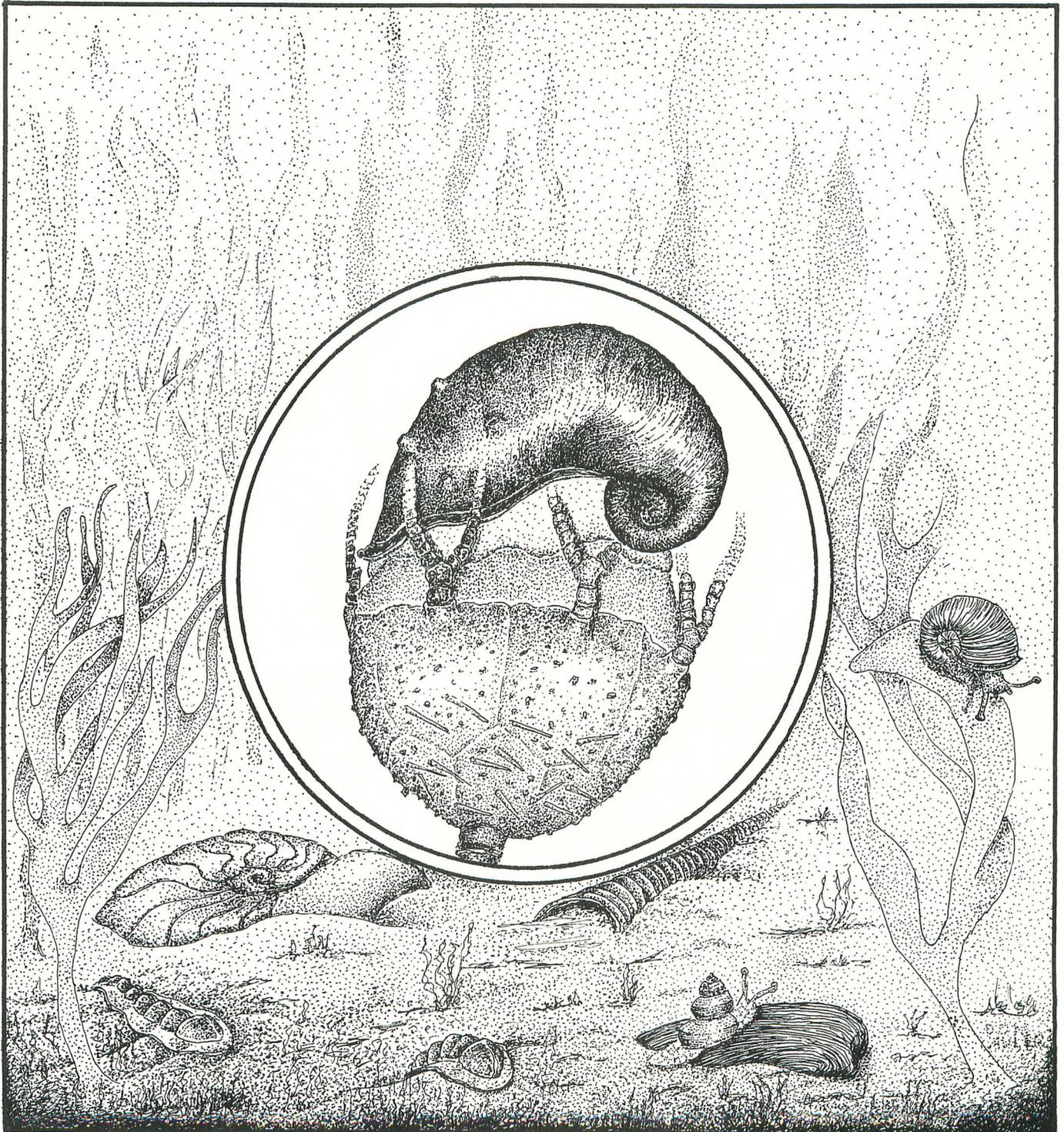


M.A.P.S. *Digest*

Official Publication of
Mid-America Paleontology Society

Volume 15 Number 4
EXPO XIV EDITION, 1992



Don Heller 1-92

PHYLUM MOLLUSCA

Gil Norris
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SUBPHYLUM DIASOMA

CLASS ROSTROCONCHIA (L. Camb. - U. Perm.) 35 genera
no Subclasses

CLASS SCAPHOPODA (M. Ord. - Holocene) 50 genera
no Subclasses

CLASS PELECYPODA (L. Camb. - Holocene) 3,300 genera

Subclass - Palaeotaxodonta 150 genera
Subclass - Idofilibrachia 140 genera
Subclass - Heteroconchia 2000 genera
Subclass - Pteriomorphia 900 genera
Subclass - Anomalodesmata 100 genera (U. Ord. - Holocene)

SUBPHYLUM AMPHINEURA

CLASS AFLACOPHORA (Holocene) 70 genera
no Subclasses

CLASS POLYPLACOPHORA (U. Camb. - Holocene) 100 genera
no Subclasses

SUBPHYLUM CYRTOSOMA

CLASS MONOPLACOPHORA (L. Camb. - Holocene) 135 genera
no Subclasses

CLASS CEPHALOPODA (U. Camb. - Holocene) 3,100 genera

Subclass - Nautiloidea (U. Camb. - Holocene) 700 genera
Subclass - Endoceratoidea (L. Ord. - Sil.) 80 genera
Subclass - Actinoceratoidea (M. Ord. - Miss.) 40 genera
Subclass - Bactritoidea (Dev. - U. Trias.) 20 genera
Subclass - Ammonoidea (L. Dev. - U. Cret.) 2,000 genera
Subclass - Coleoidea (L. Dev. - Holocene)

CLASS GASTROPODA (L. Camb. - Holocene) 7,800 genera

Subclass - Prosobranchia (L. Camb. - Holocene) 4,500 genera
Subclass - Opisthobranchia (Miss. - Holocene) 800 genera
Subclass - Pulmonata (Penn. - Holocene) 2,500 genera

Source: Fossil Invertebrates by Boardman, Cheetham, Rowell
1987

MOLLUSCA

MAPS DIGEST

EXPO XIV EDITION

Mid - America Paleontology Society
A Love Of Fossils Brings Us Together

Western Illinois University
Union Ballroom
Macomb, Illinois 61465
April - 1992



ACKNOWLEDGEMENT

History has left footprints on the earth in the form of fossils we find today. The PHYLUM MOLLUSCA is so vast; probably the largest division there is in Class, Subclass and Order.

"A Love Of Fossils Brings Us Together". When I read the articles written by these authors I can see that love coming through; they do love the particular fossil, and their hearts are in what they are writing about. They could be called "Love Letters" of the past.

I know how they feel because I have specimens I almost worship, at least I've been accused of it.

Possession of our special fossils are just that; they're in our possession such a short time (you might say on loan) compared to their age. We hold them in our possession, show them to friends and other collectors, exhibit and enjoy having them with us; then at sometime in our lives they are passed on to someone else, Universities, Museums or another collector who we hope will cherish them as we have.

That is wishful thinking of course, for we know it is the collector who finds that special specimen, that knows the spot where it lay and the day it was found that loves it the most.

I wish to thank these **Authors** and **Contributors** for sharing their love of fossils with us.

I also want to give special recognition to the officers and directors who labor so tirelessly in keeping our **M.A.P.S.** and **EXPO** going so smoothly. **THANKS.**

The Mid - America Paleontology Society was formed to promote popular interest in the subject of paleontology, to encourage the proper collecting, study, preparation and display of fossil material; and to assist other individuals, groups and institutions interested in the various aspects of paleontology. It is a non-profit society incorporated under the laws of the State of Iowa.

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COVER STORY

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An artists conception of an ancient sea bed as it may have appeared 300 to 400 million years ago with a special emphasis on the MAPS 1992 EXPO Digest Theme - MOLLUSCA.

The center insert shows the Trochinid gastropod Platyceras dumosum - with the crinoid Arthroacantha punctobrachiata, from the collection of Don Brazda; a specimen from the Devonian Arkona Shale; Arkona, Canada, x3.

Trochinids presumably lived along rocky shores, feeding on algae, but some were scavengers or feeders on crinoid feces as evidenced by some fossil specimens; an example of symbiosis.

The seascape includes pelecypods, chitons and cephalopods, in addition to named gastropod. The chitons in the drawing at first would not seem to be part of this group, but their morphology places them in the phylum MOLLUSCA.

A Field Museum paper by Dr. Richardson, "Fieldiana Geology vol.12, No's 1-4", was published in 1963 with photos of complete chiton fossils.

George Langford's fauna book on the Mazon Creek area, also published in 1963 by ESCONI, reported that although rare, more chitons were being found regularly at Pit 11.

Stephen J. Gould's recent book, "Wonderful Life", recognized the importance of the Mazon Creek phyla: pp.61-67.

Simon and Schuster's book, "Guide to Fossils", has 21 photos of Pit 11 animals.

ESCONI published the first comprehensive guide to Mazon Creek fossils in (1986 Flora) and (1989 Fauna).

At present, Northeastern Illinois University's Earth Science Department, under the guidance of Dr. Charles W. Shabica, is completing an atlas on the Fossil Fauna of Mazon Creek. It may seem that "Mazon Creek" will finally get the recognition it deserves, however most of the collecting sites are now inaccessible.

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A SELECTED BIBLIOGRAPHIC INTRODUCTION
TO THE ORDOVICIAN MOLLUSKS AND OTHER FOSSILS OF THE
TRISTATE AREA OF OHIO, KENTUCKY, AND INDIANA

by: John Pojeta, Jr., Rockville, Maryland

In the December 1991 MAPS Digest, Mark McKinzie presented an interesting article about collecting Ordovician fossils from near Lexington, Kentucky. There has been a great deal of revision of the paleontology and litho- and biostratigraphy of the Ordovician of this area in the past 30 years; I thought that it would be helpful to have an annotated list of the major newer references for MAPS members interested in collecting Ordovician fossils from the classical outcrops in the Tristate Area of Ohio, Kentucky, and Indiana. Each of the papers cited has a bibliography that will introduce you to the literature current to the date of publication of the paper. The paleontological papers cited are those that will allow you to identify specimens and understand paleoecology. Much of the new work was the result of a cooperative geologic mapping program carried out by the U.S. Geological Survey and the Kentucky Geological Survey.

MOLLUSKS From the Tristate Area

(1) Frey, R.C., 1987, The Occurrence of Pelecypods in Early Paleozoic Epeiric-Sea Environments, Late Ordovician of the Cincinnati, Ohio Area: *Palaios*, v. 2, No. 1, p. 3-23. This paper deals with the paleoecology of Ordovician pelecypods.

(2) Frey, R.C., 1989, Paleoecology of a Well-Preserved Nautiloid Assemblage from a Late Ordovician Shale Unit, Southwestern Ohio: *Journal of Paleontology*, v. 65, No. 5, p. 604-620. This paper concentrates on the paleoecology of nautiloids.

(3) Pojeta, John, Jr., 1962, The Pelecypod Genus Byssonychia as it Occurs in the Cincinnati at Cincinnati, Ohio: *Palaeontographica Americana*, v. 4, No. 30, p. 167-216, pls. 22-31. This monograph deals with all the species known from the area, gives their stratigraphic occurrences, and has a key to their identification. Subsequent to the monograph, it was discovered that the proper name for this genus is Ambonychia, which is a senior objective synonym of Byssonychia.

(4) Pojeta, John, Jr., 1966, North American Ambonychiidae: *Palaeontographica Americana*, v. 5, No. 36, p. 129-241, pls. 19-47. This monograph deals with all the genera of the pelecypod family Ambonychiidae (Ordovician-Devonian) in North America, includes a key to their identification, lists all known species, and describes all species from the Tristate Area.

(5) Pojeta, John, Jr., 1971, Review of Ordovician Pelecypods: U.S. Geological Survey, Professional Paper 695, 46 p., 20 pls. This paper summarizes information on Ordovician pelecypods from around the world and illustrates all the major taxonomic groups. Much of the figured material is

from the Tristate Area, and most of the material is from the northeastern USA and adjacent Canada.

(6) Pojeta, John, Jr., and Runnegar, Bruce, 1976, The Paleontology of Rostroconch Mollusks, and the Early History of the Phylum Mollusca: U.S. Geological Survey Professional Paper 968, 88 p., 54 pls. This paper is a world wide analysis of the molluscan class Rostroconchia, and the paper includes all species known from the Tristate Area.

(7) Pojeta, John, Jr., and Runnegar, Bruce, 1979, Rhytidentalium kentuckyensis, a new genus and new species of Ordovician scaphopod, and the early history of scaphopod mollusks: Journal of Paleontology, v. 53, p. 530-541, 3 pls. This paper describes the oldest known scaphopod mollusk, which occurs in the Ordovician rocks of Kentucky.

(8) Pojeta, John, Jr., 1988, The Origin and Paleozoic Diversification of Solemyoid Pelecypods: New Mexico Bureau of Mines and Mineral Resources, Memoir 44, p. 201-277, 24 pls. This monograph deals with solemyoids throughout the Paleozoic, and includes various little known species from the Tristate Area.

(9) Wahlman, G.P., 1992, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Symmetrical Univalved Mollusks from the Ordovician of Kentucky: U.S. Geological Survey Professional Paper 1066-0. This paper is in press and will be released this year, it includes 45 plates, and the taxonomy of all known monoplacophorans and bellerophonts from the Tristate Area, as well a summaries of the Ordovician lithostratigraphy.

(10) Modern taxonomic studies of the asymmetrical Ordovician univalves and the cephalopods of the Tristate Area are progressing, and some of this information will be available in the next two years or so.

OTHER FOSSILS from the Tristate Area

(1) Alberstadt, L. P., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---The Brachiopod Genus Platystrophia: U.S. Geological Survey Professional Paper 1066-B, 20 p., 7 pls. This paper deals with the taxonomy, stratigraphy, and phylogeny of one of the most conspicuous taxa in the Ordovician rocks of the Tristate Area.

(2) Bell, B.M., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Edrioasteroids (Echinodermata): U.S. Geological Survey Professional Paper 1066-E, 7 p, 2 pls. This paper describes six species, including one inflated specimen with the attachment structure preserved.

(3) Berdan, J.M., 1984, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Leperditicopid Ostracodes from Ordovician Rocks of Kentucky and Nearby States and Characteristic Features of the Order Leperditicopida: U.S. Geological Survey Professional Paper 1066-J, 40 p., 11 pls. 16 species, 3 new, are described.

(4) Branstrator, J.W., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States--Asteroidea (Echinodermata): U.S. Geological Survey Professional Paper 1066-F, 7p, 3 pls. Three species of well-preserved starfish are described.

(5) Elias, R.J., 1983, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Middle and Late Solitary Rugose Corals of the Cincinnati Arch Region: U.S. Geological Survey Professional Paper 1066-N, 13p., 2 pls. 4 species are described.

(6) Howe, H.J., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Middle and Late Ordovician Plectambonacean, Rhynchonellacean, Syntrophiacean, Trimerellacean, and Atrypacean Brachiopods: U.S. Geological Survey Professional Paper 1066-C, 18 p. 7 pls. This paper deals with 14 species and 8 genera many of which are abundant.

(7) Karklins, O.L., 1984, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Trepstome and Cystoporate Bryozoans from the Lexington Limestone and the Clays Ferry Formation (Middle and Upper Ordovician) of Kentucky: U.S. Geological Survey Professional Paper 1066-I, 105 p., 41 pls. 36 species, 6 new, are described, and the Middle-Upper Ordovician boundary is discussed.

(8) Neuman, R. B., 1967, Some Silicified Ordovician Brachiopods from Kentucky, U.S. Geological Survey Professional Paper 583-A, 14 p. 3 pls.

(9) Osgood, R.G., 1970, Trace Fossils of the Cincinnati Area: Palaeontographica Americana, v. 6, 281 p., many plates. Summary treatment of trace fossils in Upper Ordovician rocks.

(10) Parsley, R. L., 1981, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Echinoderms from Middle and Upper Ordovician Rocks of Kentucky: U.S. Geological Survey Professional Paper 1066-K, 9 p., 1 pl. This paper deals with carpoids, cystoids, and crinoids.

(11) Pope, J.K., 1982, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Some Silicified Strophomenacean Brachiopods from the Ordovician of Kentucky, with Comments on the Genus Pionomena: U.S. Geological Survey Professional Paper 1066-L, 30 p., 8 pls. 9 species, 1 new, are described.

(12) Ross, R.J., Jr., 1967, Calymenid and Other Ordovician Trilobites from Kentucky and Ohio: U.S. Geological Survey Professional Paper 583-B, 18 p., 5 pls. This paper, and the next one by Ross, supplement one another in describing silicified trilobites; some of the specimens preserve appendages.

(13) Ross, R.J., Jr., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Additional Trilobites from the Ordovician of Kentucky: U.S. Geological Survey Professional Paper 1066-D, 13 p, 6 pls.

(14) Walker, L. G., 1982, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---The Brachiopod Genera Hebertella, Dalmanella, and Heterorthina from the Ordovician of Kentucky: U.S. Geological Survey Professional Paper 1066-M, 17 p., 5 pls. 9 species are described.

(15) Warshauer, S.M., and Berdan, J.M., 1982, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Palaeocopid and Podocopid Ostracoda from the Lexington Limestone and Clays Ferry Formation (Middle and Upper Ordovician) of Central Kentucky: U.S. Geological Survey Professional Paper 1066-H, 80 p., 19 pls. 54 ostracode taxa are described, including 5 new genera and 18 new species.

STRATIGRAPHIC PAPERS

(1) Cressman, E.R., 1973, Lithostratigraphy and Depositional Environments of the Lexington Limestone (Ordovician) of Central Kentucky: U.S. Geological Survey Professional Paper 768, 61 p., 11 pls. Describes all the numerous members of the Lexington Limestone and discusses their environments of deposition.

(2) Cressman, E.R., and Noger, M.C., 1976, Tidal-flat Carbonate Environments in the High Bridge (Middle Ordovician) of Central Kentucky: Kentucky Geological Survey, Report of Investigations 18, 15 p. Discusses the environments of deposition of the rocks underlying the Lexington Limestone.

(3) Pojeta, John, Jr., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Introduction: U.S. Geological Survey Professional Paper 1066-A, 48 p. Provides the general information for all the other papers in the 1066 series. Includes a summary of all lithostratigraphic units, Middle-Upper Ordovician boundary, the methods for preparing the fossils, and a 30 page locality register tied to topographic maps.

(4) Sweet, W.C., 1979, Contributions to the Ordovician Paleontology of Kentucky and Nearby States---Conodonts and Conodont Biostratigraphy of Post-Tyrone Ordovician Rocks of the Cincinnati Region: U.S. Geological Survey Professional Paper 1066-G, 26 p. Discusses the use of conodonts in the biostratigraphy of the area, and includes a regional correlation chart.

(5) Weir, G.W., Peterson, W.L., and Swadley W C, 1984, Lithostratigraphy of Upper Ordovician Strata Exposed in Kentucky: U.S. Geological Survey Professional Paper 1151-E, 121 p., 7 pls. This book is the Upper Ordovician companion volume to Cressman's (1973) book on the Lexington Limestone.

MAPS

The State of Kentucky is completely mapped geologically on a scale of 1:24,000. The mapping was a cooperative project of the Kentucky Geological Survey and the U.S. Geological Survey. Many of the maps of the Blue Grass Region, which is underlain by Ordovician rocks have fossil localities marked on them, and contain lists of identifications of fossils. The maps may be obtained from the Kentucky Geological Survey, 228 Mining and Mineral Resources Building, University of Kentucky, Lexington, Kentucky 40506-0107 (telephone 606-257-5500)

Geologic and topographic maps, as well as U.S. Geological Survey publications are also available from:

U.S. Geological Survey
Earth Science Information Center
Mail Stop 507, National Center
Reston, Virginia 22092
(telephone 703-648-6045)

THE NAUTILOID CEPHALOPODS

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INTRODUCTION

Cephalopods are the most specialized and highly organized of the mollusks and, "in terms of speed, intelligence, and sensory ability, they represent the acme of invertebrate evolution" (Ward, 1988, p. 16). Although the cephalopods of today are exclusively marine carnivorous predators/scavengers, the enormous numbers of fossil nautiloid species point to a variety of life styles ranging from active predator to planktonic filter feeders. There are about 650 species of cephalopods (5-6 species of Nautilus the last surviving nautiloid) living today but over 10,000 fossil species are recognized.

The one structure that is unique to externally shelled cephalopods, setting them apart from the other mollusks, is the siphuncle--a tubular structure that runs the length of the shell or conch piercing each chamber wall. It is primarily the development of this structure, rather than just the ability to secrete septa and form chambers, in primitive monoplacophorans that is believed to have given rise to the cephalopods (Yochelson, et. al., 1973; Holland, 1987).

CLASSIFICATION

Early classifications were made by zoologists who naturally used living cephalopods as the basis for their classification systems resulting in only two divisions:

1. Tetrabranchia, possessing two pairs of gills and an external shell, which included the living Nautilus and fossil ammonite and nautiloid forms and
2. Dibranchia, possessing one pair of gills with the shell internal or absent, which included living octopus and squid species and the fossil belemnites.

This classification, along with its many equivalents, has been rejected for several reasons not the least of which is the fact that it is impossible to ascertain the number of gills in fossil forms. Also, there are good indications (e.g. modern primitive gastropods are dibranchiate) that the first ancestral mollusk, as well as the first cephalopods, had a single pair of gills.

The classification of nautiloids, as well as of cephalopods in general, has undergone many changes based on inferred phylogenetic relationships and has resulted in the following classification which will most certainly be modified in the future as more evidence is uncovered (Wade, 1988):

Phylum MOLLUSCA

Subphylum CYRTOSOMA

Class CEPHALOPODA

Subclass NAUTILOIDEA

Superorder PLECTRONOCERATOIDEA

Order PLECTRONOCERIDA (U. Camb)

Order PROTACTINOCERIDA (U. Camb)

Order ELLESMEROCERIDA (U. Camb-L. Sil)

Order YANHECERIDA (U. Camb)

Superorder ENDOCERATOIDEA

Order ENDOCERIDA (L. Ord-U. Sil)

Order INTEJOCERIDA (L. Ord-M. Ord)

Superorder ACTINOCERATOIDEA

Order ACTINOCERIDA (L. Ord-U. Carb)

Superorder DISCOSORATOIDEA

Order DISCOSORIDA (L. Ord-U. Dev)

Superorder NAUTILATOIDEA

Order TARPHYCERIDA (L. Ord-M. Dev)

Order ONCOCERIDA (M. Ord-L. Carb)

Order NAUTILIDA (L. Sil-Rec)

Superorder ORTHOCERATOIDEA

Order ORTHOCERIDA (L. Ord-U. Trias)

Order PSEUDORTHOCERIDA (M. Ord-U. Perm)

Order ASCOCERIDA (M. Ord-U. Sil)

MORPHOLOGY

The first consideration when studying cephalopods is the matter of the orientation of the conch. (Figure 1 illustrates many of the features mentioned in this section). The ventral side (venter) is the under surface of the conch and is the side where the hyponomic sinus is located. If the hyponomic sinus is not preserved, the venter is taken to be the side where the siphuncle is located. Obviously, problems arise when dealing with conchs with central siphuncles. The dorsal side (dorsum) is the upper surface (opposite the venter) and between the venter and the dorsum are located the lateral sides. Although only very rarely preserved, dorsal color patterns or markings can also indicate shell orientation (Frey, 1989; Kobluk and Mapes, 1989). (At the Dixon cement quarry, I personally collected a specimen of Michelinoceras sp. that exhibits longitudinal stripes only on one side of the shell, most probably the dorsum.)

The conch itself is divided into two main parts, the anterior living chamber (where the animal resided) and the phragmocone with its posterior termination at the protoconch (the initial chamber which is rarely preserved). The opening of the living chamber is called the aperture and it allowed the animal access to its environment. The hyponomic sinus (mentioned above) is an indentation in the aperture where the hyponome (used for locomotion and respiration) of the living animal was located.

