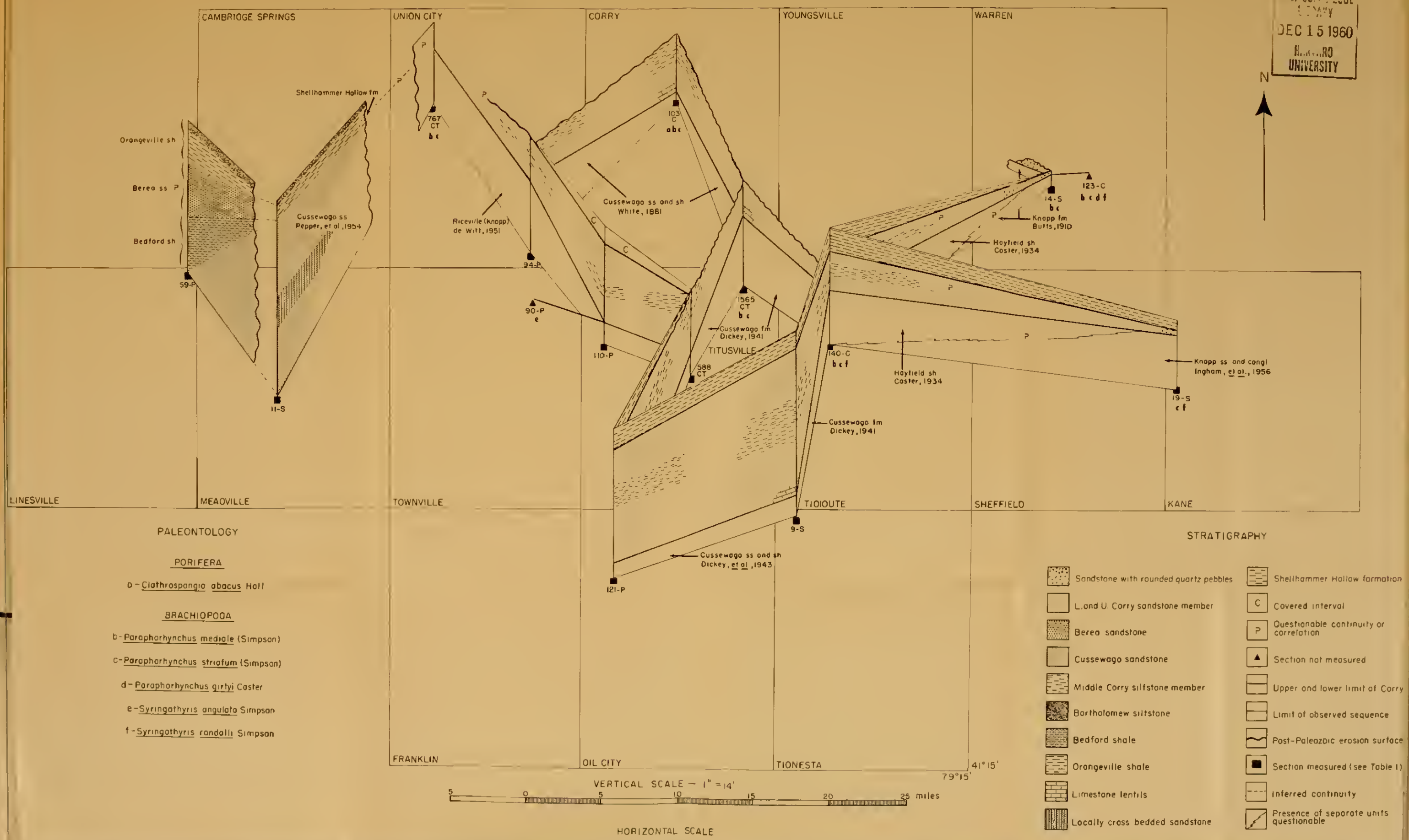
RESTORATION OF THE CONTINUITY OF THE CORRY SANDSTONE IN NORTHWESTERN PENNSYLVANIA



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