The phragmocone contains all remaining structures many of which are used for classification and identification at the generic and specific levels. The phragmocone is divided into many chambers called camerae by a series of concave partitions (chamber walls) called septa. Each camera represents part of a former living chamber that the animal closed off by the secretion of a septum as it grew larger and extended its shell. On steinkerns (fossilized remains of the inner portion of conchs without the outer shell covering), the edge of the septa where they would meet the inner edge of the shell form transverse markings called

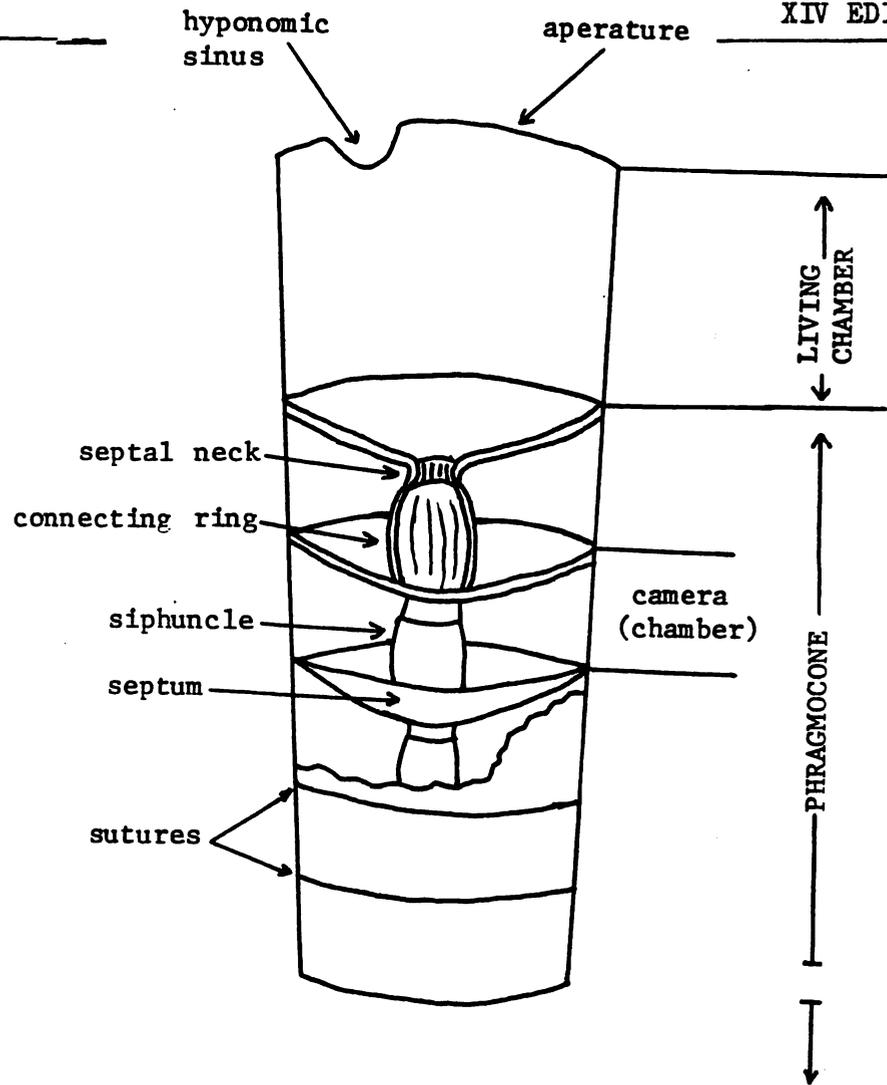


Figure 1. A sectioned nautiloid conch showing various features discussed in the text. The phragmocone extends to the protoconch (initial camerae). (Modified after Flower, 1946)

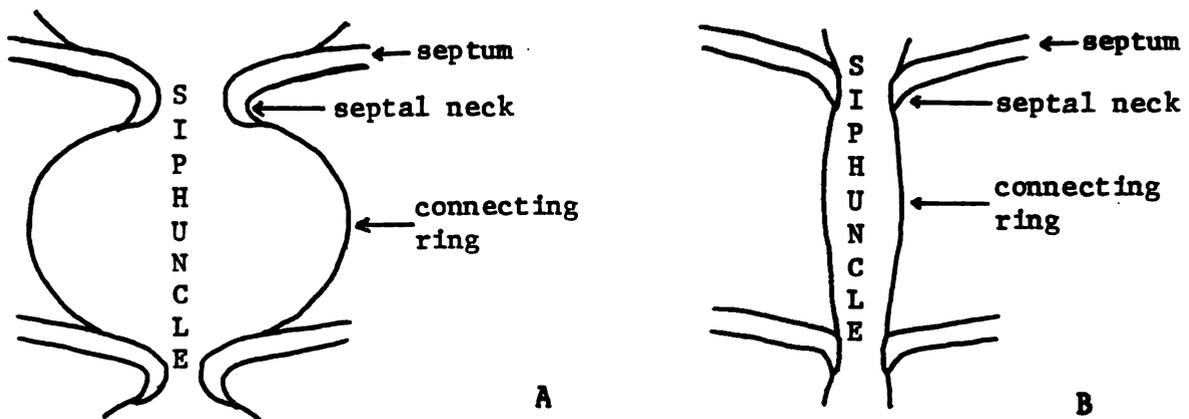


Figure 2. Diagrams showing various types of septal necks and connecting rings. A. Curved necks and expanding segments (rings). B. Straight necks and tubular segments (rings).

sutures which can be straight or display various lobes (bends away from the aperture) or saddles (bends toward the aperture).

As stated previously, the siphuncle is the most important nautiloid structure. The siphuncle of the living Nautilus is used for removing (by salinity induced osmosis) the cameral fluid from the chambers so that neutral buoyancy (actually very slight negative buoyancy) can be maintained as the animal grows. Ancient nautiloids (particularly coiled forms) undoubtedly used the siphuncle, in part, for a similar function. However, many fossil siphuncles are much larger and contain structures and deposits that have no analogies in the modern Nautilus. Possible functions of these siphuncles that have been suggested range from reproduction to the secretion of cameral and siphonal deposits.

The outer siphuncle (see Figure 2) consists of the septal necks, extensions of the septa that bend away from the aperture, and the connecting rings, cylindrical or ring-shaped sheaths that extend between and connect two successive septal necks. The various combinations of curvatures of the necks and shapes of the rings are, along with types of siphuncular and cameral deposits, used extensively in the classification of the nautiloids.

Nautiloids also displayed a wide variety of shell forms differing, primarily, in cross section, degree of curvature (conch shape), location of the siphuncle, and ornamentation. Early workers classified and identified nautiloids based mainly on conch form with such success that many of their form-genera are still considered valid (e.g. Foerste, 1932, 1933).

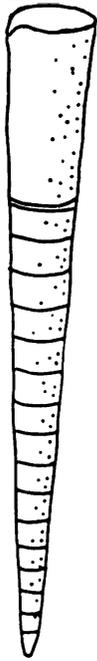
Conch cross sections can be circular, depressed, or compressed. A cross section that is depressed has a shorter dorsal-ventral diameter than lateral diameter while a compressed cross section has a longer dorsal-ventral diameter than lateral diameter.

The degree of curvature varied greatly among the nautiloids ranging from straight to tightly coiled (see Figure 3). Straight shelled forms are called orthocones, curved conchs are referred to as cyrtocones, and short rapidly expanding shells are known as brevicones. Loosely coiled conchs in which the whorls are not in contact are called gyrocones. Planispirally coiled conchs in which the whorls are in contact range from tarphycones (whorls evolute and exposed) to nautilicones (whorls involute and poorly exposed or hidden). Torticones exhibit three-dimensional coiling similar to gastropods.

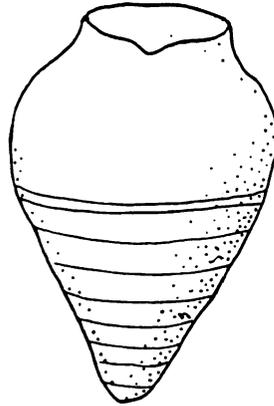
With the curves of two conchs oriented the same way, the specimen with the siphuncle near or at the concave side is said to be endogastric while the exogastric conch has the siphuncle located near or at the convex side.

Ornamentation is mostly a feature of the surface of the shell and is usually not evident on steinkerns. Surfaces can range from smooth (Michelinoceras) to crenulated (Zittelloceras) to strongly annulated (Gorbyoceras).

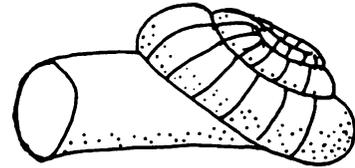
Soft-part morphology is, understandably, virtually unknown. Evidence consists of muscle-attachment scars, traces of tentacular impressions, and comparisons to modern forms. Since the nautiloids are such a diverse group of cephalopods, it would be unreasonable to assume that all members had the same number of arms or tentacles. Evidence suggests that members of the Orthocerida were equipped with 10 coleoid-like arms which seems reasonable since coleoids presumably arose from the Orthocerida through the Bactritina (Frey, 1989). Inference suggests, however, that members of the Oncocerida may have had



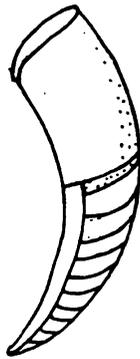
orthocone



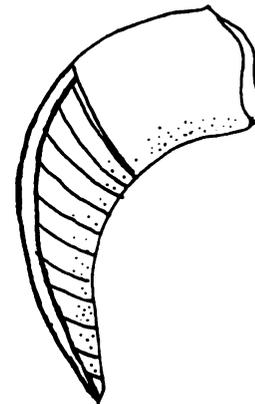
brevicone



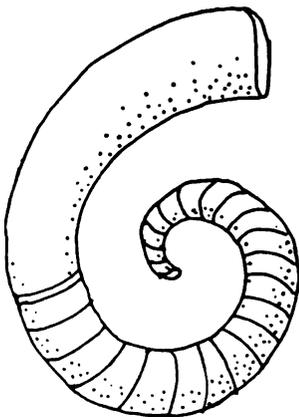
torticone



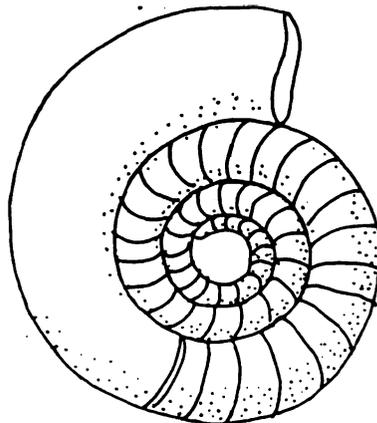
endogastric cyrtocone



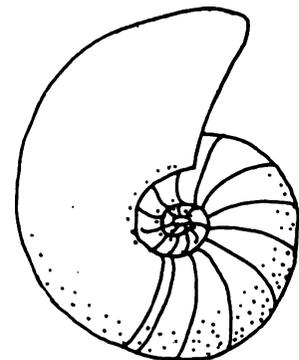
exogastric cyrtocone



gyrocone



tarphycone



nautilicone

Figure 3. Some common nautiloid shell forms. (Modified after Flower, 1964)

numerous Nautilus-type tentacles which also seems reasonable since it is assumed that the Nautilida arose from the Oncocerida (Frey, 1989).

A much more detailed discussion of nautiloid morphology is available in the Treatise Part K (Teichert, 1964) or in Flower, 1964.

ORIGIN OF THE CEPHALOPODS

As has been mentioned above, it is the presence of the siphuncle, not just of septa and chambers, that sets cephalopods apart from all other mollusks. Septa are also present in some gastropods, monoplacophorans, and hyolithids but all lack a siphuncle.

Although it has been proposed that cephalopods originated from primitive (Late Cambrian) multiseptate endogastric monoplacophorans (Yochelson, et. al., 1973), it is unclear how a siphuncle could develop in an animal that would normally separate completely from the apex of its shell before the secretion of the first septum. This septum, and succeeding ones, would not be perforated by a hole thus the animal could not develop a siphuncle (although it is remotely possible that a mutation could occur in which separation is not complete). It would seem more logical for an originally non-septate monoplacophoran with a high shell profile to serve as the ancestor of the cephalopods. In this scenario, the visceral mass would migrate forward in response to shell growth presumably as did the ancestors of multiseptate monoplacophorans. In this case, however, the visceral mass would not completely separate from the shell apex leaving behind a thin strand of tissue (the first siphuncle) around which septa would be secreted. This new siphuncle could then begin to remove cameral fluid by osmosis to achieve the neutral buoyancy which would give the primitive cephalopod an advantage over multiseptate monoplacophorans that could not remove cameral fluid.

However the transition occurred, the first true cephalopod so far discovered is Plectronoceras from the Late Franconian (Late Cambrian) of China. These first cephalopods were small endogastric cyrtocones with empty siphuncles and without cameral deposits.

ONTOGENY

The nautiloids had growth characteristics very different not only from other invertebrates but also from other cephalopods. Using Nautilus as a guide, it seems probable that most nautiloids grew slowly and reached a mature size (coincident with reaching sexual maturity) after which growth ceased. In species of Nautilus, an adult conch may contain 30-36 chambers which represents 10-20 years of growth.

Ontogeny of extinct nautiloids is based on sparse fossil evidence and on studies of Nautilus (Ward, 1987, 1988). Females probably laid only a few large (up to 45 mm in Nautilus) eggs per year (about 12 for Nautilus). Hatchlings were relatively large (up to 25 mm in Nautilus) with several camerae (7 in Nautilus) already formed. When preserved, several morphological changes are usually evident to indicate about when hatching occurred. One change involves spacing of the septa. Septa formed in the egg are usually spaced farther apart than those secreted subsequent to hatching. Also, the shell often shows a constriction and a change in ornamentation from embryonic markings to true growth lines that begin only after hatching has occurred.

Septa formation occurs infrequently in Nautilus and the rate of formation decreases in cold water, at greater water pressure, and as maturity is approached. The formation of a new septa is initiated when the cameral liquid, which is removed by the siphuncle by osmosis, in the previous chamber falls below the level of the siphuncle. As the animal moves forward, a thin septa is secreted with the new chamber full of liquid. Removal of liquid in the new chamber begins only after the septa has been strengthened enough to with stand the near vacuum that results as fluid is withdrawn. During this period, neutral buoyancy is maintained by the removal of liquid in the previous chamber which compensates for the increase in weight of the growing animal. Such growth is permitted by the continuous secretion of new shell material at the aperature.

As the cameral fluid is removed, some gas does filter into the chambers from the siphuncle but the gas pressure is always less than one atmosphere. The rate of fluid removal can be adjusted and evidence indicates that some fluid can be returned to the chambers to compensate for a weight reduction due to damaged shell material (Ward, 1987, 1988).

As most nautiloids approached maturity, the spacing between the newly formed septa nearest the living chamber began to decrease (the chambers became smaller). This reflects the animal's final fine-tuning adjustments so that neutral buoyancy could be maintained as growth slowed and then stopped and, although variable from one individual to another, usually affected the final 2-6 camerae.

Truncation, in which juvenile portions of the conch were periodically shed, occurred in the Ascocerida and some species of the Orthocerida as a method of maintaining neutral buoyancy during ontogeny.

SEXUAL DIMORPHISM

In a study by Saunders and Spinosa (1978), it was determined that Nautilus males have larger shells and broader apertures than females. They also determined that dimorphism is a function of sexual maturity since juveniles display no significant differences.

To determine sexual dimorphism in fossil nautiloids, large numbers of specimens are needed so that a significant population can be sampled. This has been accomplished for only a few species (Teichert, 1964). It has even been proposed that some populations in which two similar forms have been designated as separate species may, in fact, simply be sexual variants of the same species. This is further complicated by the fact that two similar forms may indeed be separate species.

LIFE MODES/PALEOECOLOGY

The debate over the orientation (vertical or horizontal) of straight shelled nautiloids was finally resolved upon sectioning specimens and examining the interiors of the camerae. Camerae located near the posterior end of many medium to large straight shelled forms often contain a series of structures called cameral deposits that are concentrated on the venter. They are believed to be organic secretions which counterbalanced the mass of the living animal in order to counteract the buoyant effect of gas in the phragmocone so that the conch would remain in a "comfortable" horizontal orientation (with the venter down) instead of the awkward vertical position that was at one time postulated (Flower, 1939, 1957; Frey, 1989). As the animal grew and increased its mass, the mass of the cameral deposits would also have increased so that the centers of gravity and

buoyancy would remain coincident near the middle of the conch and a horizontal orientation could be maintained (see Figure 4). There is, however, a point of diminishing returns in which increased cameral deposits must have been accompanied by an increase in subsequent gas chamber size to maintain neutral buoyancy. As this occurred, overall shell size and mass increased which would have limited the swimming ability and maneuverability of the individual.

Color markings, mentioned above, can also indicate horizontal or vertical orientation. Horizontally oriented conchs usually have such patterns (when preserved) only on the dorsum (Foerste, 1930; Frey, 1989). This makes sense if the color markings acted as camouflage patterns (Cowen, et. al., 1973). When seen from above, markings on the dorsal side of a swimming nautiloid would have blended in with the substrate background and disrupted the shell profile to potential predators. The ventral side, on the other hand, was devoid of markings. Such a pale surface would have been more likely to blend in with the brighter surface waters, when viewed from below, than a patterned surface.

Smaller, curved nautiloids usually do not contain cameral deposits and apparently did live in a somewhat vertical position (or possibly parallel and confined to the substrate). Color markings on these conchs often form banding that encircles the entire shell which would indicate a benthonic mode of life (Foerste, 1930; Frey, 1989).

The swimming ability of neutrally buoyant fossil nautiloids, particularly coiled forms, would probably not have been much different than that of Nautilus. The presence of a deep hyponomic sinus in many species seems to indicate that these individuals were equipped with movable hyponomes for propulsion. Although the preferred direction of movement would have been horizontal (and backwards), neutrally buoyant individuals would have been able to rise and descend through the water column (Westermann, 1973). Coiled forms would have had an advantage over longicones in that neutral buoyancy could be maintained without the necessity of secreting heavy cameral deposits thus allowing for greater maneuverability.

Possibly the most maneuverable group of nautiloids were members of the Ascocerida. In the Ascocerida (as well as in some of the Orthocerida), periodic truncation of juvenile longiconic portions of the conch would lessen the weight. The mature conch, after a final truncation, would consist of a relatively large living chamber with the few remaining camerae located dorsally over the living chamber to maintain a horizontal attitude and neutral buoyancy. This, along with the presence of a deep hyponomic sinus, indicates exceptional maneuverability.

Not all nautiloids were able to maneuver in the water column, however. Those with closely spaced septa (small gas chambers), highly depressed forms (low volume to surface area ratios), or extremely large siphuncles (heavy with small gas chambers) were most likely confined to the substrate. In addition, the ornamentation of some forms (e.g. Zitteloceras with its crenulated frills) would be drag-inducing thus limiting their maneuverability. Extremely depressed forms (e.g. Gonioceras) may have lived as benthonic burrowers similar to present day flounders.

Holland (1987) suggests that the feeding habits of the nautiloids were as varied as shell morphology ranging from planktonic filter feeders to free-swimming nektonic predators to benthonic grazers. Evidence exists for active nautiloid predation on brachiopods and trilobites in the form of damaged

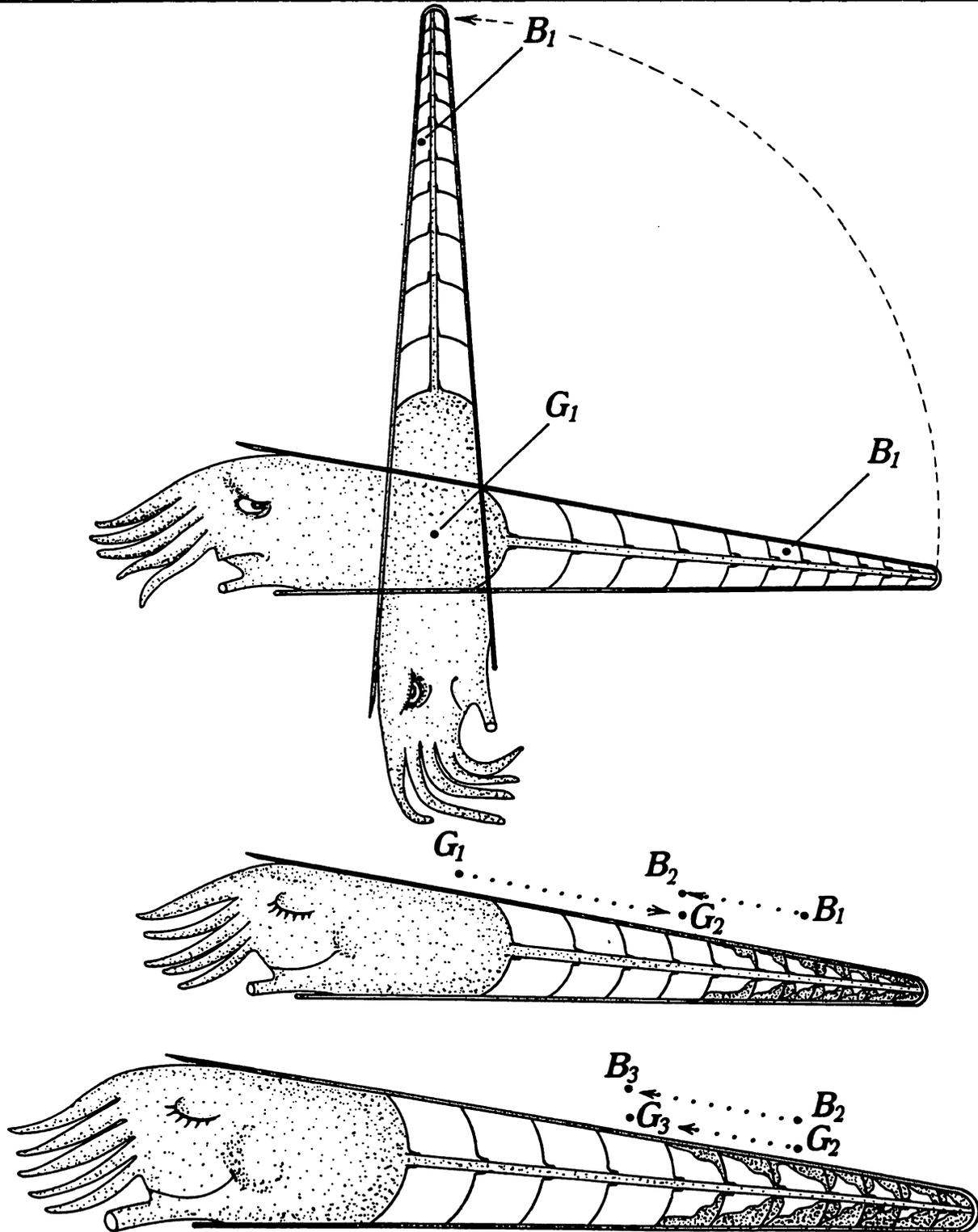


Figure 4. Whimsical diagram showing the effect of cameral deposits on conch orientation. As the animal grows, the cameral deposits also increase so that the center of mass and the center of buoyancy are coincident near the middle of the conch. (modified after Flower, 1957)

specimens consistent with presumed nautiloid feeding apparatuses (Alexander, 1986; Frey, 1989).

Hewitt and Stait (1988) report cyclical variations in the septal spacing of several shallow water Ordovician nautiloids. (I have personally found a large Cameroceras cf. C. alternatum in the Platteville that also shows variable septal spacing.) They reasonably assume the cause to be temperature variations that would have affected feeding and growth rates. Seasonal fluctuations is given as the underlying cause of these temperature variations. The presumed equatorial habitat of many of these nautiloids complicates this reasoning. In an earlier article, Hewitt (1984) states that some type of migration cycle could also account for the temperature differences and, hence, the variable septal spacing. He then, unfortunately in my opinion, dismisses this possible cause in favor of local temperature changes (seasonal cycles). Most living cephalopods undergo some type of migration (either monthly or seasonal) and it is not unreasonable to assume a similar behavior in extinct forms.

It has been generally assumed that postmortem distribution of floating conchs due to currents and tides, as well as possible seasonal and/or monthly migration patterns, could have deposited the shells of many nautiloids in preservation sites often far removed from normal habitat areas (Reyment, 1958). These fossil nautiloid assemblages would not represent true biological associations. However, recent studies of Nautilus shells following death indicate that postmortem drift may not be as common an event as once thought. Apparently, most shells are deposited on the substrate in the immediate area in which death has occurred (Frey, 1989). My studies of the distribution of Platteville nautiloid species in which consistently similar faunas (made up of known floaters as well as postmortem sinkers and Goniceras, a genus known to be confined to the substrate) occur at widely separated localities tend to support the conclusion that at least some fossil assemblages represent true biological associations.

THE ORDERS

Presently, 14 orders (see Figure 5) of nautiloids are recognized and range from Late Cambrian to Recent. Since Plectronoceras, as stated above, is the oldest recognizable cephalopod, it is assumed that the ancestral nautiloid (and, hence, cephalopod) order was the Plectronocerida. This order gave rise to two other orders in the Late Cambrian, the Protactinocerida and the Ellesmerocerida. The Ellesmerocerida, in turn, gave rise to the Yanhecerida also in the Late Cambrian. Most species in all four orders consisted of endogastric cyrtocones although some longicones and exogastric cyrtocones were present. Coiled forms were present in the post-Cambrian Ellesmerocerida. Habitats are presumed to be confined to the benthos of the inner and outer shelf. The Ellesmerocerida was the only order to survive the Late Cambrian bottleneck (see below in Evolutionary History) and thus it gave rise to all post-Cambrian cephalopods.

The Endocerida, consisting mostly of medium to large orthocones, evolved from the Ellesmerocerida in the Early Ordovician and contains the largest nautiloids known with some individuals reaching an estimated nine meters. Siphuncles were very large and were composed of structures known as endocones. These cone-in-cone features apparently served the same counterweight function as did cameral deposits in other orders. Color patterns, when preserved, are found only on the dorsum. Some species also exhibit variably space septa which, as has been stated above, is indicative of either seasonality or migration. Most members were probably nektonic swimmers reaching depths of 300-500 m with the

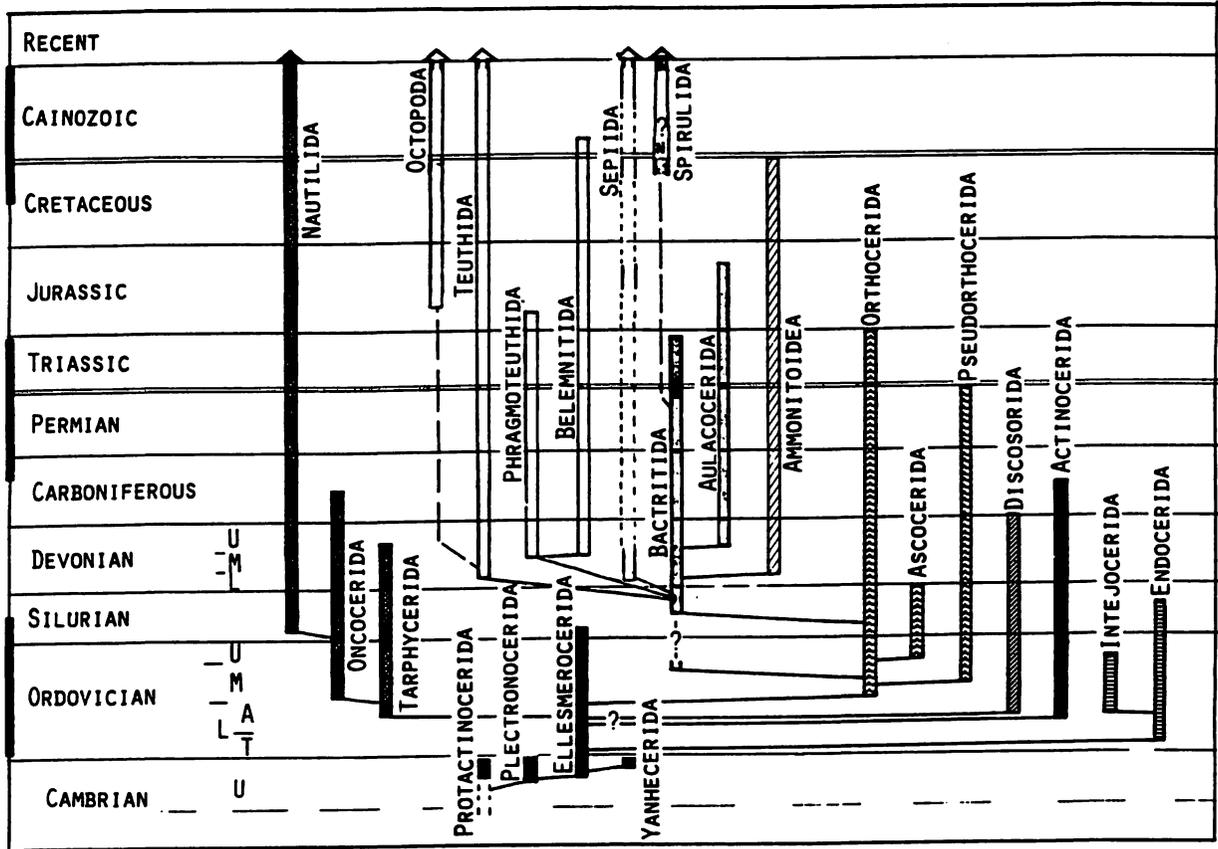


Figure 5. Phylogenetic chart of the nautiloids and their descendants. (Modified after Wade, 1988)

largest forms confined to the benthos (all depth limit estimates from Westermann, 1973).

The Endocerida gave rise to the Intejocerida in the Early Ordovician. The members of this order are similar to those of the Endocerida except that longitudinal radial lamellae (blades) were present in the siphuncle instead of endocones.

The Actinocerida, derived from the Ellesmerocerida in the Early Ordovician, consists mostly of medium to large, slightly to extremely depressed longicones with massive cameral and siphonal deposits. They were probably fairly active swimmers inhabiting the nektobenthos up to 150 m in depth. The extremely depressed forms (e.g. Gonioceras) were specialized as benthonic crawlers and burrowers confined to the substrate.

The Discosorida, also derived from the Ellesmerocerida, is a rare order that arose in the Early Ordovician. This order consists mainly of primitive endogastric cyrtocones with closely spaced septa although exogastric cyrtocones were later present. Members of this group inhabited the benthos to a depth of 50-100 m.

The Tarphycerida evolved from the Ellesmerocerida in the Early Ordovician and contained mainly coiled forms. The living chamber was carried beneath the coils and neutral buoyancy was probably accomplished by the removal of cameral liquid similar to Nautilus. This, along with the presence of a deep hyponomic sinus, indicates that most of the Tarphycerida were active nektonic swimmers. Flower (1984) abandoned the order Barrandeocerida and placed forms previously assigned to it in the Tarphycerida. The reasons cited for this abolishment include similar structures in both orders once thought to be confined to the Barrandeocerida and the polyphyletic nature of the Barrandeocerida which contained families that apparently arose from different parts of the Tarphycerida.

The Oncocerida, a very diverse order containing mostly exogastric cyrtocones or brevicones but also some coiled forms, evolved from the Tarphycerida in the Middle Ordovician. Closely spaced septa and the absence of cameral deposits suggest that most members of the Oncocerida were nektobenthic saltaters that may have grazed on the substrate at a depth of up to 150 m. Some breviconic forms with more widely spaced septa may have been filter feeders in the plankton.

The Nautilida, derived from the Oncocerida in the Early Silurian, contains mostly coiled forms and the only surviving nautiloid--Nautilus. This order contained the majority of late Paleozoic and all Mesozoic and Cenozoic coiled forms. These coiled forms were active nektonic swimmers reaching depths of 300-500 m.

The Orthocerida evolved from the Ellesmerocerida in the Early Ordovician. This group gave rise to the Bacitrida and, ultimately, to the ammonites. Most forms were orthoconic longicones with small central tubular siphuncles and substantial cameral deposits to maintain neutral buoyancy. There is evidence that some species truncated juvenile portions of the conch during ontogeny. Most were active nektonic swimmers.

The Pseudorthocerida, derived from the Orthocerida in the Middle Ordovician, were very similar to the Orthocerida but differed in having expanded siphuncular segments and more complex deposits in the siphuncle.

The Ascocerida evolved from the Orthocerida in the Middle Ordovician and represent some of the most specialized nautiloids ever to appear. Juvenile orthoconic or cyrtococonic portions of the conch were periodically truncated resulting in an adult shell characterized by a relatively large living chamber and a phragmocone with only a few camerae. The most advanced forms concentrated the camerae of the adult conch over the living chamber dorsally to maintain neutral buoyancy and a horizontal orientation. This, along with a deep hyponomic sinus, points to extreme maneuverability and active nektonic swimming ability.

EVOLUTIONARY HISTORY

The virtually explosive increase in the number of cephalopod species in the Late Cambrian represents a late phase of the initial metazoan radiation in which new innovations (in this case neutral buoyancy) gave animals a competitive edge. Empty ecospace waiting to be filled and the low level of competition at this time contributed to the initial success of the nautiloids (Holland, 1987). This initial nautiloid radiation is well documented in the Late Cambrian rocks of the Fengshan Formation (Franconian and Trempealeauan) of China. This diverse nautiloid fauna, reported by Chen and Teichert (1983a, 1983b), has greatly changed our view of early cephalopod evolution. Rocks of the lower Yenchou Member of the Fengshan Formation have yielded only 3 species of the original nautiloid genus Plectroceras. The rocks of the upper Yenchou have produced 12 species in 3 orders. The culmination of this initial radiation took place during the deposition of the Wanwankou Member of the Fengshan Formation. About 120 species representing 34 genera have been collected from rocks of the Wanwankou. This first radiation event was completed in about 7.5 million years with the Wanwankou maximum lasting only about 2.5 million years. At the end of this period and about 2.5 million years before the end of the Cambrian the first of three major bottlenecks in the history of the nautiloids occurred. It appears that only two genera, Clarkoceras and Ectenolites both of the Ellesmerocerida, survived to continue the nautiloid lineage into the Ordovician (Teichert, 1985, 1988).

The greatest nautiloid diversity occurred during the Ordovician when nine new orders (Endocerida, Intejocerida, Actinocerida, Discosorida, Tarphyocerida, Oncocerida, Orthocerida, Pseudorthocerida, and Ascocerida) appeared. This second radiation event occurred when the Ellesmerocerida diversified after the Cambrian bottleneck. The only extinction to occur during the Ordovician was of the Intejocerida.

During the Silurian the Nautilida evolved and the Oncocerida and the Discosorida diversified. Extinctions during the Silurian include the Ellesmerocerida, the Endocerida, and the Ascocerida. The Bactritida also evolved during the Silurian from the Orthocerida.

The Devonian saw a slight increase in species of the Nautilida as well as the extinction of the Tarphyocerida and the Discosorida. A major event was the appearance of the first ammonoids which evolved from the Bactritida. The extinctions that occurred during the Silurian and the Devonian were more a gradual decrease in diversity than what is normally thought of as a sudden extinction. The only possible exception is the disappearance of the Discosorida which corresponds to the Framennian extinction event during the Late Devonian.

However, the extinction of one order can hardly be called a crisis in the evolution of the nautiloids (Teichert, 1985, 1988).

The Carboniferous was a time of diversification of the Nautilida (as well as of the ammonoids) along with the extinction of the Oncocerida and the Actinocerida.

The Permian saw a gradual decrease in Nautilida diversity from 70 genera to only 11 at the end of the Permian. Of these 11 genera, 4 continued into the Triassic and 3 others evolved directly into new Triassic genera (Teichert, 1985, 1988). What appears to be a major extinction is really just a continuation of the decreased diversity experienced during most of the Permian. This decrease in diversity is accompanied by the extinction of the Pseudorthocerida near the end of the period.

During the Triassic the Nautilida continued to diversify until about 5-6 million years before the end of the Triassic when the nautiloids experienced their second major bottleneck. At this time the Orthocerida became extinct leaving only one order, the Nautilida. Apparently, only one genus of the Nautilida, Cenoceras, persisted into the Jurassic where it immediately began to diversify.

The remainder of the Mesozoic saw a continued diversification of the Nautilida with only a slight reduction at the end of the Cretaceous. "As with the Permian-Triassic boundary, the Cretaceous-Tertiary boundary was no hurdle in the evolution of the nautiloids" (Teichert, 1988, p. 13).

The third major bottleneck in nautiloid evolution occurred in the late Tertiary resulting in only Nautilus surviving to the present. Some would have us believe that Nautilus is a "living fossil" doomed to extinction. However, it is just possible that, as with the first two bottlenecks, a subsequent radiation event may result in a diversification of the nautiloids once again (Teichert, 1985, 1988). Since each Nautilus species is genetically variable, "it appears that living nautiloids may be actively speciating" (Holland, 1987, p. 13).

As mentioned above, the nautiloids passed through the Cretaceous-Tertiary boundary virtually intact; the ammonites, on the other hand, became extinct. Why? Several explanations based on the differences in morphology, ontogeny, and life habits between the nautiloids and the ammonites have been proposed.

One explanation is centered around shell design. The nautiloids relied on the slow process of calcification to strengthen the shell and septa (which are twice as thick as actually needed in Nautilus) in order to resist water pressure. This added a great deal of weight to the animal. The ammonites, on the other hand, grew at a faster rate by reducing the amount of calcium carbonate secreted in the shell and septa while still remaining pressure resistant. This was accomplished by the introduction of corrugations in the interior shell wall and the septa, evident in the curved and fluted sutures on the outer shell of the ammonites. The resulting shell was well designed for fast growth and to resist pressure but poorly designed to resist the many Late Cretaceous shell-crushing predators (Ward, 1983).

A second explanation points to the great number of ecologically specialized species of ammonites that would be susceptible to large or even small scale environmental changes. The few nautiloid species, on the other hand, exploited a wide range of habitats and were thus more likely to survive environmental change (Landman, 1984).

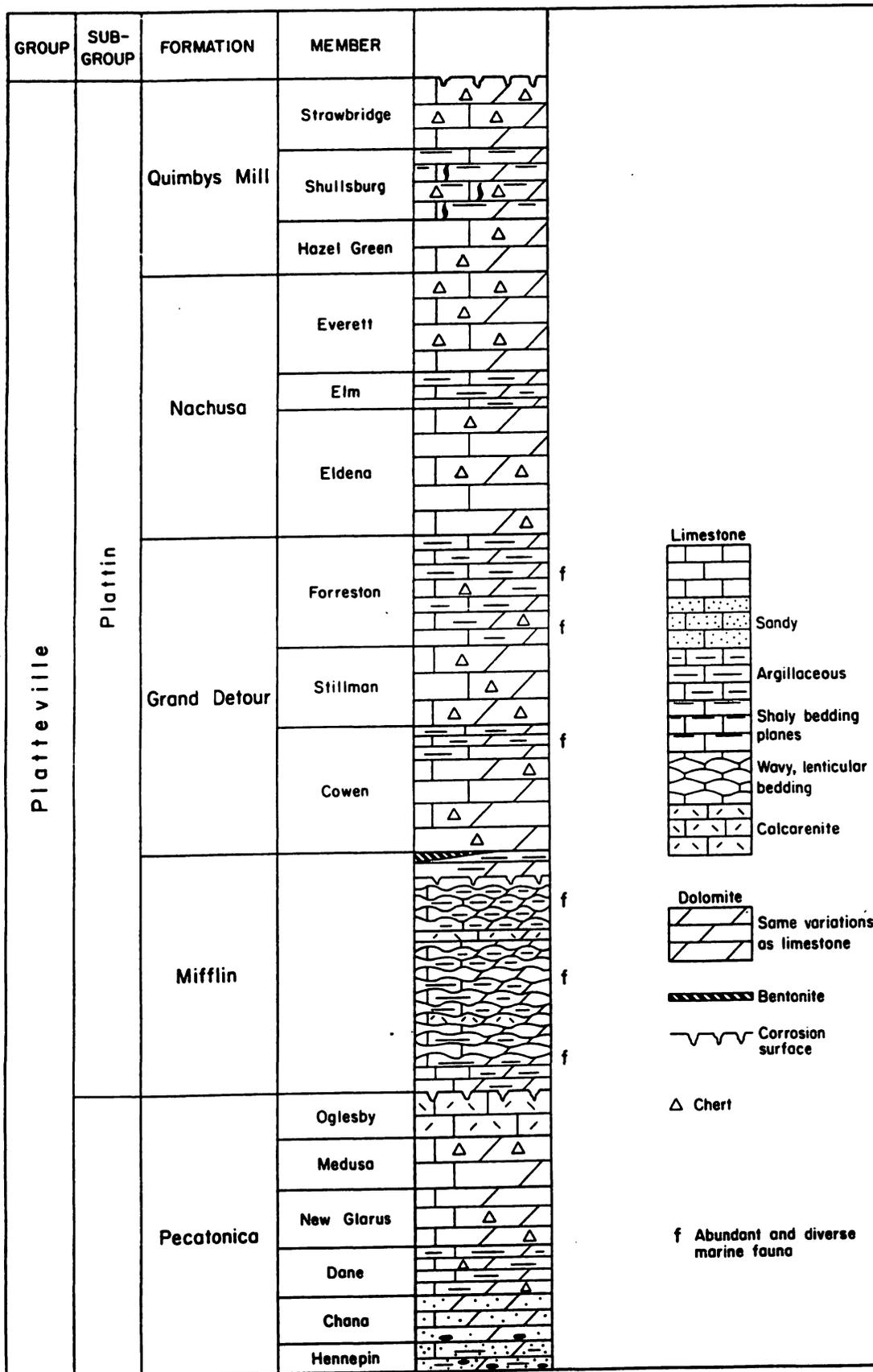


Figure 6. Stratigraphy of the Platteville Group in Northern Illinois. (Modified after Willman and Kolata, 1978)

A third explanation seems to explain both the rapid dispersal of ammonite species and their subsequent extinction. It involves the difference in reproductive strategies between ammonites and nautiloids. As stated above, most nautiloids, at least from the Mesozoic onward, produced few but large (5-25 mm with size increasing through time) eggs that would hatch into large juveniles with several camerae already formed in the shell. These juveniles would then immediately adopt the deep-water adult life-styles in the area of hatching, not an efficient method of dispersal. Fossil evidence shows that, although extremely numerous, ammonite eggs were very small (with size actually decreasing through time) resulting in 1 mm juveniles at the time of hatching. These juveniles would spend time feeding in the plankton which accounts for their rapid world-wide dispersal. Unfortunately, this also made them susceptible to the terminal Cretaceous event which resulted in the collapse of the planktonic system (Landman, 1984; Holland, 1987; Ward, 1983, 1992). Whatever caused this collapse, the ammonite progeny were decimated spelling the end of the entire group.

THE PLATTEVILLE NAUTILOID FAUNA

The Middle Ordovician Platteville (Blackriveran) strata (see Figure 6) of the Upper Mississippi Valley area contains a diverse (Catalani, 1987) and locally abundant nautiloid fauna. Of the 10 orders present during the Middle Ordovician, 9 are represented in Platteville rocks. Table 1 is a preliminary listing of the nautiloid taxa present in Platteville rocks. This list compares the Mifflin Formation and the Grand Detour Formation, those with the most abundant and diverse faunas, in terms of the taxa present in each formation and their relative abundance. This list does not include the proposed fourteen new species and six new genera that I have found in the Platteville nor does it include undefined species of the genera listed.

Since the dominant lithology of Platteville rocks is dolomite, most fossil cephalopods are preserved as steinkerns.

For comparisons to be made, a somewhat subjective way of determining the relative abundance of a particular species in each of the two formations had to be worked out. A scale of relative abundance was arrived at by normalizing the total number of specimens of each species collected to a number of specimens collected per 100 collecting hours. On this scale, a species was considered rare (R) if less than 5 specimens were collected, occasional (O) if between 5 and 10 specimens were collected, common (C) if between 11 and 15 specimens were collected, and abundant (A) if more than 15 specimens were collected.

A total of 28 genera and 40 species of cephalopods are represented in Table 1. Only specifically named species are included in the species count while those designated as "sp." are included to indicate the presence of genera for which species were not able to be determined or to indicate forms not identifiable with published species. In addition to the obvious similarities and differences in the cephalopod faunas of the two formations, there is also a difference in the relative abundance of many of the shared taxa. Both of these differences readily characterize a formation.

The most commonly collected species differs for each of the formations. Whitfieldoceras mumiaforme is by far the most common species of the Mifflin Formation. The most common species of the Grand Detour Formation is more difficult to answer since the two members of the Grand Detour differ in the most common species. For the older Cowen Member Beloitoceras plebeium is the most common while Zitteloceras beloitense is the most frequently found species in the

TABLE 1. Occurrence and abundance of Platteville cephalopods.

ORDER	Species	Mifflin Fm	Grand Detour Fm
ELLESMEROCERIDA:			
	<i>Cyrtoceras crenulata</i>	R	O
ENDOCERIDA:			
	<i>Cameroeras aff. alternatum</i>		R
	<i>Endoceras annulatum</i>	O	O
ACTINOCERIDA:			
	<i>Actinoceras beloitense</i>	R	C
	<i>A. bigsbyi</i>		R
	<i>A. janesvillense</i>	O	O
	<i>Gonioceras kayi</i>		R
	<i>G. occidentale</i>	O	C
DISCOSORIDA:			
	<i>Ulrichoceras beloitense</i>	O	R
TARPHYCERIDA:			
	<i>Centrocyrtoceras annulatum</i>	C	R
	<i>Chidleyenoceras sp.</i>	R	R
	<i>Plectoceras occidentale</i>	R	R
	<i>P. robertsoni</i>	O	O
	<i>Trocholites sp.</i>	R	R
ONCOCERIDA:			
	<i>Allumettoceras planodorsatum</i>	C	R
	<i>A. aff. planodorsatum carletonense</i>		R
	<i>Beloitoceras carveri</i>	R	R
	<i>B. houghtoni</i>		R
	<i>B. janesvillense</i>	O	O
	<i>B. lycum</i>	R	O
	<i>B. norwoodi</i>		O
	<i>B. pandion</i>	O	R
	<i>B. plebeium</i>		A
	<i>B. aff. huronense</i>	R	R
	<i>B. aff. isodorus</i>		R
	<i>Cyrtorizoceras aff. minneapolis</i>		R
	<i>Kentlandoceras sp.</i>	R	
	<i>Loganoceras sp.</i>		R
	<i>Manitoulinoceras neleum</i>		O
	<i>Oncoceras abruptum</i>		R
	<i>O. tetreauvillense</i>		R
	<i>Richardsonoceras beloitense</i>		C
	<i>R. romingeri</i>		R
	<i>R. scofieldi</i>		R
	<i>R. simplex</i>		O
	<i>Tripteroeras oweni</i>		R
	<i>T. planoconvexum</i>	R	O
	<i>Zitteloceras beloitense</i>	R	A
	<i>Z. clarkeanum</i>	R	R
ORTHO CERIDA:			
	<i>Anaspyroceras cylindratum</i>	O	
	<i>A. lesueuri</i>	O	O
	<i>Kionoceras sp.</i>		R
	<i>Metaspyroceras aff. minneapolis</i>	O	R
	<i>Michelinoceras sp.</i>	C	C
	<i>Whitfieldoceras clarkel</i>	R	
	<i>W. mumiaforme</i>	A	R
PSEUDORTHOCERIDA:			
	<i>Ehipplorthoceras sp.</i>		R
	<i>Gorbyoceras sp.</i>	C	C
ASCOCERIDA:			
	<i>Redpathoceras sp.</i>		O

Forreston Member. The most common genus, however, in both formations is Beloitoceras. It follows, then, that members of the Oncocerida represent the largest component (both in number of individuals and number of species) of the fauna in both formations increasing in species diversity through time from 9 (39% of Mifflin species) to 23 (61% of Grand Detour species).

The Mifflin and Grand Detour Formations can be compared in terms of the total diversity of their cephalopod fauna by simply counting the number of genera and species in each. The Mifflin contains 19 (68%) of the total genera and 23 (58%) of the total species while the Grand Detour contains 27 (96%) and 38 (95%) respectively indicating not only a much greater cephalopod diversity in the Grand Detour but also an increase in the cephalopod diversity through time.

CONCLUSION

Never as abundant or as diverse as their descendants the ammonites, the nautiloids have enjoyed quiet success through survival. Three radiations (Cambrian, Ordovician, and Jurassic), the last two after severe extinction events, have allowed the nautiloids to survive until the present. Relatively untouched by the two greatest extinctions (end Permian and end Cretaceous), the nautiloids seemed content to "go their own way" unconcerned with "current events". And today, Nautilus may once again be the single surviving genus that begins a new radiation event. We can only hope. For, even though the biosphere would hardly miss Nautilus, we would be much poorer if we were deprived of this "living fossil". As Shakespeare once said: "I shall not look upon his like again".

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A TRIASSIC JOURNEY THROUGH NEVADA

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Our story begins about 245 million years ago. That region of the world we call the Arctic was a relatively warm sea covering parts of regions we now call Greenland, Spitsbergen, Russian Siberia and Arctic Canada with an arm extending from British Columbia to Southeastern California. Towards the end of the Permian there was wide spread extinction of many ammonoid families. During the Triassic, the seas began to swarm with many new life forms. The ammonoids began to flourish again with great diversity, sharing the seas with ichthyosaurs, counterparts of today's whales and dolphins. It is in these marine deposits, now uplifted to about 5000 feet in elevation that we will visit.

The first Triassic exploration of Western North America began under the leadership of J.D. Whitney of the Geological Survey of California. The state politicians were more interested in gold discovery than geology and Whitney had great difficulty in funding the survey. W.M. Gabb was the paleontologist with the survey who described ammonoids from the Humboldt and East Ranges in what is now present day Nevada. Shortly thereafter, Clarence King led the 40th Parallel Survey by the Federal Government, finding new Triassic localities in Nevada. F.B. Meek and C.A. White's description of the cephalopods and geologic findings were published in this project. Many of the collecting localities became known as a result of mining activities in the 1800s.

We begin our present day trip in Lone Pine, California. Highway 395 winds north thru the Owens Valley with the Sierras on the west side and the Inyo Mountains on the east. From Lone Pine we can see Mt. Whitney, the highest mountain in the contiguous United States. As we are about to leave Lone Pine, we drive east towards the former town of Owenyo and then up the old McAboy trail leading to Saline Valley. Our first stop on the right side of the trail is the Neopopanoceras beds, the highest stage of the Lower Triassic. This locality and most of the then known Triassic deposits of the Western United States were visited and described by J.P. Smith of Stanford University in the early 1900 s.

The ammonoids are found in a dark grey limestone bed about a yard thick and 150 yards long. Most of Smith's generic assignments have been modified. The Haugi Zone in the Northern Humboldt Range, which includes fauna of this locality, is currently under study by Bucher, Guex and Taylor. About a mile up the trail on the right side, there is an older Meekoceras bed in a light grey limestone. The preservation is poor here. Most of the ammonoids are distorted and look like they have been stretched. Smith described over 20 ammonoids from this locality. Nearly all of these specimens except Inyoites oweni, can be found in excellent condition at other Nevada and Idaho localities. For this reason, I still revisit this locality in hope of finding more Inyoites. It is a coincidence that at a site we will discuss later, my friend Jim Jenks has found 6 Inyoites stokesi and in 20 years of collecting at this site, I have never found one!

After a short drive back to Lone Pine and Highway 395, we drive towards Bishop, California. At Bishop, we take Highway 6 and head towards Montgomery Pass Casino in Nevada. For those persons who have never been to Nevada, the casinos almost always have fine inexpensive food, large clean rest rooms and very modestly priced rooms. From the casino it is less than an hours drive to the New York Canyon area near Luning. At Luning, we stop at the Longbranch saloon and talk to the owner, Dick Hegg. Hegg spent part of World War II at the nearby munitions depot at Hawthorne and fell in love with the area around Luning. He tells many stories about paleontologists from Austria, France, Switzerland and geology students from the United States who have studied the Triassic and Jurassic in New York Canyon. One of the most well known European workers was Jean Guex of Switzerland. Siemon Muller did extensive geologic mapping and collecting in this region in the 1930s.

From the Longbranch we drive about 4 miles east on a dry lake bed and walk about 1½ miles up the main branch of New York Canyon. One can see most of the colors of the rainbow on the walls of the canyon and step on chunks of colorful copper ore as we hike towards one of the collecting localities in the canyon. It is a phenomenon here that has attracted so much world wide interest. This is one of the few known localities in the world where the Upper Triassic and Lower Jurassic are both exposed and fossiliferous. The Gabbs Formation (Triassic) is overlain by the Lower Jurassic Sunrise Formation. In this vicinity, the most common Upper Triassic ammonoids we find are of the genera Arcestes, Cochloceras and Rhabdoceras.

They are usually found in a hard dark grey mudstone along with ichthyosaur parts.

From Luning, we take Highway 361 north to Gabbs and then east to Berlin Ichthyosaur State Park. Several nearly complete ichthyosaurs have been uncovered here and a building has been constructed over one specimen for public viewing. Here, the most important Upper Triassic exposure is the Luning Formation which is exposed in Union Canyon. The descriptions of the ammonoids and the stratigraphy of the Union District Shoshone Mountains is contained in U.S.G.S. Professional Paper 322 by Norman Silberling. Silberling has spent much of his life working on mapping, stratigraphy and Triassic paleontology in Nevada. He has also given encouragement and guidance to many graduate students and other workers. He has been most generous and helpful to the amateur collectors.

From the park, we drive on dirt roads for about 50 miles north to Highway 50 and then to a gold mine in the Desatoya Mountains. Don and Kathy Jung have operated the New Pass Mines for over 30 years. It is a beautiful experience to collect ammonoids at an elevation of 7800 feet in a pine forest, then have a shower, enjoy dinner with the Jungs and have a room with a fifty mile panorama. There are exposures of both Middle and Upper Triassic ammonoids here. F.N. Johnston described the Upper Triassic ammonoids in the September 1941 Journal of Paleontology. Some of the less common Anisian stage genera I have found here are Balatonites, Cuccoceras and a new genus Augustaceras described by Bucher (1988).

From the New Pass Mines, we drive west on Highway 50 to Fallon, then north on Highway 95 to Lovelock, north on Interstate 80 a few miles to Oreana, then a short drive east to the Humboldt Mountains and Fossil Hill. This is one of the most important and interesting Middle Triassic sites in North America. J.P. Smith made several trips here in the early 1900s, collecting thousands of ammonoids mostly in float. In his 1914 monograph, he described 110 Upper Anisian species from this vicinity. In the following years, many collections were made here. Some of them ended up in Europe at the British Museum of Natural History where Spath also studied and refigured some of the material (1934, 1951). During the 1950s and 1960s, Silberling and others mapped the entire Humboldt Range. At this time it would be appropriate to introduce Tim Tozer of the Canadian Geologic Survey. Tozer has spent a great part of his lifetime working on all phases of the geology and paleontology of the Triassic. He has traveled to most parts of the world, discussed stratigraphy with

all of the important workers and most importantly organized the efforts of previous workers and present day stratigraphers to develop a time scale for the Triassic. His book The Trias and its Ammonoids: The Evolution of a Time Scale is a monumental land mark as it has a wealth of information for the professional and the amateur written with the style of a master mystery writer that makes it impossible for the reader to lay the book down until he has read it from cover to cover.

During the 1960 s Tozer and Silberling were coordinating their efforts and ideas. Silberling was busy making painstaking stratigraphically controlled population samples from bedrock collections on the south side of Fossil Hill and at a nearby site on Saurian Hill. With new information, larger population samples and observation of intraspecific variation, Silberling began work on reorganizing most of the work done on the ammonoid fauna of the West Humboldt Mountains. Soon, he was joined in the work by Kathryn Nicols, a post-doctoral fellow at U.S.G.S. and later to become his wife. In this work, U.S.G.S. Professional Paper 1207, Smith's 110 Upper Anisian ammonoid species had been reduced to 37. The Rotelliformis, Meeki and Occidentalis zones at Fossil Hill became a world wide biostratigraphic standard of reference for the Upper Anisian. Many of the ammonoids found here are quite cosmopolitan. The author has a Siberian collection in which Gymnotoceras rotelliformis (Meek) is represented. These Middle Triassic rocks belong to the Fossil Hill Member of the Prida Formation of the Star Peak Group.

To collect here, one must be prepared for almost any weather scenario. I have collected in the snow, rain, wind and oppressive heat. Years ago, during wet cycles one might endure rain for several days and see lots of cattle. For the last five years, much of Nevada has been in a severe drought and now one sees mostly flocks of sheep in this area. The shepherders are usually from Spain or Peru and always welcome company in the late afternoon for a bowl of stew. Two years ago, I brought three Japanese paleontologists, Hisao Ando, Haruyoshi Maeda and Kazushige Tanabe to this locality. The first afternoon was a beautiful warm one. By the next morning, the temperature had dropped to 40°Fahrenheit, and my friends were very cold and uncomfortable. Last year, my friend Wolfgang Weitschat (Hamburg University) wanted to compare the Spitsbergen fauna with the Nevada counterparts. The first thing we did before leaving for Nevada was the purchase of a warm coat and sleeping bag for Wolfgang.

One cannot anticipate every event. On my next trip here, I punctured a tire, struggled with a frozen lock nut and then found that I also had a loose steering box. I survived these inconveniencies, but tore the cartilage in my knee climbing the hill. On the way down, I made a rare encounter with a large rattle snake that didn't want to move off the trail. Remembering my grandson had asked me to get him a rattle snake skin, I combined a rest for my knee with the skinning of the snake.

From Lovelock, we drive for about 250 miles east on Interstate 80, then turn north on Highway 233 for 25 miles to Montello, and then drive 18 miles on a gravel road to the Gamble Ranch. On this ranch of over 75,000 acres, one can step back in time and see cattle drives with real cowboys. Until two years ago, Jim Fretwell had been the ranch foreman for 25 years, always giving everyone a warm welcome and a helping hand if needed. In the 1950s during a survey of the regional stratigraphy of Northwestern Nevada, Grant Steele (Gulf Oil Company) made a collection of Lower Triassic ammonoids on the ranch about a mile northeast of Crittenden Springs. Bernhard Kummel (Harvard University) described the ammonoids in the July 1962 Journal of Paleontology. The preservation of the Meekoceras fauna at this locality is considered to be the finest in North America. This site has been visited over the past 30 years by most of the Triassic specialists and many amateur collectors. The deposition of these beds continue to be a subject of much differing interpretation. Some of the beds lie in a manner corresponding to similar beds in Idaho, whereas some are completely overturned. Jim Jenks, a metallurgical engineer from Salt Lake City, Utah has been collecting and studying the area for 25 years. His favorite tool is a steel bar about six foot long. He usually moves more boulders in an hour than the usual collector does in a day of hard work.

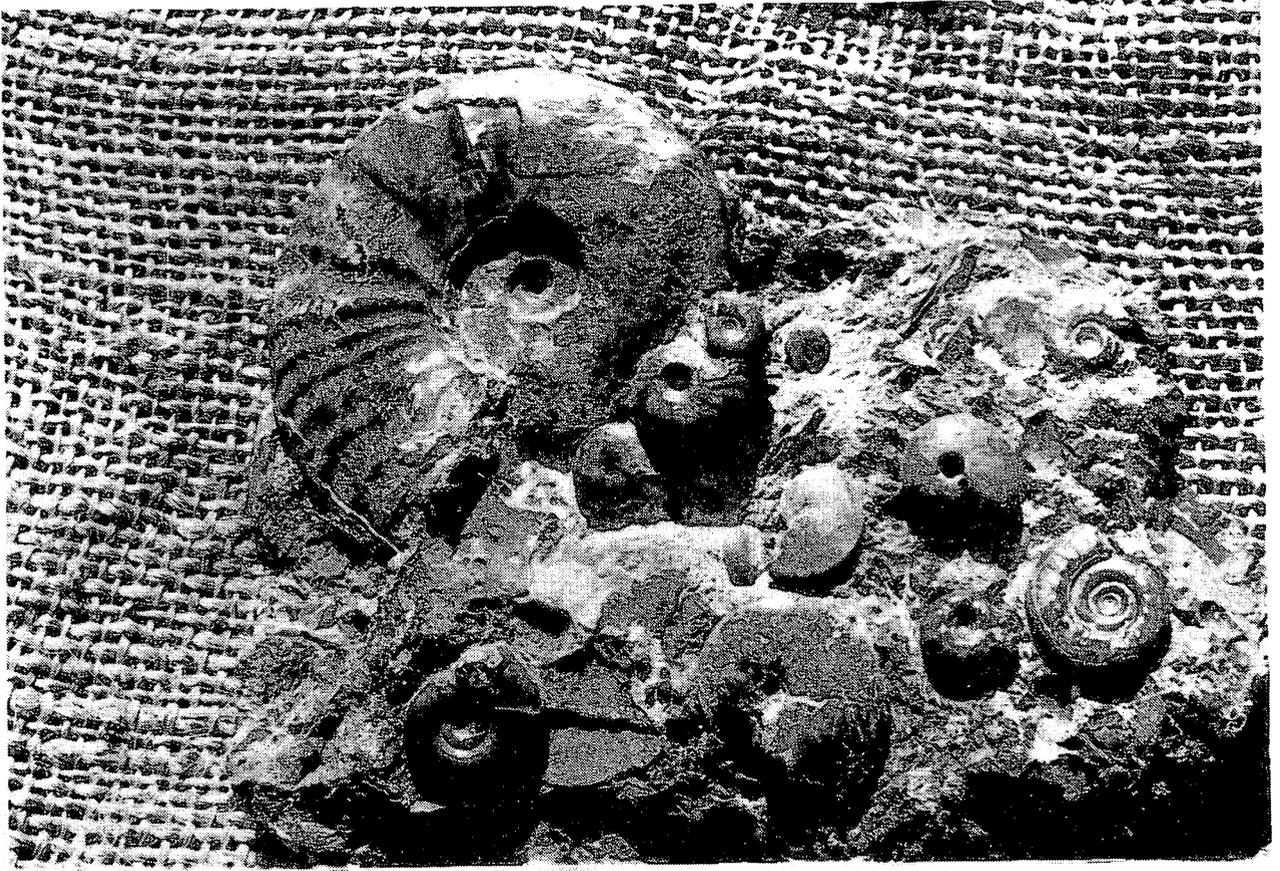
Here, one finds the oldest ammonoids in the world with "colour" patterns. About five years ago, I sent Royal Mapes (Ohio University) some specimens which later resulted in the paper The Oldest Ammonoid "Colour" Patterns by Mapes and Sneek published in Palaeontology, 1987. More intense collecting and study was done in June, 1988 under the umbrella of a National Geographic Society Research Project directed by Royal Mapes. Wolfgang Weitschat has collected the genera, Arctoceras, Paranannites and Xenoceltites from Spitsbergen which are also represented here.

For the serious student, complete listings and descriptions of the ammonoids found in the above mentioned localities can be found in the references. For the collector, there are many other Triassic collecting localities in California, Idaho and Nevada. However, as in most other places, material is getting scarce and one must move a lot of rock and hike a lot to be successful.

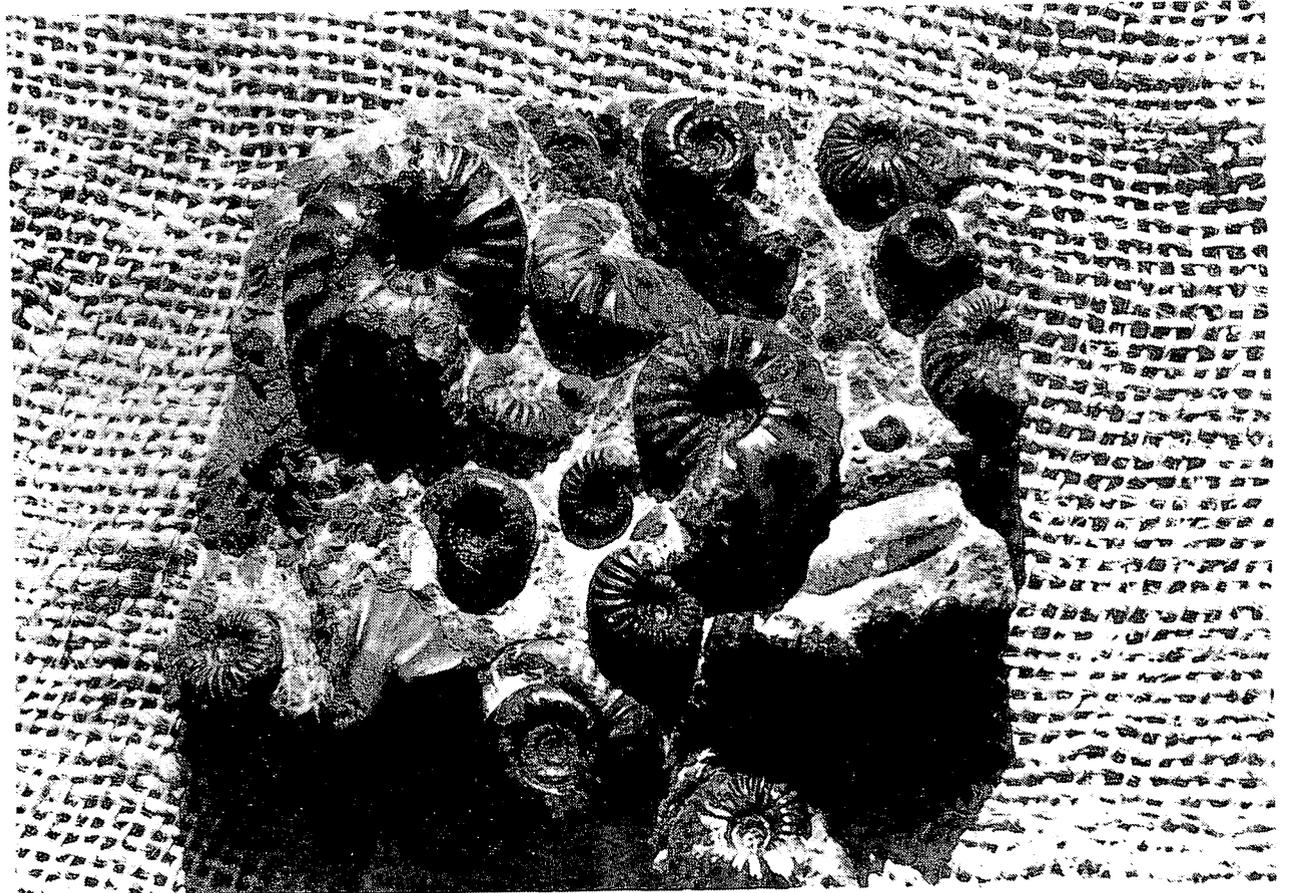
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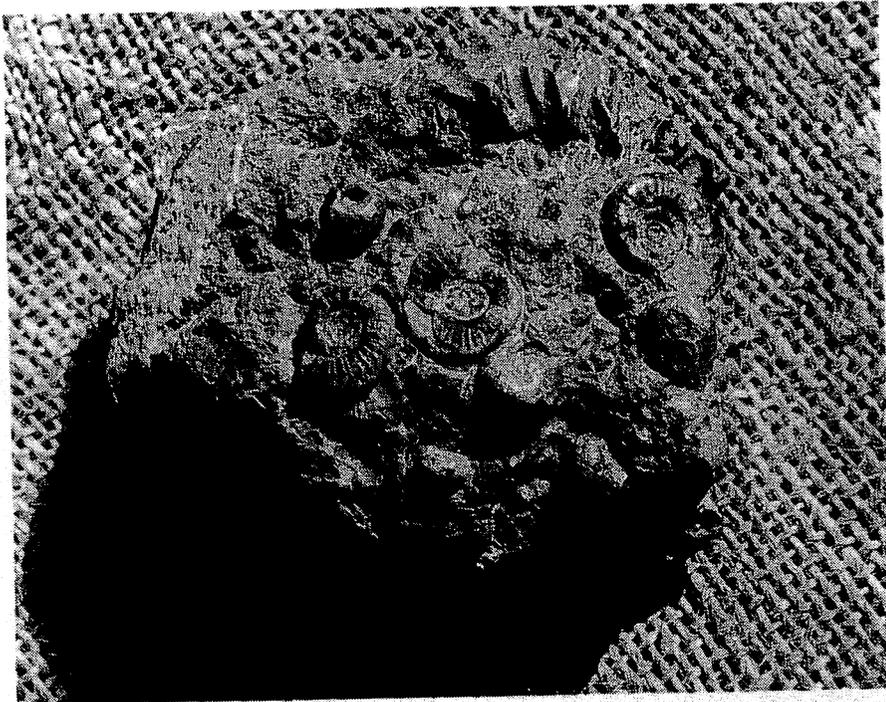
B



C



D



- A Lower Triassic slab, Crittenden Springs, Nevada
Smithian stage
- B Middle Triassic slab, Fossil Hill near Lovelock
Upper Anisian stage, Meeki zone
- C Middle Triassic slab, New Pass Mines
Upper Anisian stage, Rotelliformis zone
- D Lower Triassic slab, Union Wash, California
Spathian stage, Haugi zone

All figures one half natural size

- Arctoceras tuberculatum
Dieneroceras knechti
Dieneroceras spathi
A Juvenites septentrionalis
Meekoceras gracilitatus
Owenites koeneni
Paranannites aspenensis
- B Frechites nevadanus
Parafrechites meeki
Tropigastrites louderbacki
- D Karangatites multicameratus
Neopopanoceras haugi
"Acrochordiceras" cf. "A" inyoense
- C Proarcestes gabbi
Gymnotoceras rotelliformis
Paraceratites clarkei
Atractites sp.

10
11 NEW LATE PALAEOZOIC HYOLITHA (MOLLUSCA)
12 FROM OKLAHOMA AND TEXAS, AND THEIR
13 PALAEOENVIRONMENTAL SIGNIFICANCE

14
15 by JOHN M. MALINKY, ROYAL H. MAPES and THOMAS R. BROADHEAD

16
17 ABSTRACT. Recovery of over 900 hyoliths from fourteen localities in Oklahoma and Texas greatly increases
18 the number of late Palaeozoic hyolith occurrences in North America; they include *Lirothea wilsoni* Malinky
19 and Mapes, 1983 and *Darwinites grafordensis* gen. et sp. nov. Many of the hyoliths lack opercula and
20 taxonomically important features of the aperture, or they are crushed; these specimens are indeterminate. In
21 Oklahoma the hyoliths are restricted to the dark grey to black, non-fissile, phosphatic shale members (=
22 'core' shales) of Pennsylvanian cyclothems. These shales are thought to be the most offshore facies of the
23 cyclothem. The occurrence of hyoliths in dark grey, locally phosphatic, shale members of cyclothems farther
24 south in Texas further supports the assignment of these shales to offshore, slightly oxygen-poor marine
25 environments rather than to shoreline lagoons.

26
27 LATE Palaeozoic hyoliths are little known because of their rare occurrence and generally poor
28 preservation. Hyoliths range from early Cambrian to late Permian, but are only abundant in the
29 Lower Palaeozoic. Bulk sampling of shales in Oklahoma and Texas to recover bactritoid cephalo-
30 pods (Mapes 1979) has demonstrated that hyolith abundance and diversity are greater in the late
31 Palaeozoic than was previously believed.

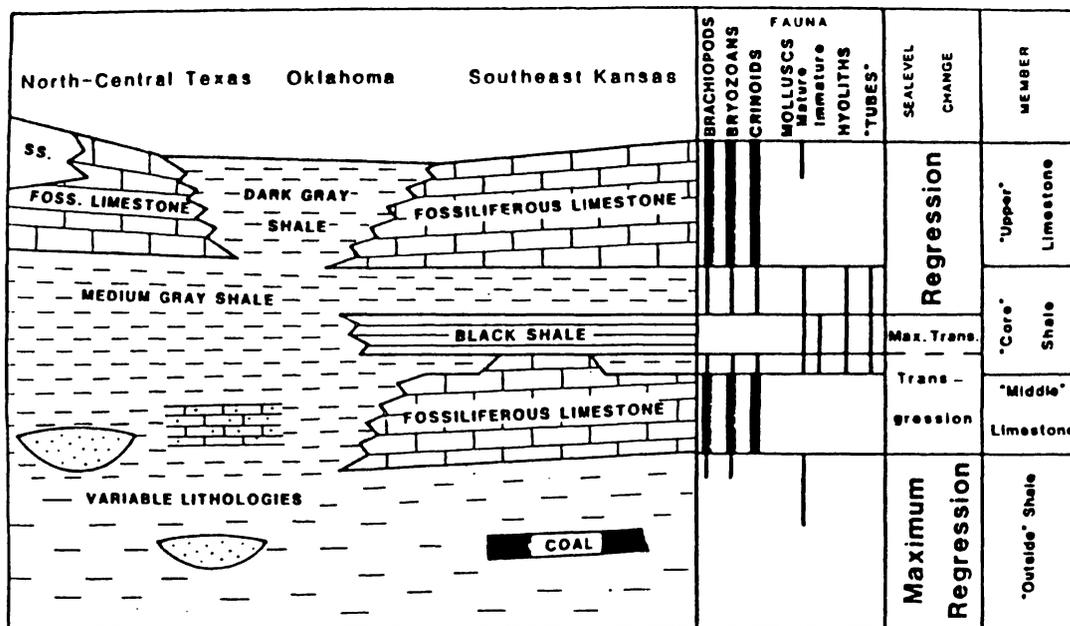
32 The first record of a Pennsylvanian hyolith is *Hyolithes carbonaria* Walcott, 1884, probably from
33 the Ely Limestone in eastern Nevada. Walcott termed the unit from which he recovered his specimen
34 the 'Lower Carboniferous limestone', although subsequent investigations have demonstrated that
35 unit to be early Pennsylvanian rather than late Mississippian in age (Larson and Langenheim 1979).
36 No other Pennsylvanian specimens were known (Yochelson and Saunders 1967) until *Lirothea*
37 *wilsoni* Malinky and Mapes, 1983 was discovered in the Eudora Shale Member of the Stanton
38 Formation in south-eastern Kansas and in the Wolf Mountain Shale Member of the Graford
39 Formation in north-central Texas. The facies in which that species was discovered represents an
40 offshore, oxygen-poor, though otherwise normal marine environment at the Kansas locality (Heckel
41 1975) and probably at the Texas locality as well (Malinky and Boardman 1983, 1984). *L. wilsoni*
42 was the first hyolith to be recovered from an oxygen-stressed environment in the late Palaeozoic,
43 and the first North American hyolith to be assigned to a genus other than *Hyolithes* Eichwald,
44 1840. Now over 900 additional specimens have been recovered from localities in Oklahoma and
45 Texas. These specimens enhanced our knowledge of the palaeoecology and palaeoenvironmental
46 preferences of late Palaeozoic hyoliths, and help to clarify the concept of *Hyolithes* Eichwald,
47 1840. Our purpose is to document these occurrences and briefly discuss their palaeoenvironmental
48 significance.

49
50 PALAEOENVIRONMENTAL SIGNIFICANCE
51

52 Pennsylvanian strata in the northern Midcontinent are dominated by transgressive-regressive lithic
53 sequences, or cyclothems. The furthest offshore unit of each cyclothem usually consists of a fissile,
54 black, phosphatic shale facies at the base and a non-fissile grey shale facies at the top (text-fig. 1).
55 These facies constitute the 'core' shale (Heckel and Baesemann 1975), so called because it usually

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occupies a central position between an underlying transgressive limestone and an overlying regressive limestone. The black facies is thought to represent an anoxic, offshore, marine environment, deposited below a layer of anoxic water at maximum transgression; the grey shale is interpreted as a dysaerobic offshore facies, emplaced with the partial return of bottom oxygen at the start of regression (Heckel 1977). The lithic character and stratigraphic position of northern Midcontinent 'core' shales provides for their easy recognition; in the southern Midcontinent, however, and particularly in Oklahoma, the distinctive lithic character of the 'core' shales is lost at some localities because the black fissile facies is absent. Additionally, these southern Midcontinent cyclothems are usually dominated by shale which further obscures their cyclicity. The identification of 'core' shales in the southern Midcontinent is therefore made more difficult because of lithic similarities between 'core' shales and the nearshore shales, and because of the absence of limestones. Such shale-dominated cyclothems in this region define the terrigenous-detrital facies belt (Heckel 1968).



TEXT-FIG. 1. Diagram showing distribution of Hyolitha and other commonly occurring macroinvertebrates within Midcontinent Pennsylvanian cyclothems. Relative thickness of vertical lines indicates relative abundance of tax; thick lines indicate common taxa; thin lines indicate scarce taxa. 'Tubes' refer to problematic organisms of uncertain affinities now under study. Lithologic symbols standard. Cyclothem modified after Heckel (1977).

The palaeontological character of northern Midcontinent 'core' shales is distinctive; the abundance and diversity of conodonts attains a maximum in the black 'core' shale, and several conodont taxa are restricted to that facies (Heckel and Baesemann 1975). In contrast, the distribution of conodonts in some 'core' shales from the terrigenous-detrital facies belt may be irregular and does not follow the patterns seen elsewhere. The 'core' shale interval in these cyclothems was recognized by Boardman *et al.* (1984), using the distribution of macrofaunal assemblages throughout the cyclothem. They amplified and applied the community succession model of Calver (1968), which was derived from faunal distribution in Westphalian cyclothems of Great Britain, to cyclothems in

MALINKY, MAPES AND BROADHEAD: LATE PALAEOZOIC HYOLITHA

the terrigenous-detrital facies belt. They determined that the *Caneyella*, *Dunbarella*-ammonoid-radiolarian community which usually occurs in a black, phosphatic shale, occupied the most offshore position, whereas the *Trepostira*, *Sinuitina*-ammonoid-*Anthraconeilo* community in medium to dark grey shales, occurs in facies marking the start of regression. This latter community has been divided into two, including the *Sinuitina*-juvenile ammonoid-*Anthraconeilo* subcommunity which includes rare corals, trilobites, echinoderms (including blastoids), and sponges; molluscs are common and include gastropods, bivalves, cephalopods, scaphopods, rostroconchs, and polyplacophorans; faunal diversity is high, but the abundance of organisms varies among localities.

The majority of hyoliths collected to date from localities in the terrigenous-detrital facies belt were discovered within dark gray 'core' shales containing the *Sinuitina*-juvenile ammonoid-*Anthraconeilo* subcommunity (text-fig. 1), although the relative abundance of hyoliths in that community is highly variable among localities. Hyolith occurrences in the Smithwick Formation (Atokan) and the Deese Group (Desmoinesian) have not been investigated in the same detail as those from other Midcontinent localities. These two units apparently represent a wide range of environments (Fay *et al.* 1979; Kier *et al.* 1979), although cephalopods, trilobites, blastoids, and other fauna at the same position as the hyoliths suggest that the hyolith-bearing units represent offshore marine environments.

The apparent restriction of Midcontinent Pennsylvanian hyoliths to known 'core' shales in the terrigenous-detrital facies belt in Oklahoma probably reflects a genuine preference for that environment. Numerous early and more recent palaeontological studies of the limestones and other near-shore units in cyclothems (e.g. Mudge and Yochelson 1962; Moore 1964), and recent petrologic and petrographic studies of the limestones (see Heckel 1984, bibliography) have failed to locate hyoliths. Thus, the occurrence of hyoliths only in 'core' shale members of Midcontinent Pennsylvanian cyclothems provides an additional tool for the recognition of such 'core' shales in areas where other evidence is inconclusive or ambiguous.

The cyclic nature of Pennsylvanian strata in north-central Texas has long been recognized, although the furthest offshore unit has been in dispute. Diversely fossiliferous shales above the basal fluvial/deltaic package in these cyclothems have formerly been interpreted as lagoonal in origin (Erleben 1975), with the overlying limestone regarded as the most offshore facies. Malinky and Boardman (1983, 1984) suggested that the fossiliferous shale is a 'core' shale, depositionally similar to those from northern Midcontinent localities. This interpretation is based upon high faunal diversity, the presence of phosphate nodules at many localities, and diagenetic patterns in the limestone members of these cyclothems. Hyoliths have been recovered only from the diversely fossiliferous shale members of Texas cyclothems, such as the Wolf Mountain Shale (Graford Formation; Missourian), the Finis Shale, Bluff Creek Shale, and Wayland Shale (all Graham Formation; Virgilian). Their occurrence in the shale facies suggests that such units are 'core shales' and supports the assignment of these shales to offshore marine environments rather than to marginal marine lagoons.

SYSTEMATIC PALAEOONTOLOGY

Introductory comments. Outside Eastern Europe and the Soviet Union the taxonomy of the Hyolitha has long been neglected, and remains particularly underdeveloped in North America. The generic name *Hyolithes* Eichwald, 1840 has been extensively used for many North American hyolith species; at one time it encompassed over 360 species (Sicclair 1946). This broad generic concept is the result of a vague and generalized original description of *Hyolithes* by Eichwald (1840, p. 97) in which only the sub-triangular transverse outline of the shell and the presence of apical septae were noted. Much of the original description consisted of discussion of possible affinities, a matter still of argument. Consequently, a variety of organisms possessing shells with generally sub-triangular transverse sections came to be included in *Hyolithes*. All species now encompassed by that genus warrant re-examination.

Sysoiev (1958, 1959) emended *Hyolithes* but still retained a variety of transverse shapes within the genus. We prefer a generic concept more closely conforming to Eichwald's original specimens as illustrated by Fisher (1962, p. W123 fig. 67. 1a-d). We consider *Hyolithes* to have a broad, depressed dorsum,

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139 grading into a pronounced longitudinal sulcus at each edge of the dorsum, and rounded lateral margins. The
140 venter is slightly inflated and the ligula is low and ventrally curved. The dorsal apertural margin has a flare
141 and the transverse section is sub-triangular. The apical end of the shell curves dorsally. The operculum is
142 unknown.

143 The standards of quality for type specimens of *Hyalithes* species have changed. Now only specimens
144 retaining well-preserved apertural detail should be used as types. The apertural features, as well as a number
145 of other characters of the conch and operculum, have been used for generic and specific level taxonomy
146 (Marek 1966a) although we judge that a well-preserved conch lacking an operculum, or even the internal
147 mould of the conch, can be confidently identified to genus and species in some taxa.

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149 *Repository.* All specimens are housed in the National Museum of Natural History, Washington, DC.

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Phylum MOLLUSCA
Class HYOLITHA Marek, 1963
Order HYOLITHIDA Matthew, 1899
Family HYOLITHIDAE Nicholson *vide* Fisher, 1962
Genus DARWINITES gen. nov.

Type species. *Darwinites grafordensis* gen. et sp. nov.

Diagnosis. Hyolith having a small ligula on the ventral apertural margin, a low dorsal ridge with flattened flanks, and a depressed sub-triangular transverse section; the aperture is expanded noticeably, and the mould tapers rapidly to a pointed apex.

Discussion. The absence of longitudinal sulci and an apertural flare on the dorsum of *Darwinites* clearly distinguish it from *Hyalithes*. Furthermore, *Darwinites* possesses a dorsum with a narrowly rounded median keel, whereas the dorsum on *Hyalithes* is rounded. The low ventral shelf, narrowly rounded dorsal ridge, and conical shape of *Darwinites* separate it from *Lirotheca* Malinky and Mapes, 1983 (from the Pennsylvanian of Kansas). Furthermore, the dorsal ridge on *Lirotheca* is inflated rather than depressed and the ventral ligula is larger. These features support generic status for *Darwinites*.

Etymology. This genus is named for Darwin R. Boardman in recognition of his work in field and laboratory studies of Midcontinent stratigraphy and palaeontology.

Darwinites grafordensis gen. et sp. nov.

Text-fig. 2A-C

Diagnosis. See genus.

Material. Three specimens: holotype, USNM 390488, loc. V-2, Virgilian; paratype, USNM 390487, Poc. M-3, Missourian; and paratype, USNM 390489, loc. V-3, Virgilian. See Appendix for locality details.

Description. The dorsum possesses a low median dorsal ridge, with a narrowly rounded crest and flattened flanks adjacent to it. The lateral margins are broadly rounded and the venter is flat with a small ligula along the apertural margin. The transverse shape is depressed, and the mould tapers rapidly toward the apex. The apex curves slightly toward the dorsum.

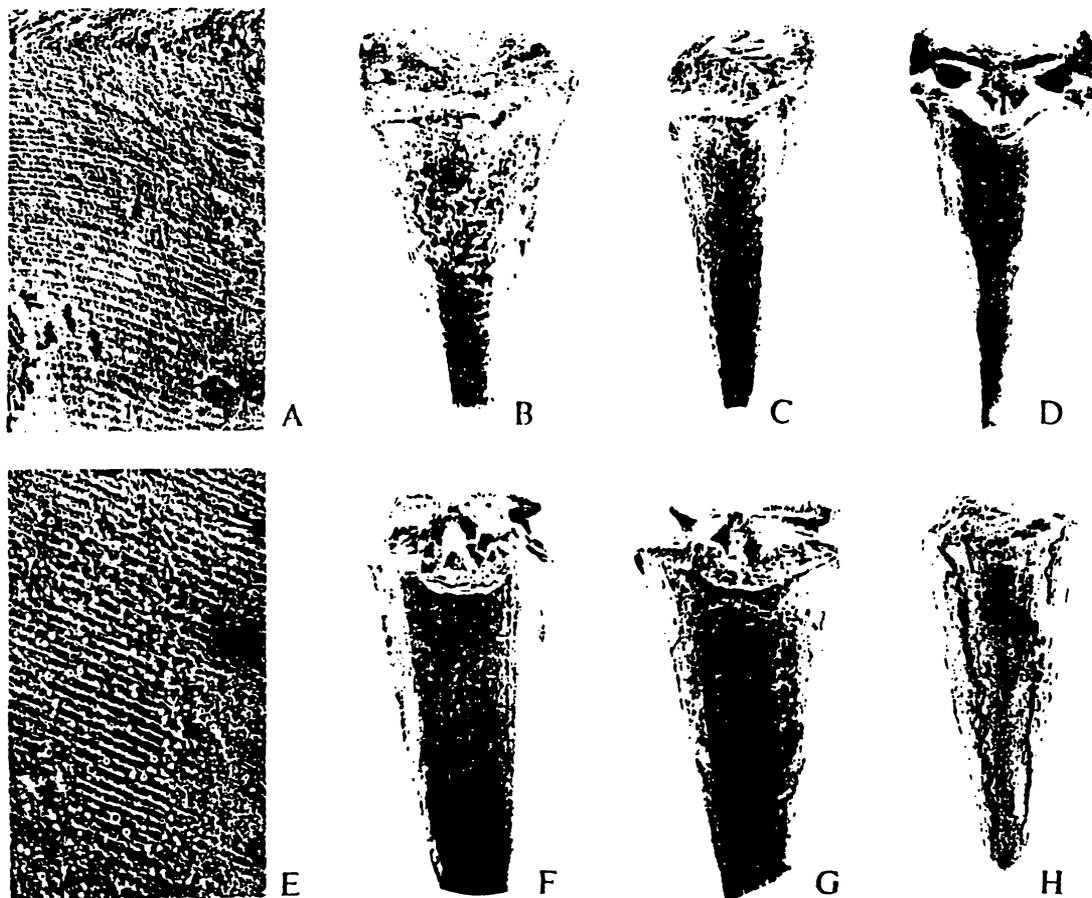
Closely spaced transverse lirae occur on the internal mould of the dorsum (text-fig. 2A), and a faint sulcus is present along each edge of the venter near the apertural end. The operculum has a single set of clavicles (monoclavicate). The conical shield is large and flattened, whereas the cardinal shield is smaller and indistinct. Other details of the mould and the shell are unknown.

The three specimens occur as limonitized internal moulds and only the holotype is well preserved. The holotype is 2.5 mm long, with an apertural width (W) and apertural height (H) of 2.5 mm and 1.7 mm, respectively. The paratypes are comparable in size.

Discussion. *Darwinites* is monospecific. *D. grafordensis* is the second hyolith species to be discovered in the Midcontinent Pennsylvanian of North America, and only the second North American hyolith

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MALINKY, MAPES AND BROADHEAD: LATE PALAEOZOIC HYOLITHA



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TEXT-FIG. 2. SEM photomicrographs of Midcontinent Pennsylvanian Hyolitha. All specimens are internal moulds. A-C, *Darwinites grafordensis* gen. et sp. nov. A, lirae on left flank of dorsum, holotype, USNM 390488, Virgilian, loc. V-2, $\times 240$; B, dorsum, holotype, $\times 20$; C, dorsum, paratype, USNM 390487, Missourian, loc. M-3, $\times 20$. D, *Lirotheca wilsoni* Malinky and Mapes, 1983: dorsum showing prominent moulds of clavicles on operculum, hypotype, USNM 390490, Virgilian, loc. V-2 $\times 10$. E-H, *Hyolitha* incertae sedis. E, dorsum, USNM 390468, Desmoinesian, loc. D-1, $\times 9$; F, dorsal view showing fragmentary monoclavicate operculum, USNM 390466, Desmoinesian, loc. D-1, $\times 8.2$; G, dorsal view showing fragmentary operculum, USNM 390495, Virgilian, loc. V-3, $\times 5.4$; H, venter, USNM 390485, $\times 5.0$.

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taxon assigned to a genus other than *Hyolithes*. Similarly preserved species belonging to closely related genera include *L. wilsoni* Malinky and Mapes, 1983. Differences between those genera have been noted above.

Etymology. The species is named for the Graford Shale, in which hyoliths were first discovered in Texas.

Genus LIROTHECA Malinky and Mapes, 1983

Types species. *Lirotheca wilsoni* Malinky and Mapes, 1983, p. 348.

Diagnosis. Hyoliths having a narrowly rounded dorsum with a prominent flare along the dorsal apertural rim and a ventral ligula: the dorsum has a narrowly rounded median keel; the transverse section is inflated and sub-triangular.

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221 *Discussion.* Differences between this genus and *Hyalithes* Eichwald, 1840 were noted by Malinky
222 and Mapes (1983), and differences between this form and *Darwinites* were discussed above. The
223 occurrence of *Lirotheca* at new localities in Oklahoma and Texas extends its geographic range from
224 south-eastern Kansas, and its discovery in Virgilian strata extends its stratigraphic range from
225 Missourian only into the Desmoinesian and Virgilian.

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Lirotheca wilsoni Malinky and Mapes, 1983

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Text-fig. 2b

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1983 *Lirotheca wilsoni* Malinky and Mapes, p. 348, fig. 1A-C, F, G.

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Diagnosis. See genus.

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Material. Four specimens: hypotypes, USNM 390490 and 390491, loc. V-2, Virgilian; USNM 390492, loc. D-
1, Desmoinian; and USNM 390493, loc. V-3, Virgilian. See Appendix for locality details.

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Description. The dorsum is inflated and possesses a narrowly rounded median keel with inflated flanks adjacent
to it. The lateral margins are rounded, and shallow indentations occur on the apertural rim along the lateral
margins. A shallow sinus also occurs along the aperture where the dorsal keel and apertural rim intersect, and
the entire apertural rim is flared. The venter is flat, and the ventral ligula is strongly curved toward the venter.
The apex curves slightly toward the dorsum.

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Faint transverse lirae cover much of the dorsum. The lirae are straight across the flanks of the dorsal ridge
but curve on the ridge crest to create a shallow sinus. Transverse lirae also cover much of the venter. A sulcus
is present along each margin of the venter; each extends from the shelf about three-quarters the length of the
mould toward the apex.

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The operculum is monoclavicate with well-developed clavicles near the dorsal edge. The conical shield on
the ventral side is flat whereas the dorsal cardinal shield and furrows are inconspicuous. No lirae occur on the
operculum.

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Discussion. The recovery of these larger, well-preserved specimens of *L. wilsoni* affords the oppor-
tunity to supplement the description of the holotype and paratypes, especially concerning details
of the operculum. On the holotype the clavicles are covered with sediment, whereas on these speci-
mens the clavicles are well exposed, so that their monoclavicate nature is certain. The holotype
from the Eudora Shale in Kansas is smaller than the specimens described above, and may repre-
sent a juvenile.

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Class HYOLITHA *incertae sedis*

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Text-fig. 2E-H; Table 1

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Material. More than 900 specimens, with a distribution among localities shown in Table 1. See Appendix for
locality details.

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Description. The dorsum on specimens included under this heading varies from depressed to inflated, and the
keel on the dorsum varies from angular to narrowly rounded. The lateral margins on most are also narrowly
rounded, and the venter ranges from flat to slightly inflated. The transverse section varies from inflated to
depressed sub-triangular. All specimens are elongate, reflecting a low angle of apical expansion.

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The apex varies from straight on most specimens to curved, either dorsally or ventrally, or to the left or
right when viewed from the dorsum. A few specimens have fragmentary monoclavicate opercula; otherwise
no apertural detail is known.

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Most specimens are preserved as limonitized internal moulds. The moulds are generally smooth, although
on a few specimens they show faint, closely spaced, transverse lirae near the apertural end. Some specimens,
particularly those from the Deese Group, retain shells, but they are crushed, partially dissolved, and preserved
little detail. All other features of these specimens are unknown.

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Discussion. Specimens included under this heading are regarded as *incertae sedis* below the class
level because they lack the apertural features necessary to confidently assign them at lower taxo-
nomic levels. Three orders are currently included in the class Hyolitha: the Hyolithida, Orthothecida,

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MALINKY, MAPES AND BROADHEAD: LATE PALAEOZOIC HYOLITHA

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280 and Toxeumorphida (Peel and Yochelson 1984). The Hyolithida are distinctive because of the ligula
281 along the ventral apertural rim; their opercula are subdivided into cardinal and conical shields
282 separated by furrows, and the interior of the opercula possesses one or more pairs of processes
283 termed clavicles (Marek 1966a, p. 71, fig. 10A-C); transverse sections are sub-triangular. The
284 Orthothecida lack the ventral ligula, and their opercula have neither shields nor interior clavicles
285 (Marek 1966b, p. 91, figs. A-B); transverse sections on some are kidney-shaped whereas on others
286 they are sub-triangular like those of hyolithids (Marek 1966a, p. 59, fig. 3). The Toxeumorphida
287 are poorly known although available specimens suggest strongly that their transverse shapes are
288 circular. All the current specimens have sub-triangular transverse sections, so that the Toxeumorphida
289 are probably not represented.

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TABLE 1. Distribution of hyoliths listed under *Hyolitha incertae sedis* in southern Midcontinent 'core' shales. Details for localities are given in the Appendix. Sample weights are approximate. All specimens have been deposited at the National Museum of Natural History (USNM).

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Locality	Sample weight (kgm)	Number of specimens	Number
A-1	2000	19	390463
A-2	270	7	390464
D-1	136	571	390465-390469, 390481, 390483- 390484, 390494
D-2	22.7	1	390470
D-3	109	5	390471
D-4	680	3	390472
D-5	109	33	390473
M-1	0.5	1	390474
M-2	0.5	2	390475
M-3	680	47	390476, 390495, 390496
V-1	45	1	-390477
V-2	432	195	-390478, 390482
V-3	432	134	390479, 390485, 390486
V-4	108	4	-390480

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Except for the few specimens retaining fragmentary opercula (text-fig. 2F, G), no Pennsylvanian specimens can be confidently placed in either the Hyolithida or Orthothecida. The specimens with opercula are undoubtedly hyolithids because the remains of clavicles are clearly evident on the opercula, despite poor preservation otherwise. Among the other specimens the lack of well-preserved apertural characteristics preclude distinction between the Hyolithida and Orthothecida. By themselves, transverse outline, lirae, or other features of the moulds cannot be used to diagnose or recognize hyolith taxa at any level (Marek 1966a). Better preserved specimens from Oklahoma and Texas may demonstrate that several taxa are present in the Midcontinent Pennsylvanian.

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Acknowledgements. Partial support for this study was provided by the Smithsonian Institution in the form of a Postdoctoral Fellowship to J. M. M. Thanks are due to the Ohio University Research Committee and to

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397 the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial
398 support to R. H. M. (PRF No. 15821-AC2). We thank E. L. Yochelson (U.S. Geological Survey) and R. E.
399 Grant (National Museum of Natural History) for their comments on the manuscript. Heidi Wolff assisted
400 with the SEM.

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- 463 Typescript received 6 March 1985
 464 Revised typescript received 13 September 1985

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APPENDIX

List of localities

ATOKAN

A-1 Smithwick Formation. Shale is exposed 5.6 km east and 1.4 km south of US Highway 190 and county road FM 1121 junction, near Rochelle, McCulloch Co., Texas (Speck Mountain 7.5' quad.; Mapes and Furnish 1981).

A-2: Atoka Formation. Shale is exposed on the north bank of Delaware Creek approximately 100 m east of state highway 48, approximately 2.4 km north of Wapanucka, Johnston Co., Oklahoma (NW1/4 SW1/4 SW1/4, sec. 1, T2S, R8E, Wapanucka 7.5' quad.).

DESMOINESIAN

D-1: Deese Group. Limited shale exposure in cutbank of unnamed stream on the Daube Ranch, near Mannsville, Johnston Co., Oklahoma (SW1/4 SW1/4 SE1/4, sec. 31, T3S, R4E, Mannsville 7.5' quad; loc. P-10 of Mapes 1979).

D-2: Atwood Shale (Lower Wewoka 2). Shale exposed on north side of state highway 12, 3.8 km south-west of the junction of state highways 12 and 48 in Allen, Pontotoc Co., Oklahoma (SW1/4 SE1/4, sec. 13, T5N, R8E, Lake Holdenville 7.5' quad.).

D-3: Wewoka Shale. Shale exposed in the east bank of unnamed stream at the shoreline of Lake Okmulgee in Okmulgee State Recreation Area, 9.6 km west of Okmulgee, Okmulgee Co., Oklahoma (NE1/4 SE1/4 SW1/4, sec. 18, T13N, R12E, Lake Okmulgee 7.5' quad.).

D-4: Wewoka Shale. Shale exposed 3.2 km east and 3.2 km south of Homer, Pontotoc Co., Oklahoma. Shale crops out 120 m east of north-south road in a gully (S1/2 NW1/4 SW1/4, sec. 4, T3N, R7E, Francis 7.5' quad.; loc. P-8 of Mapes 1979).

D-5: lake Neosho Shale Member of Altamont Formation. Shale not in place; exposed in a now overgrown vacant lot adjacent to and parallel with US Highway 51, 0.2 km south of 129th St. exit, Broken Arrow, Tulsa Co., Oklahoma (NE1/4 NE1/4, sec. 32, T19N, R14E, Broken Arrow 7.5' quad.).

MISSOURIAN

M-1: unnamed shale (probably Exline equivalent). Shale exposed in stream bank south-west of Mound Valley, Labette Co., Kansas (centre line west, SE1/4 NW1/4, sec. 25, T6N, R7E, Mound Valley 7.5' quad.).

M-2: Tackett Shale (probably equivalent to Exline). Shale exposed in a series of gullies 2.4 km north of Sasakwa, Seminole Co., Oklahoma (centre line west, SE1/4 NW1/4, sec. 25, T6N, R7E, Sasakwa 7.5' quad.).

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520 M-3: Wolf Mountain Shale Member of Graford Formation. Shale is exposed in a construction site for a
521 housing project on west side of Lake Bridgeport; exposure is 0.8 km west and 0.8 km south of the junction of
522 US Highway 380 and the Lake Bridgeport bridge, Wise Co., Texas (Wizard Wells 7.5' quad; loc. 3 of Tucker
523 and Mapes 1978; and see Malinky and Mapes 1983).
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VIRGILIAN

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527 V-1: Finis Shale Member of Graham Formation. Shale exposed 0.8 km north-east of oil storage tanks on
528 Curtis Ranch, 1.9 km east of US Highway 281, 3.5 km south-east of Jacksboro, Jack Co., Texas (Jacksboro
529 Northeast 7.5' quad.).

530 V-2: Bluff Creek Shale Member of Graham Formation. Shale exposed 1.6 km south-east of end of a private
531 road near a pond dam; the road is located 9.6 km north-east of Whon, along the road connecting Whon and
532 Trickham, Coleman Co., Texas (Speck Mountain 7.5' quad).

533 V-3: Bluff Creek Shale. Exposure located near a pond dam 0.69 km east of county road FM 568 and 17.5
534 km south of Bangs, Brown Co., Texas (Bangs 7.5' quad).

535 V-4: Wayland Shale Member of Graham Formation. Shale exposed on south-west side of hill 0.2 km north
536 of road connecting Whon and Trickham, and 2.6 km east of intersection of that road and the private road
537 leading to locality V-1, Coleman Co., Texas (Speck Mountain 7.5' quad).

Note: This article was submitted by Cecil and Helen Minshew.

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TEXAS CRETACEOUS AMMONITES

by

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Introduction

Cretaceous exposures (Figure 1) cover about twenty-eight percent of Texas extending from Texarkana in the northeast corner southwest on a broad curve almost to El Paso in the west. The Lower Cretaceous outcrops are further inland and cover an area almost three times larger than that of the Upper Cretaceous. This Period, 135 through 65 million years ago (MYA), is not fully represented in Texas outcrops. The oldest Cretaceous beds of this Period in Texas are in the Torcer Formation of Valanginian Age (131 MYA - 126 MYA) and are exposed only in the Malone Mountains of West Texas in southern Hudspeth County. Figure 2 shows selected Cretaceous stratigraphic units in Texas along with comparable European stages.

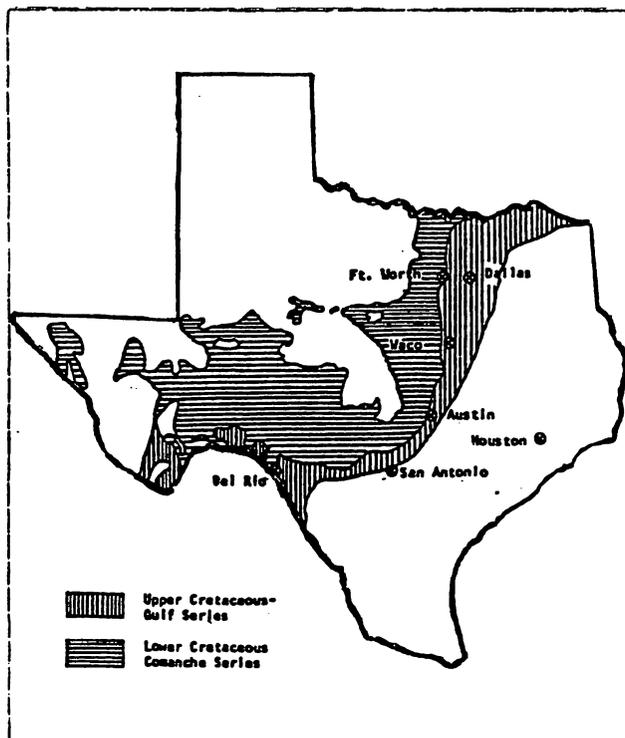


Figure 1.
Cretaceous Exposures in Texas

At various times during the Cretaceous Period in Texas the land was inundated by marine seas. Warm seas provided a variety of conditions: shallow and deep water, tidal flats, extensive reef formations, turbulent currents, and quiet pools. Conditions were very similar to those found today offshore of southern Florida. A gamut of marine vertebrate and invertebrate fauna developed. A group of now-extinct rudistid clams formed large reef complexes in the warm, clear, shallow waters. Coral reefs were created also. Oyster banks were widespread in near-shore bay and lagoon marine environments. Mud flats in low-lying coastal areas allowed the preservation of dinosaur tracks. These ancient Texas environments formed during the Cretaceous Period allowed the creation of one of the most intensely fossiliferous areas found anywhere in the world.

Texas provided excellent living environments for a wide variety of ammonites during a portion of the Cretaceous Period between 115 and 65 MYA. Many areas of Texas were inundated by marine seas and became part of the inland seaway connecting the Gulf of Mexico with the Arctic Ocean. Large numbers of ammonites inhabited these Texas waters at the beginning of the

SERIES	GROUPS	FORMATIONS/MEMBERS		MYA	EUROPEAN STAGES				
		NORTE-CENTRAL TEXAS	CENTRAL TEXAS						
UPPER CRETACEOUS	GULF	NAVARRO	/	/	65	MAESTRIGETIAN			
			KEMP	KEMP					
			CORSICANA	CORSICANA					
			HACATOCH	/					
		TAYLOR	KEYLANDVILLE	/	/	70	CAMPAIAN		
			MARLBROOK MAPL	BERGSTROM					
			PECAN GAP	PECAN GAP					
			WOLFE CITY	/					
		AUSTIN	ÖZAN	/	SPRINKLE	78	SANTONIAN		
			AUSTIN CHALK	AUSTIN CHALK	PHYLOGERVILLE				
					BURDITT				
					DESSAU				
					JONAH				
			VINSON						
EAGLE FORD		ATCO		82	CORIACIAN				
	EAGLE FORD	ARCADIA PARK	EAGLE FORD	86	TURBIAN				
		HEITON	SOUTH BOSQUE						
	EAGLE FORD	/	/	92	CENOMANIAN				
EAGLE FORD	HEITON	EAGLE FORD							
	LAZRANT	LAKE WACO							
LOWER CRETACEOUS	COMANCHE	WOOD-BINE	WOODBINE	PEPPER	100	ALBIAN			
		WASHITA	BUDA	BUDA					
			GRATSON	DEL RIO					
			MAIN STREET	GEORGETOWN					
			PANPAN						
			KENO						
			DENTON						
		PORT WORTH							
		DUCK CREEK							
		FREDERICKS-BURG	KIAMI CHEI	KIAMI CHEI					
			GOODLAND	EDWARDS					
			WALNUT	COMANCHE PEAK			WALNUT		
		TRINITY	ANTLERS	PALUXY			PALUXY	108	APTIAN
				GLEN ROSE			GLEN ROSE		
	TWIN MENS.		HENSEL						
			COW CREEK						
	PALEOZOIC ROCKS		HAMMETT						
			115						

Figure 2. Correlation of Cretaceous stratigraphic units in Austin - Waco - Dallas - Fort Worth areas.

Cretaceous Period. However, near the end of the Period the number and variety of ammonites had greatly declined, and they ceased to exist by the end of the Mesozoic Era.

The abbreviations UK (Upper Cretaceous, Gulfian Series) and LK (Lower Cretaceous, Comanchean Series) have been used extensively in this work. The UK contains the Navarro, Taylor, Austin, Eagle Ford and Woodbine Groups. The LK contains the Washita, Fredericksburg and Trinity Groups.

Ammonites are divided into two general categories: cosmopolitan and endemic. The cosmopolitan were spread worldwide by the oceans and seas while the endemic were restricted to local areas. At the time, Pangaea had recently separated thus providing shorter open-water journeys than would be necessary today for the cosmopolitan type to spread far and wide. As the Zuni Sea of the Cretaceous Period transgressed and regressed over the North American Craton, many cosmopolitan ammonites were deposited in the sediments. These fossils are identical to those found in the four corners of the world today. It is thought that endemic species evolved by being isolated from the open oceans by the growth of large reefs. Texas seas, as well as others, provided these special conditions. The endemic type comprises about thirty percent of the total ammonite population.

Amateur paleontologists favor ammonites due to their relative rarity, unique ornamentation, and intricate, coiling shapes. Today ammonite research is an active area when, seemingly, work on other mollusks is on the decline. Because of ammonites' short life span and rapid evolution, scientists use them as markers in stratigraphic research to aid in correlating sediments throughout the world. Generally, two areas can be said to be of the same age if the same cosmopolitan ammonite is found in each area.

Published professional literature lists about two hundred ammonite genera and six hundred fifty species in the Texas Cretaceous Period. Many of these ammonites have been described and identified in the last few years, and it is thought that many more are yet to be named. We plan to summarize this material in a future publication. Some of the highlights and descriptions of some common ammonites are presented in this article.

Ammonite Classification

The classification of ammonites has undergone constant review and change since the 1800's. C.W. Wright authored the Cretaceous ammonite classification system revision in the 1957 Treatise of Invertebrate Paleontology. This revision was based largely on the forty years' work of L.F. Spath. Twenty years after the 1957 Treatise publication, Wright wrote that, "-- over three hundred new Cretaceous genera have been published along with many proposed revisions to the classification system." Again, in 1981, Wright revised the Cretaceous classification system in The Ammonoidea, edited by M.R. House and J.R. Senior. Wright concludes that after forty-five years' study on ammonites his new system is "--always liable to be overturned by new discoveries or by a better explanation of known material." Figure 3 compares the order of Cretaceous ammonite Superfamilies found in the 1957 Treatise to the order in the 1981 Ammonoidea classification.

Classification

<u>Treatise</u>	<u>Ammonoidea</u>
Phyllocerataceae	Phylloceratidae
Lytocerataceae	Lytocerataceae
(Tetragonitidae)*	Tetragonitaceae
Ancylocerataceae	Haplocerataceae
Turrilitaceae	Perisphinctaceae
Scaphitaceae	Desmocerataceae
Haplocerataceae	Hoplitaceae
Perisphinctaceae	Acanthocerataceae
Desmocerataceae	Ancylocerataceae
Hoplitaceae	Douvilleicerataceae
Acanthocerataceae	Deshayesitaceae
	Turrilitaceae
	Scaphitaceae

Figure 3. Comparison of Cretaceous Ammonite Classification Order

*Family Tetragonitidae changed to Superfamily Tetragonitaceae in Ammonoidea

Differences are found in the heteromorphic families, Turrilitaceae and Scaphitaceae. In 1957 these two Superfamilies were considered to be "old" stock or phylogerontic (as seen in Adkins, 1928). However, in 1981, Turrilitaceae and Scaphitaceae were moved to a later position. Also, the 1957 Hoplitaceae was subdivided into three 1981 Superfamilies: Hoplitaceae, Douvilleicerataceae and Deshayesitaceae.

Morphology

Each fossil phylum and class has unique descriptive terms, and in order to study and identify fossils, the terms should be learned and used properly. Figure 4 illustrates and names common ammonite features.

1. BODY CHAMBER. The body chamber is the last portion of the shell occupied by the living animal.
2. APERTURE. The aperture is the exit of the body chamber and is directed forward (adoral).
3. SEPTA. The posterior shell compartments or septa, successively vacated as the animal built and moved into a new body chamber, were partially filled with fluid and used to regulate hydrostatic pressure or water depth.
4. SIPHUNCLE. A siphuncle or tube connects the septa to allow fluids and gases to fill or empty the chambers enabling the ammonite to ascend or descend.
5. PROTOCONCH. The center of the ammonite spiral is the protoconch and is the first chamber occupied by the juvenile.
6. PHRAGMOCONE. The septa form the phragmocone. The body chamber and protoconch are not included.
7. WHORL. Each shell volution is termed a whorl. The outer portion of the whorl is designated ventral and the inner portion is dorsal.

8. FLANK. The side portion of a whorl is the flank.
9. UMBILICUS. The concave surface on either side enclosed by the last whorl is called the umbilicus.
10. KEEL. A keel is a ridge running along the ventral edge of some ammonites.
11. SUTURE PATTERN. Sutures form a line of contact between the septa and the inside of the shell and can be seen only on some steinkerns or specimens with part of the shell missing. Comparison of suture patterns is essential in separating look-alike ammonites.
12. LAPPET. A lappet is a projection from the aperture which may be a male ammonite feature.

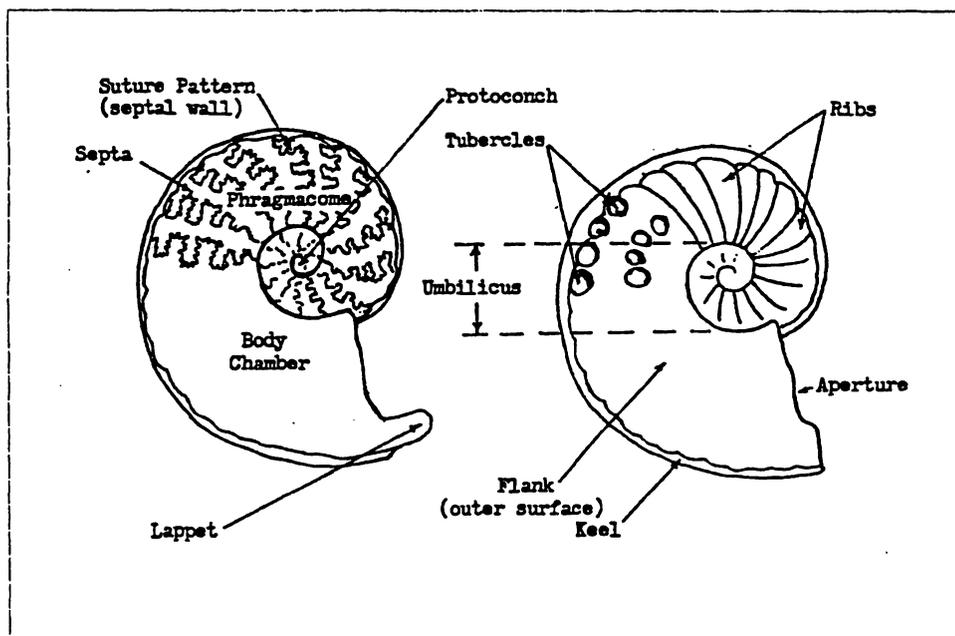


Figure 4. Common Ammonite Features

Shells of ammonites were variously ornamented. Perhaps ornamentation served as a defensive mechanism, camouflage or as a wall-strengthening function. Ornamentation consists of ribs and tubercles which occur in many types, sizes and patterns. Tubercles might appear on the ribs or might appear to be separate from them, and spines grew on some species. Color patterns are thought to have been present on the shell.

Ammonites are further defined by the shell shape. Involute types have overlapping whorls which enclose the previous whorl. Evolute types do not have overlapping whorls. However, there are many stages to be found between involute and evolute. Ammonites that have only partial or no coiling may be found and are called heteromorphs. General types of ammonite shells are given in Figure 5, cross sections of whorl outlines are in Figure 6, and direction of rib slant is shown in Figure 7.

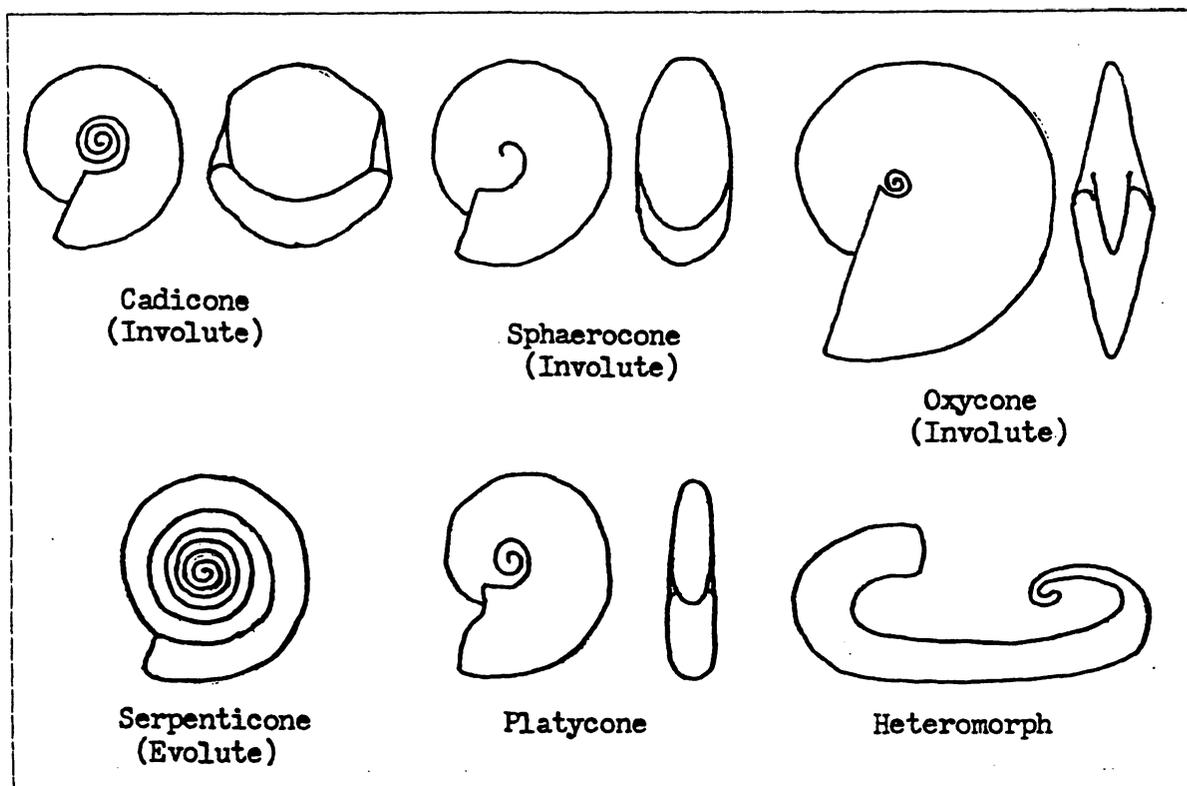


Figure 5. Types of Ammonite Shells (redrawn from Lehman)

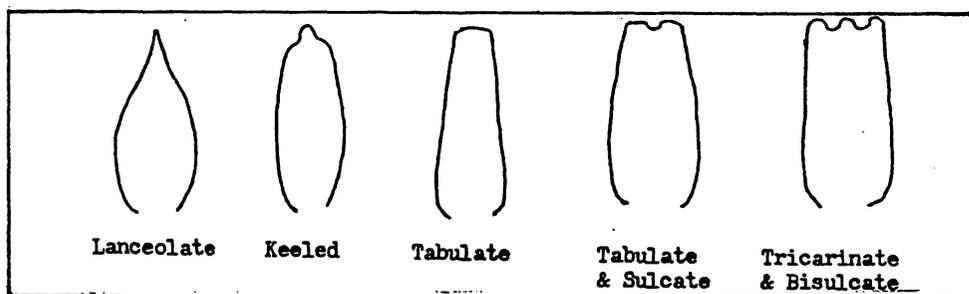


Figure 6. Types of Whorl Outlines

Ammonite Size is relative and subject to interpretation. For this publication the following sizes are used: Micromorph = up to one inch (25 mm), Small = one to three inches (25-75 mm), Medium = three to eight inches (75-200 mm), Large = eight inches to three feet (200-900 mm), and Giant = over three feet (over 900 mm). Careful measurement of the ammonite specimen provides good hard information for identification. Figure 8 illustrates locations for measurements.

Ammonite Identification Problems

Paleontologists have devised many methods to sort out and cope with the diversity of identification problems. W.S. Adkins, in the 1920's, felt unique shell

features helped categorize the ammonites, and G. Scott, in 1940, used general shell structure. Lately, several authors rely heavily on suture patterns for separation of genera. The main difficulties are: Ornamentation can, and often does, change with the specimen's age. Thus, the outer whorl of a mature ammonite can be different from that of a specimen of a juvenile of the same species. Suture Pattern can change as the ammonite ages. Therefore, the pattern on an inner whorl probably is different than that on an outer whorl. Sexual Dimorphism creates different sizes, and there is controversy as to which sex is "macro" and which is "micro". The general belief is that the female (macroconch) is larger than the male (microconch). Many "identified" species actually may be a different sex of the same species. Short Life Span and Rapid Evolution caused many

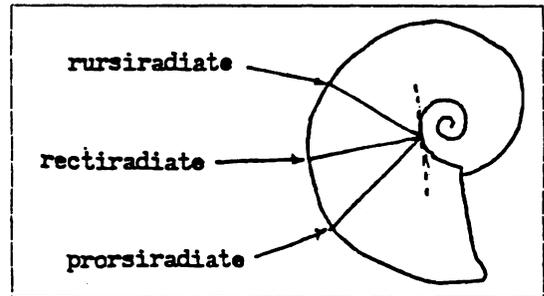


Figure 7. Types of Rib Angles

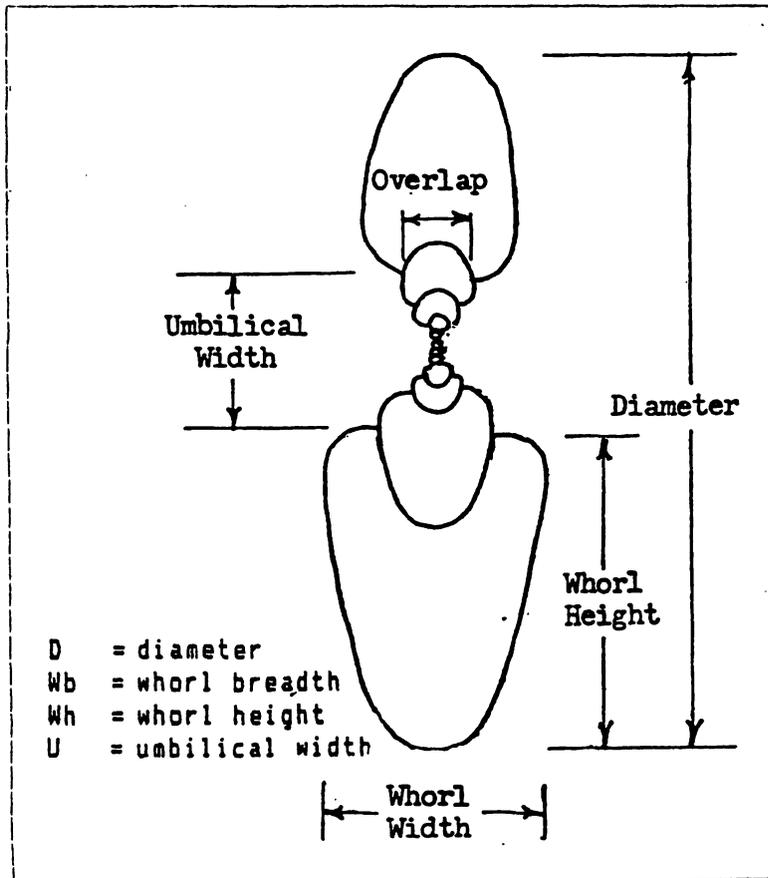


Figure 8. Locations for Measurements

variations. The rapid evolution often allowed the re-development of features found on earlier genera. Thus, in many cases, a young species may have features of an older one. Steinkerns (internal molds) are the most commonly found ammonite fossil. Thus, their state of preservation is of extreme importance in identification. The living chamber is rarely found with the main ammonite shell. Steinkerns have the advantage of revealing the suture pattern and internal ornamentation. External ornamentation is generally unknown.

All of the identification methods developed by paleontologists have value. Usually, identification is achieved through using a combination of all techniques.

Steps To Identification

Collect and record precise data from the best specimens available for

Figure 9
AMMONITE MEASUREMENT DATA

Sample

Genus/Species *Prionocyclus hyatti*

Location Found *Tallassee County*

Group/Formation *Eagle Ford Group* *Arcadia Park Form.*

Ammonite Shape *evolute - robust*

Whorl Shape *depressed*

Rib Pattern *coarse, distinct*

Ornamentation *shoulder tubercles; nodate, siphonal keel*

Specimen Number	1	2	3
Diameter (D), mm	<u>33.8</u>	_____	_____
Umbilical Dia. (U), mm	<u>13.4</u>	_____	_____
Whorl Height (Wh), mm	<u>11.3</u>	_____	_____
Whorl Breadth (Wb), mm	<u>15.8</u>	_____	_____
Wb/Wh Ratio	<u>1.40</u>	_____	_____

Suture Drawing

identification. It is preferred to have more than one specimen to compare. Reliable, accurate identifications require exact location and detailed geological information (including group and formation). Careful observation of the whorl shape, rib pattern and other ornamentation should be made. Basic measurements, including umbilical diameter, whorl height and breadth, and whorl ratio are necessary. Sketch the suture pattern if visible. Figure 9 is a typical ammonite measurement form.

After the basic data have been obtained, the following Identification Key can be used to help identify the specimen to the genera level. The Key presents steps to narrow the search by identifying features as being present or absent. The first step divides ammonites into either conventional, flat, coiled ammonites or heteromorph ammonites. Conventional ammonites are divided into keeled and non-keeled types. Heteromorphs are divided into those in one plane or those in more than one plane. At this time this Key does not include all genera found in Texas.

Artificial Key To Texas Cretaceous Ammonite Genera
(Revised Adkins, 1928, Key)

- I. Discoidal coiling (shell almost a planospiral coil).
- A. No Keel
1. Venter convexly rounded in adult.
 - a. Ribs cross venter.
 - (1) Large (Eopachydiscus)
 - (2) Medium (Douvilleiceras, Kazanskyella, Tarrantoceras)
 - (3) Small (Moremanoceras, Quitmanites, Stoliczkaia [Mantelliceras, Dufrenoyia - ribs may be interrupted on venter])
 - b. Ribs do not cross venter.
 - (1) Mid-line of venter smooth.
 - (a) Micromorph complex suture.
 - [1] Oval whorl form (Kossmatella)
 - [2] Square to trapezoidal whorl form (Tetragonites)
 - (b) Micromorph simplified suture.
 - [1] Ribs and tubercles are absent. (Flickia)
 - (c) Macromorph. (Pachydiscus)
 - (2) Form compressed, venter is truncated or excavated.
 - (a) Venter excavated, bounded by nodes. (Metioceras)
 - (b) Venter narrow, involute, not bounded by nodes. (Placentoceras)
 - (3) Form not compressed. (Mammites, Pseudaspidoceras)
 - (4) Mid-line of venter is tuberculate.
 - (a) Mid-tubercle is prominent. (Acanthoceras, Budaiceras, Conlinoceras)
 - (b) Mid-tubercle is reduced or absent in adult. (Eucalycoceras)
 2. Venter is narrow.
 - a. Giant species.
 - (1) Ribs do not cross venter in some species. (Parapuzosia)
 - b. Medium species.
 - (1) Saddles are generally undivided. (Engonoceras, Knemiceras, Metengonoceras, Protengonoceras)
 - (2) Saddles are divided. (Sphenodiscus, Coilopoceras)
- B. Keel present.
1. Keel is nodose or serrate.
 - a. Nodose keel. (Prionocycloceras)
 - b. Coarsely serrate keel. (Barroisiceras)
 - c. Medium-sized serrations on keel, ribs are fine and numerous. (Collignonoceras)
 2. Keel is uninterrupted.
 - a. Whorl is taller than wide and thin from side to side.
 - (1) Numerous curved ribs and no tubercles. (Oxytropidoceras)

- (3) Branching flat ribs on its early whorls. (Manuaniceras)
 - (4) Ribs with steep forward slopes with flank and shoulder tubercles, but no umbilical tubercles. (Venezoliceras)
 - b. Whorl is taller than wide, but not thin side to side.
 - (1) Three plus rows of tubercles.
 - (a) Three or more rows of tubercles. (Mortoniceras, Texanites)
 - (b) Multiple rows of tubercles. (Craginites)
 - (2) One or two rows of tubercles.
 - (a) Two ventral-shoulder tubercles and no mid-flank tubercles. (Mortoniceras (Drakeoceras))
 - (b) Ribs and tubercles normally absent. (Dipoloceras)
 - (c) Ribs are many and obscure. (Prohysteroceas)
 - c. Whorl is quadrate with three rows of tubercles, keel not depressed. (Pervinqueria)
- II. Heteromorphs, partially uncoiled or coiling not discoidal.
- A. Coiled or bent in one plane.
 - 1. Shaft is simple and straight (early minute coil rarely preserved). (Baculites, Sciponoceras, Lechites)
 - 2. Several subparallel shafts with early helical coiling. (Hamites, Metaptychoceras)
 - 3. Open plane, spiral usually followed by shaft or hook.
 - a. Two almost parallel shafts, tubercles connected across venter by rib. (Idiohamites)
 - b. Irregular coil, ribs thin, tubercles joined across venter by rib. (Allocrioceras)
 - c. Fragments only, two rows of ventrolateral and one row of ventral tubercles. (Phlycticroceras)
 - 4. Evolute or involute shell followed by a shaft or hook. (Scaphites, Yezoites, Worthoceras)
 - B. Coil or inflections not in one plane.
 - 1. Coil is a loose spire followed by shaft and hook. (Anisoceras)
 - 2. Coil is a tight, turrilitic spire at some stage.
 - a. Four rows of equal-sized tubercles, middle row separated by spiral groove, tending to uncoil at the body chamber.
 - (1) Apical angle starts at tight coil. (Mariella (Plesioturrilites))
 - (2) Apical angle starts with a straight shaft. (Mariella (Wintonia))
 - b. Two to four equal-sized tubercles with ribs in a tight coil. Variable apical angle. (Turrilites)
 - c. Two or three tubercles per rib, very dense ribs. (Ostlingoceras (Ostlingoceras))
 - d. Middle row of tubercles are fewer and larger, ribs almost absent. (Hypoturrilites)
 - 3. Coiling is irregular and tubercles are subordinate to dense ribs. (Bostrychoceras, Nostoceras)

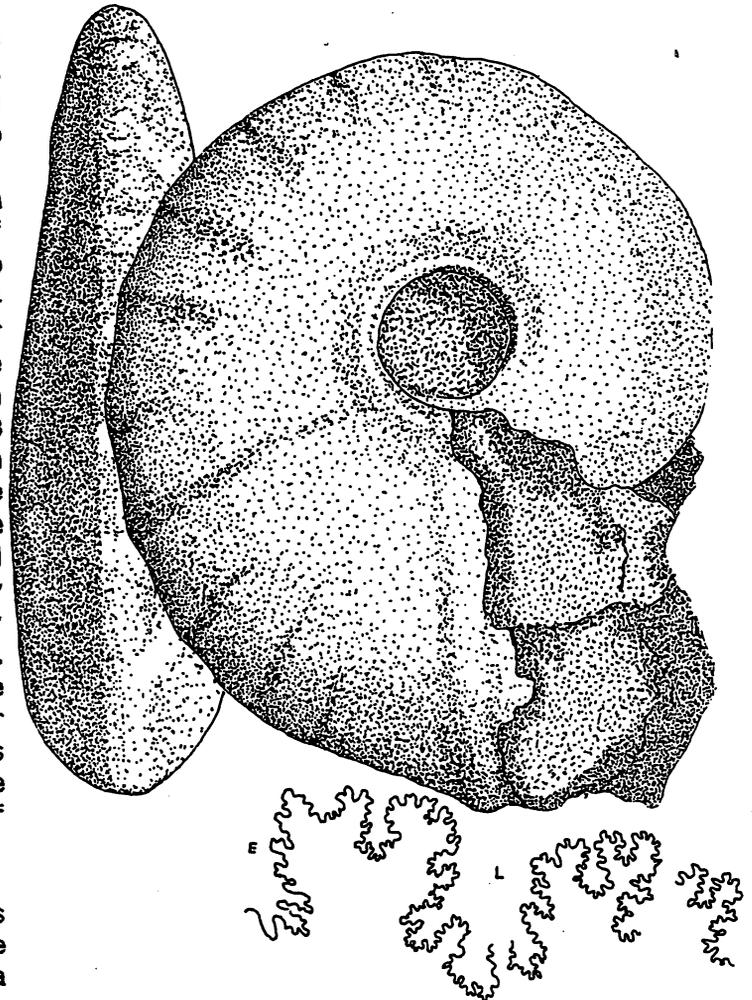
Some Common Texas Cretaceous AmmonitesEopachydiscus marcianus (Shumard, 1854)

LK Washita (Duck Creek, Georgetown), Fredericksburg (Edwards) - Albian
Superfamily Hoplitaceae

- 1854 Ammonites marcianus Shumard*
 1860 Ammonites brazoensis Shumard
 1904 Pachydiscus laevicaniculatus Roemer manuscript; Lasswitz
 1955 Eopachydiscus laevicaniculatus (Lasswitz, ex Roemner manuscript);
 Wright
 1955 Eopachydiscus brazoensis (Shumard); Wright
 1957 Eopachydiscus marcianus (Shumard); Wright

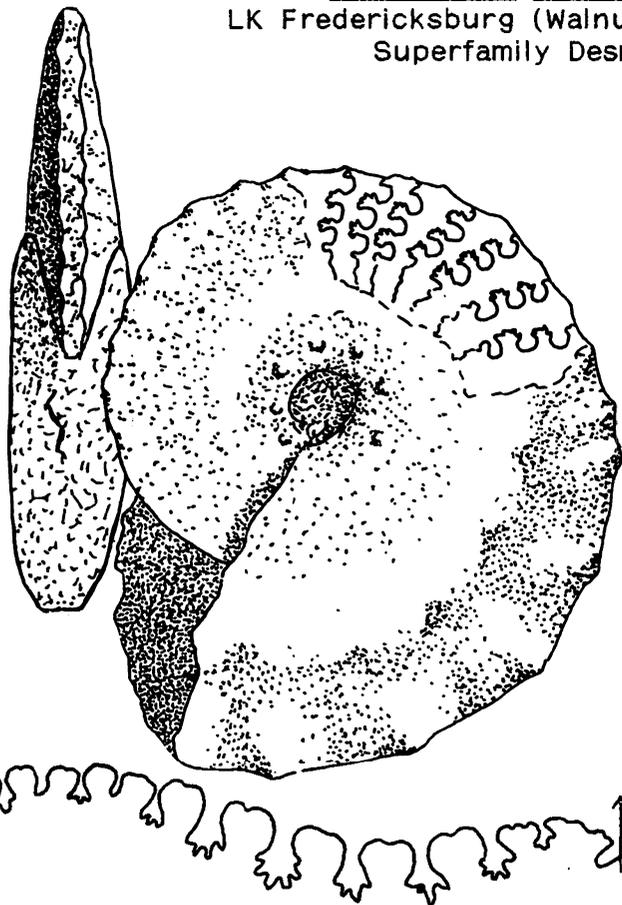
E. marcianus is so numerous in some localities near Lake Texoma, it has been used as flower bed edging and gate posts. Medium to large-sized, it is moderately involute and compressed with a high oval whorl. The diameters of juvenile specimens range from 2 to 6 inches (50 to 150 mm), and 14 inches (355 mm) is common for adults. Cragin measured one specimen at 2 feet (610 mm) in diameter with a whorl height of 8 inches (200 mm) and a whorl width of 6 inches (150 mm). The ribs are gently undulating and cross the rounded venter, swinging forward in the crossing. These ribs may be elevated in the young, but may fade to obscurity in some adults. Whorls are few in number. The suture pattern is a major identification feature, and it is composed of a trifold lateral lobe and numerous auxiliaries, all of which, are minutely frilled.

*Note: This synonymy is intentionally abbreviated. The species actually went through a Pachydiscus stage for both Ammonites marcianus and A. brazoensis in the early 1890's and through a Desmoceras stage for all three species in the mid-1920's.



x 0.7

Engonoceras gibbosum Hyatt, 1903
LK Fredericksburg (Walnut, Goodland) - Albian
Superfamily Desmocerataceae



Suture pattern enlarged.

x 1

E. gibbosum is medium-sized with an oxycone shape. Measurements of our steinkern are: diameter: 3 inches (75 mm), whorl height: 1.75 inches (44 mm), whorl width: 0.8 inches (20 mm). Umbilicus width is 0.3 inches (8 mm), and the Wb/Wh ratio is 0.47. (These measurements compare favorably with Hyatt's specimens.) Tubercles are obvious on the lateral edge of the venter and umbilicus, but are faint on the flank. The number of flank tubercles does not seem to be related to either umbilical or ventral tubercles. The later alternate on each side producing a zigzagging outline to a flat, narrow venter. Ribs are not perceptible. A major feature is the engonocerid suture pattern which is well-separated. Each side has ten lateral lobes and eleven saddles, a number of which are bifid or notched.

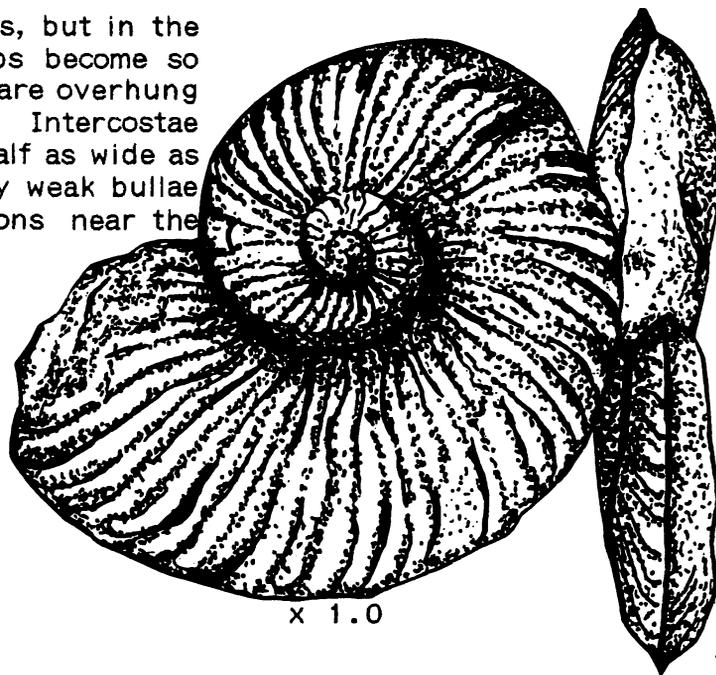
Manuaniceras supani (Lasswitz, 1904)

LK Fredericksburg (Walnut, Goodland, Comanche Peak, Kiamichi) - Albian
Superfamily Acanthocerataceae

- 1904 Sonneratia supani Lasswitz
- 1920 Schloenbachia acutocarinata (Shumard); Adkins and Winton
- 1927 Oxytropidoceras n.sp. (aff. supani Lasswitz); Adkins
- 1938 ?Oxytropidoceras sp. ind. Riedel
- 1956 Oxytropidoceras carbonarium (Gabb); Benavides
- 1966 Manuaniceras supani (Lasswitz); Young

M. supani is one of the most widely spread ammonites of the Fredericksburg Division. It ranges from Williamson County on the south to the Red River on the north and westward beyond Ft. Stockton, even into Chihuahua, Mexico. M. supani is medium-sized, obtaining diameters up to 8 inches (200 mm), and has a slightly expanding umbilicus with an elongate oval whorl section. The height-width ratio of the whorls decreases at the greatest diameter. Ribbing is dense, and the

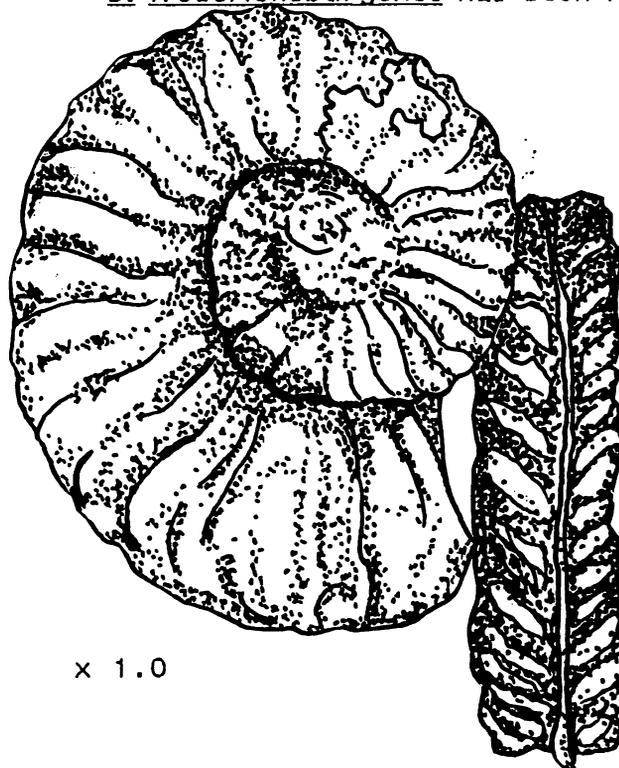
young have flattened ribs, but in the mature specimens the ribs become so high that the intercostae are overhung by the walls of the ribs. Intercostae are normally about one-half as wide as costae. Elongate and very weak bullae might appear at bifurcations near the umbilicus.



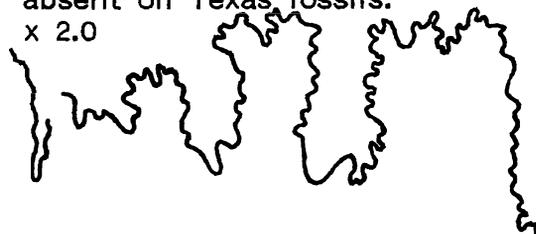
Diploceras fredericksburgense Scott, 1928
 UK Fredericksburg (Upper Goodland) - Albian
 Superfamily Acanthocerataceae

- 1928 Diploceras fredericksburgense Scott
- 1951 Diploceras (Diplasioceras) fredericksburgense Scott; Collignon
- 1966 Diploceras fredericksburgense Scott; Young

D. fredericksburgense has been found in the Upper Goodland Limestone in Tarrant County. The holotype measures 3.25 inches (83 mm). The venter has a longitudinal groove with a thin prominent keel which is a striking feature of this species. The coiling is nearly flat, almost slender, and the umbilicus is wide and deep. The whorl section is quadrate. The ribs are irregular and flexuous, either single or dividing near the venter. Occasionally, the ribs flare, thicken, and turn forward. Sometimes the ribs thicken at the ventrolateral edges then gradually fade away beside the sulcate area. Umbilical tubercles, common on the African form, are absent on Texas fossils.



x 1.0

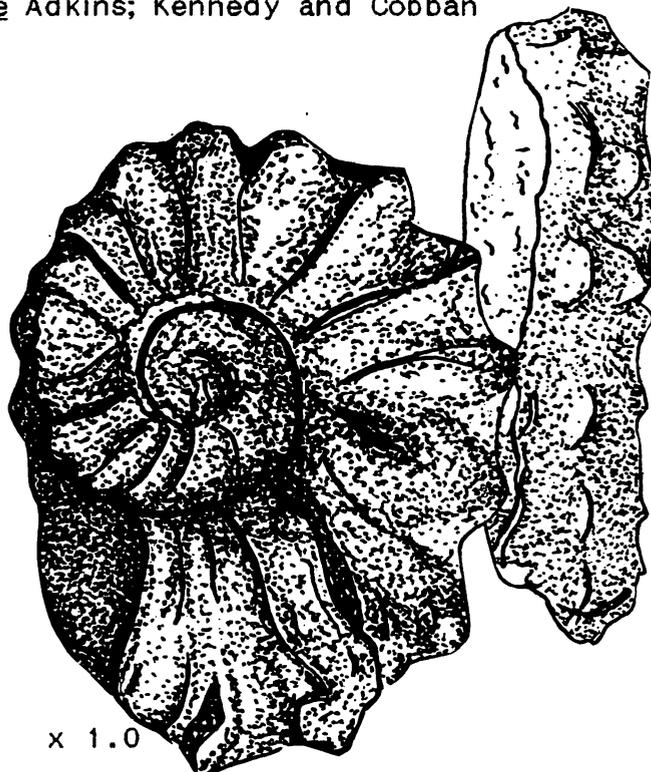


x 2.0

Acanthoceras bellense Adkins, 1928
UK Eagle Ford (Tarrant) - Cenomanian
Superfamily Acanthocerataceae

- 1928 Acanthoceras bellense Adkins
1942 Acanthoceras aff. rhotomagense (Defrance); Moreman
1942 Acanthoceras aff. hunteri Kossmat; Moreman
1942 Acanthoceras validum Moreman
1942 Acanthoceras aff. sherborni Spath; Moreman
1942 Acanthoceras stephensoni Adkins; Moreman
1942 Acanthoceras aff. cunningtoni (Sharpe); Moreman
1942 Acanthoceras aff. cunningtoni var. cornutum Kossmsat; Moreman
1942 Acanthoceras pepperense Moreman
1959 Acanthoceras n. sp. aff. A. turneri White, Adkins; Matsumoto
1990 Acanthoceras bellense Adkins; Kennedy and Cobban

A. bellense is small to medium-sized with fairly evolute coiling. The holotype measures 3.5 inches (87.5 mm), and an average of the specimens studied by Kennedy and Cobban is 3.5 inches (87.5 mm). It has a moderately deep and wide umbilicus with rounded walls taking about thirty per cent of the specimen's diameter. The whorls are massive and slowly expanding. The venter is flattened with broadly rounded ventrolateral shoulders. The intercostal whorl section is depressed trapezoidally with the greatest breadth just outside the umbilical shoulder. The primary ribs are bullate alternating with shorter or non-bullate primary at the smallest

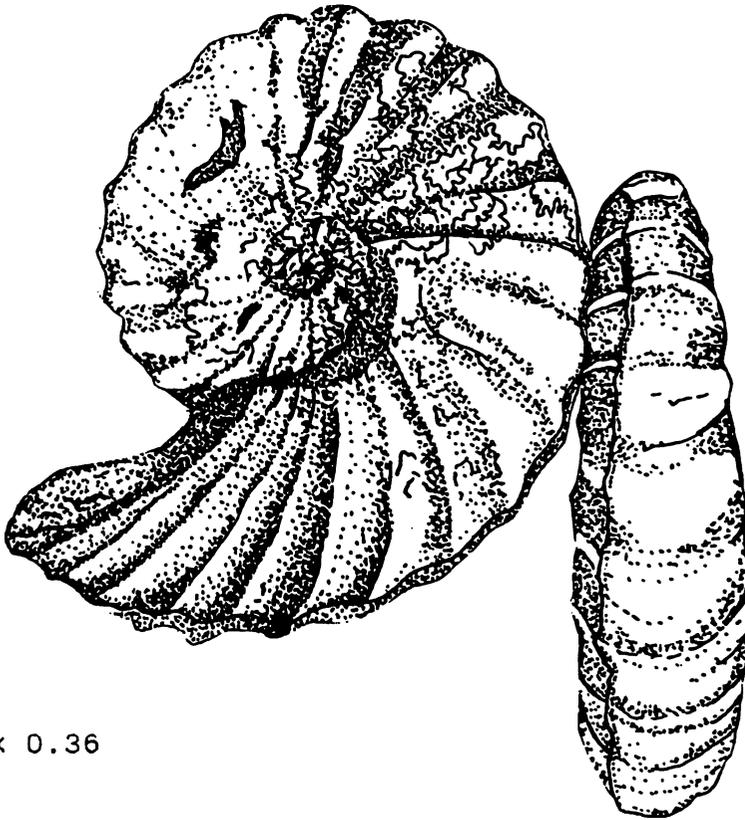


diameter. In middle growth, ornamentation is highly variable with most specimens having 17-20 primary ribs per whorl. Bullae give rise to straight, broad prorsiradiate ribs (weak to strong) which terminate in inner ventrolateral tubercles that are initially clavate but become conical and horn-like as the specimen's size increases.

Metioceras geslinianum (d'Orbigny, 1850)
UK Eagle Ford (Britton) - Turonian
Superfamily Acanthocerataceae

- 1841 Ammonites catillus d'Orbigny
1850 Ammonites geslinianus d'Orbigny

- 1927 Metoicoceras irwini Moreman
 1942 Metoicoceras ornatum Moreman
 1942 Barroisiceras trinodosum Moreman
 1942 Barroisiceras brittonense Moreman
 1981 Metoicoceras geslinianum (d'Orbigny); Wright and Kennedy



x 0.36

M. geslinianum is strongly dimorphic with the microconch ranging in size from 5.3 inches (135 mm) to 8.3 inches (210 mm) in diameter. It is evolute, stoutly whorled, coarsely ribbed and tuberculate. Commonly, there are eight to ten strong umbilical bullae per whorl in the middle growth stages. The ribs are strong, straight, prorsiradiate in pairs with additional short intercalatories for about 20 ribs per whorl. The macroconchs are adult when the diameter is between 7.7 inches (195 mm) and 9.6 inches (245 mm). Coiling is more involute than in the microconch, the whorl section is higher and more

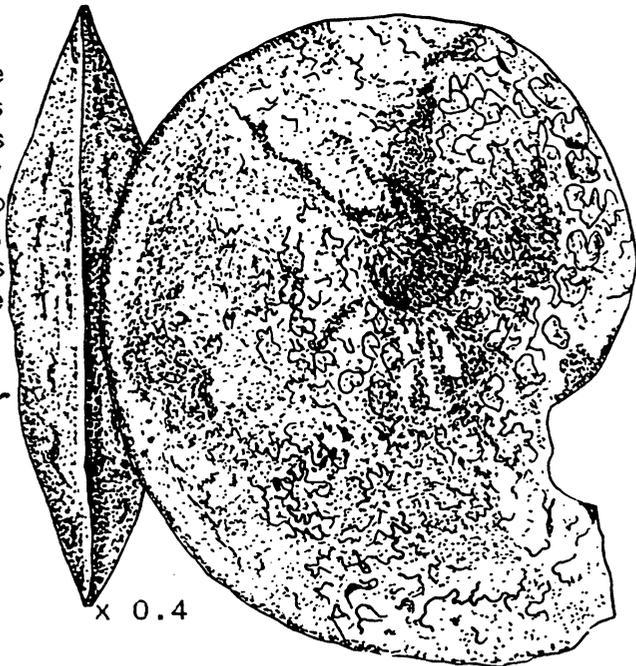
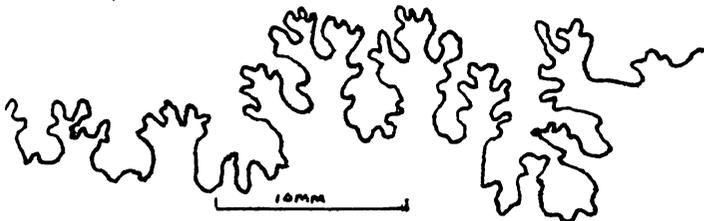
compressed, and the tubercles are lost on the body chamber. The macroconch umbilicus is smaller with many more ribs, numbering twenty-eight to thirty-two in most cases.

Coilopoceras springeri Hyatt, 1903
 UK Navarro (Escondido) - Maestrichian
 Superfamily Acanthocerataceae

- 1903 Coilopoceras springeri Hyatt
 1931 Coilopoceras eaglefordense Adkins
 1931 Coilopoceras chispaense Adkins
 1931 Coilopoceras sp. aff. C. springeri Hyatt; Adkins
 1978 Glebsoceras chispaense (Adkins); Young and Powell
 1978 Coilopoceras eaglefordense Adkins; Young and Powell
 1980 Coilopoceras springeri Hyatt; Cobban and Hook

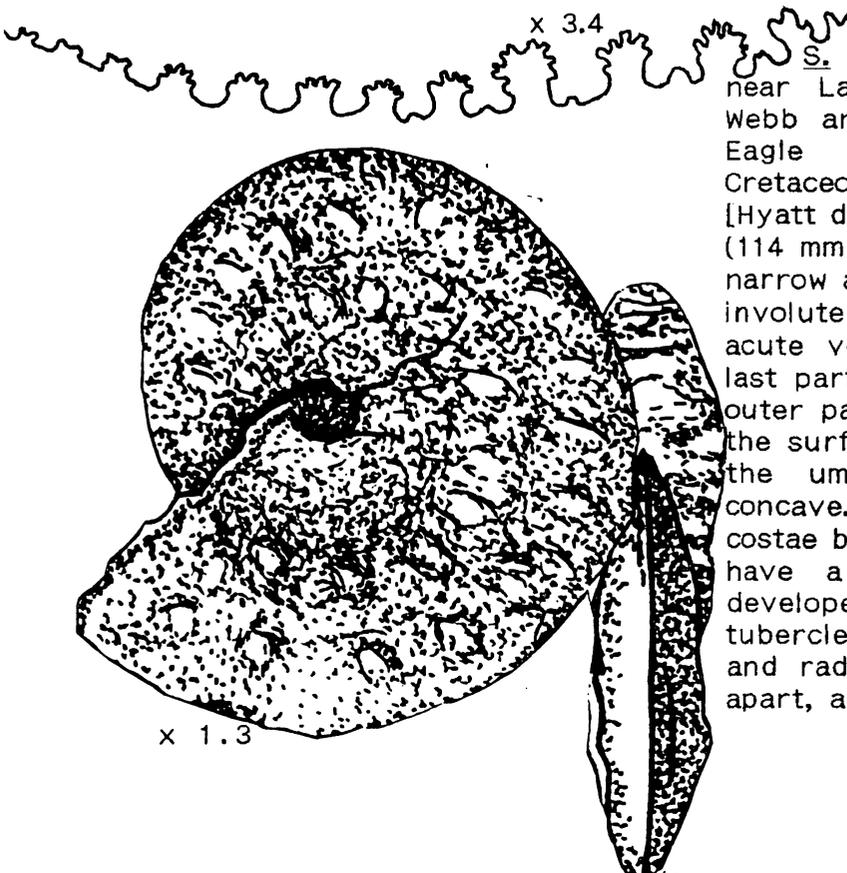
C. springeri represents both the smooth and ribbed forms of the genus. Specimens with diameters ranging from seven inches (175 mm) to fourteen inches (355 mm) have been described by Kennedy. In the middle and late growth stages it is compressed, involute, smooth or feebly ribbed with a sharp venter. It can

be stouter, more evolute and those with ribs can have about twelve ribs per whorl. No ventrolateral tubercles are found. The venter in very early whorls is well-rounded but changes to lanceolate later. There is no keel. Occasionally, if the ribbing is pronounced, umbilical bullae are present.



Sphenodiscus pleurisepta (Conrad, 1857)
 UK Navarro (Escondido) - Maestrichian
 Superfamily Acanthocerataceae

- 1857 *Ammonites pleurisepta* Conrad
- 1873 *Ammonites pedernalis* Binckhorst
- 1898 *Sphenodiscus pleurisepta* (Conrad); Bohm



S. pleurisepta is found in Texas near Laredo and near Eagle Pass in Webb and Maverick Counties from the Eagle Pass Beds of the Upper Cretaceous. This medium-sized species [Hyatt describes a range from 4.5 inches (114 mm) to 7.5 inches (190 mm)] has a narrow and abrupt umbilical zone. It is involute and has a solid keel. The acute venter becomes blunted on the last part of the exposed volution. The outer part of the whorl is convex while the surface between the inner line and the umbilical shoulder is definitely concave. There can be fold-like, short costae between tubercles, and they may have a bifurcated look when well-developed. Two distinct rows of lateral tubercles (nodes), transversely elongated and radiating about 0.3 inches (8 mm) apart, are a feature of the species.

Idiohamites fremonti (Marcou, 1858)

LK Washita (Duck Creek), Fredericksburg (Kiamichi and Del Carmen) - Albian
Superfamily Turrilitaceae

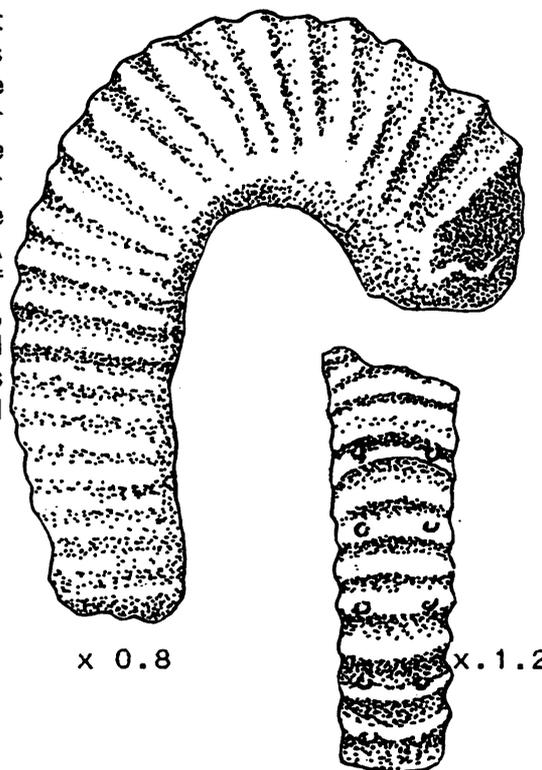
1858 Hamites fremonti Marcou

1928 Exiteloceras fremonti (Marcou); Adkins

1933 Idiohamites fremonti (Marcou); Adkins

1965 Idiohamites comanchensis (Adkins and Winton); Clark

I. fremonti is usually found as straight or hooked, candy-cane fragments 2 inches (50 mm) to 4.7 inches (120 mm) long. The circular to oval whorl section has a diameter of about 0.8 inches (20 mm). Ribs are ventrally prominent and become obscure over the dorsal border. The ribs can be perpendicular or slightly oblique. A tubercle is found on the ventral margin of every second to fourth rib. Occasionally, tubercles are found below the mid-lateral position. It is a rarity to find these fossils with either shell or suture pattern. Mud casts frequent Texas collections.

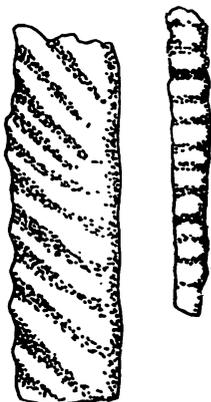


Sciponoceras gracile (Shumard, 1860)
UK Eagle Ford (Britton) - Upper Cenomanian
Superfamily Turrilitaceae

1860 Baculites gracile Shumard

1951 Sciponoceras gracile (Shumard); Cobban

The protoconch and initial whorl of S. gracile are rarely found. The remainder is a slender, straight ammonite that enlarges gradually toward the aperture. The cross section is circular to oval. The diameter of the shaft is about 0.28 to 0.35 inches (7 to 9 mm). Occasional large adults [shaft diameter about 1.6 inches (40 mm)] are thought to be macroconchs. Ornamentation consists of prorsiradiate, ventral ribs and regularly spaced constrictions which are 1.0 to 1.5 diameters apart and have 5 to 7 ribs in between. The ribs become stronger near the dorsally facing aperture. The suture has a bifid, lateral lobe and a small



x 1.0

trifid, antisiphonal lobe. Saddles and E, L and U lobes are rectangular in shape. The S. gracile zone is an important coordinating zone for the Upper Cenomanian from Texas through to Montana and in Western Europe. The type species is from Grayson County, Texas.

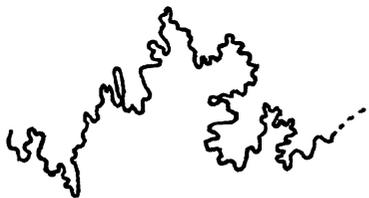
Mariella (Wintonia) brazoensis brazoensis (Roemer, 1849)
 LK Washita (Main Street, Grayson, Del Rio, Georgetown) - Albian
 Superfamily Turrillitaceae

- 1849 Turrillites brazoensis Roemer
- 1853 Paraturrillites (Plesioturrillites) brazoensis (Roemer); Breistroffer
- 1957 Mariella (P.) brazoensis (Roemer); Arkell, Kummell and Wright
- 1965 Mariella (P.) brazoensis brazoensis (Roemer); Clark
- 1978 Mariella (Wintonia) brazoensis brazoensis (Roemer); Klinger and Kennedy

These medium to large conical shells can reach one foot (305 mm) in length with a diameter of eight inches (200 mm). The body chamber uncoils, but is rarely found in place. The whorls coil tightly with an overlap that obscures one row of tubercles. Two sets (four rows) of tubercles are found on each whorl, and the two sets are separated by a spiral band. The tubercles are lengthened and aligned obliquely on the whorl flank. Occasionally, the tubercles are joined by a slight elevation. The suture pattern is rarely preserved.



x 0.9



x 0.8

Otoscaphtes subevolutus (Bose, 1928)
LK Washita (Grayson, Del Rio) - Cenomanian
Superfamily Scaphitaceae

- 1928 Scaphites subevolutus Bose
1978 Eoscaphtes subevolutus (Bose); Young and Powell
1979 Otoscaphtes subevolutus (Bose); Young*



O. subevolutus is a micromorph fossil and is discoidal. The specimens are often preserved as iron pyrite. The hook and shaft is almost always found broken and separated from the coiled shell. The initial whorls are evolute and the umbilicus may occasionally be perforate. The discoidal part of the shell is followed by a curved shaft and a semi-circular hook. The aperture is not well described. Ornamentation reports vary. Clearly, the early whorls are nearly smooth and later whorls develop ribs which become intercalated by about four, thin, rather obscure ribs. This intercalation continues over the shaft and hook. Young states that the measurements are about 0.4 inch (10 mm) each for the evolute shell, the shaft and the hook. Measurements are most often made of the coiled part. Six specimens by Bose averaged 0.35 inch (9 mm) diameter, 0.16 inch (4 mm) width of last whorl, 0.16 inch (4 mm) height of last whorl, and 0.12 inch (3 mm) diameter of umbilicus.

*Note: In 1979, Young renamed the genus to Otoscaphtes, but was unsatisfied with the designation. Kennedy, in 1988, when dealing with slightly younger Texas fossils in the Eagle Ford Group, stated Yezoites equals Otoscaphtes and the earlier Yezoites prevails. Kennedy did not review the subevolutus species.

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'RELIC' MOLLUSCAN FAUNAS OF
NEOCENE AGE TO LIVING TAXA

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INTRODUCTION

In forming comparison suites of Pliocene/Pleistocene pectinidae from such diverse geological and geographical localities, as the Santa Barbara Formation of California; the Caloosahatchee Marl of Florida; the Waccamaw/Dublin limestone of South Carolina; and the Yorktown of North Carolina/Virginia, the identical taxa/taxon pectid assemblage appears along the southernmost Atlantic States.

Because of large quantities of specimens collected and checked against available literature, obvious synonyms were eliminated and nomenclature brought up to date where possible. All listed specimens were collected in units and localities noted, genera and species mentioned here were personally collected by associates and presently in the research - collection of FOSSIL QUARTERLY.

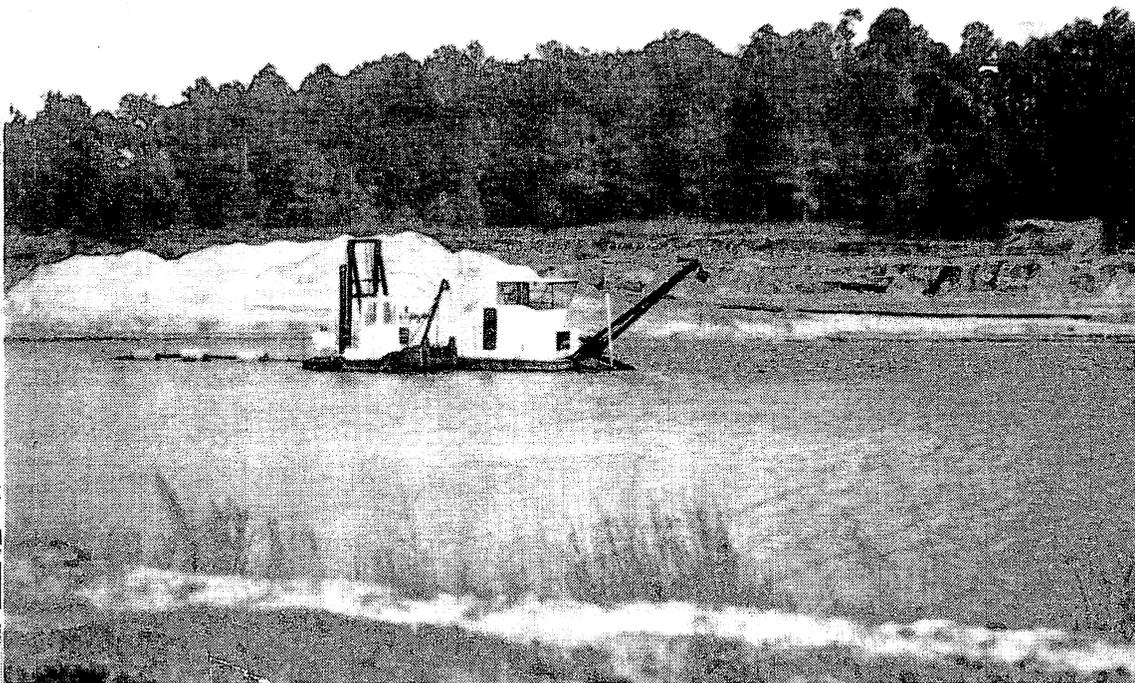
A brief acknowledgement and bibliography is included in closing.

In discussing the 'relic' *Chlamys islandica*, its range and that of the various subspecies is given, as well as that of the 'familial' *Chesapecten* which is a well-collected taxa/taxon along the southern Atlantic coastal formations.



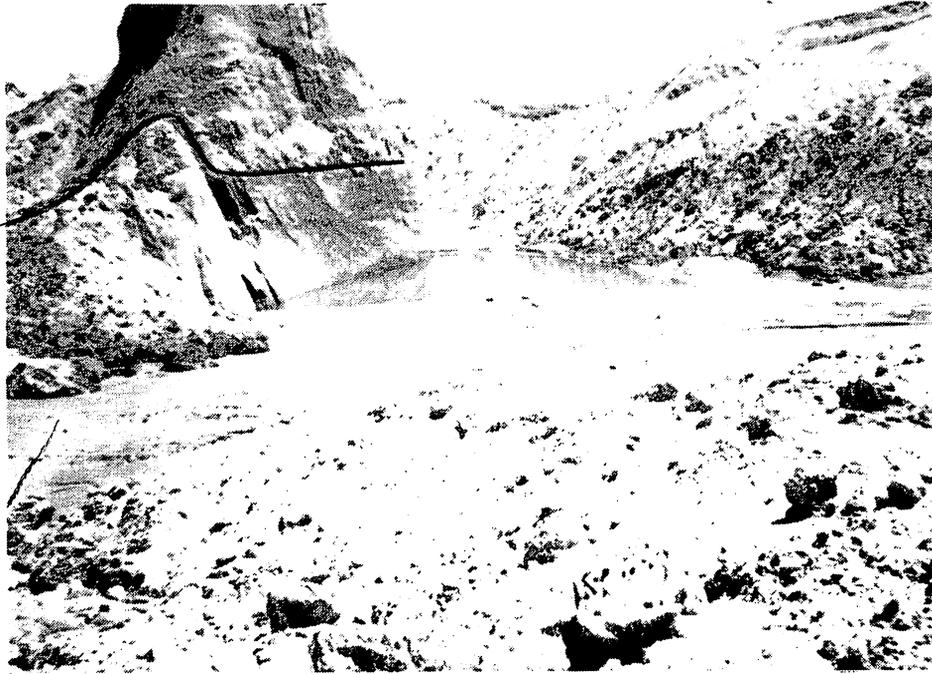
Upper Pliocene/Lower Pleistocene : Caloosahatche marl. Spoil piles, open shell pit operations of the APAC Newburn mine on Newburn Road 1.0 mile north of Richardson Road, 0.5 miles northeast of Florida Highway 780, 1.6 miles west of I-75.

Photograph courtesy Gary Lumannick, Miami, Florida.



Upper Pliocene : Waccamaw formation. Intracoastal Canal at 82nd Avenue, North Myrtle Beach, Horry County, South Carolina. Dredge is dumping fossiliferous limestone-sediment on east bank of Canal.

Photograph courtesy Rita McDaniel, Surfside Beach, South Carolina.



Dredged spoil pile of Pliocene: Yorktown formation sediments at Lee Creek Mine of the Texasgulf Chemical Company quarry, 6 miles north of Aurora, Beaufort County, N.C. Upper darker sediment dumped upon Pliocene sediments is blue sandy-clay deposits of Miocene: Pungo River formation. Both units contain large series of well preserved pectens, plus the index coral *Septastrea crassa* which occurs in small reefs.

Photograph courtesy: Rita McDaniel, Surfside Beach, South Carolina .



Upper Pliocene, Santa Barbara formation. *Pecten caurinus* beds below the drainage cut, with *Chlamys islandica jordani* bed in bank above the drainage cut.

Transfer Dump Hill, Santa Barbara, California.

Photograph courtesy: William L. Stafford, Santa Barbara, California.

I

The genus Pecten was introduced into binomial nomenclature in 1776 by O. F. Muller, and still used by taxonomists for many different forms of fossils and living fan-shells, but mainly recognized for the Latin pecten or scallop.

Prior to its division into the many sub-genera, pectens are large, strongly inequal, free-living scallops, resembling the type species (Pecten maximus Linnaeus) may be seen in such living forms as Pecten novaezelandiae Reeve, 1853 (New Zealand); Placopecten magellanicus (Gmelin), 1791 (East Coast United States), and occurs in fossil-form in Japan, Belgium, France and North Africa, synonym forms as fossils may be seen from the Pliocene through Pleistocene in equal abundance, with many taxon contributing to the 'familial' sequence of this paper.

Subgenera as Euvola and Janira heretofore considered as synonyms, are outside the scope of this paper, so I shall restrict myself to material easily collectable from localities noted.

Considered a descendant from a Jurassic ancestor, Mesozoic scallops with close affinities to Tertiary scallops may be due to convergence rather than theorized affinity.

Pectens are hermaphrodite, reaching maturity when two or three years old and spawning chiefly in summer. According to Fleming "larvae were produced in quantity when the water temperature reached 10c and appeared in surface waters over the scallop beds when they were several weeks old." Larval pectinidae are known to be highly mobile and to have a long pelagic stage. Verliger larvae are members of the plankton and can travel for great distances.

In fossil pectinids with living descendants, we find that life histories have been completed for numerous taxa/taxon groups. Among others in our collection, we find Chlamys islandica (Muller), Placopecten magellanicus (Gmelin), Carolinapecten eberous (Conrad). Pecten maximus (Linnaeus), and Pecten novaezelandiae (Reeve).

The genus Pecten lives on the continental shelf between low tide and depths to 80 fathoms, but generally on the upper part of the shelf where (according to Fleming) their photosensitive organs can function. Pectens live on the surface of the sea-floor and range over a variety of bottom sediments, including shelly-sand and gravel, but avoiding mud and silty bottoms.

A study of the fossil shells have produced numerous series of valves preserved in 'life' positions, with valves closed or partially linked. In Florida, at Caloosahatchee beds of concentrated shelly marls of a compact limestone coquina, large populations of pectens are preserved, attesting to abundant food sources provided by the gentle Pliocene currents. These once-living pectids being suspension feeders, extracts living or dead organic particles from passing currents.

In the Chlamys we find the sessile epifaunal habit of free-living scallops, capable of moving rapidly and erratically across the sea floor as if by jet propulsion, making prodigious leaps of irregular trajectory in a series of zigzags.

As noted earlier, subspecies of Chlamys exhibit few differences in morphology that can be attributed to changes in environment. However in living forms (i.e. Greenland/Iceland) appear larger than eastern seaboard forms, which may have links to neo-tropical seas.

It also appears that scallops as a whole, have more solid and strongly pigmented shells in the shallower than deep water habitats.

In both fossil and living Chlamys they vary in size, rib number, and color, retaining for scallops, a similar sculpturing and in shell characteristics. Examination of collected populations of Chlamys from single collecting stations (Woods Hole Marine Laboratory dredged several series) illustrate variation from one shell to another within single interbreeding populations, and similar events must have occurred during Neogenic time.

Ernst Mayr, 1942 in his "Systematics and the Origins of Species", defined the term population as consisting of "organisms, collectively, inhabiting an area or region comprising the total sum of co-specific individuals in a particular locality, at a particular time". For our purpose 'a fossil population' is no more than a sampling of dead individuals (the remains of) or indeed relics from a former living population.

It has been suggested that fossilization is sometime selective, i.e. young pectens (verligers) up to 30 mm. long are much rarer than longer mature individuals. Fossil sampling at relatively distant regions may indicate populations undergoing stress, frantic feeding of verliger stages by predatory benthic fish, while at some localities (St. Mary's formation, Calvert Cliffs, Maryland) populations of ontogenetic suites of Chesapeecten nefrens (Ward and Blackwelder), 1975, may be collected by the thousands, to disappear from their zone of habitation, and reappear as fully mature individuals many times their verliger-size, in sedimentary zones a dozen feet away.

II

LARVAL MIGRATION

Taxa that undergo planktotrophic development depend on planktonic organisms for nutrition during the free-swimming larval stage. Mollusks and many other marine taxa passively transported by ocean currents are extremely numerous. A number of tropical mollusks have planktotrophic larvae that remain in the plankton for six months or more, maintaining distributions spanning the Atlantic or encompassing numerous island chains in the Pacific.

In temperate waters, most plantotrophic mollusks have more modest dispersal capabilities with the planktonic larval stage lasting approximately 3 - 6 weeks. Currents of only 0.5 km/h can transport these larvae up to 150 - 500 km. in a single breeding period.

C.A. Fleming remarks in "The Genus Pecten New Zealand", 1957, that "a 20 m.p.d. current could transport a long lived pelagic larvae on a course up to 1,760 miles, and a 30 m.p.d. current "could do so on a much shorter course".

Davies, A.M., 1929, in his "Faunal migration since the Cretaceous Period", suggests the Siberian coast as the route of the Pliocene migration from North Pacific waters to the North Atlantic. However, it was subsequently believed that the Arctic coast of North America the more probable route (see MacNeil, 1967). Another theorist for the Arctic route, Soot-Ryen, T., 1932, in "pelecypoda with a discussion of possible migrations of Arctic pelecypoda in Tertiary Times".

Planktotrophic species having a relatively long planktic stage will have the ability to disperse over wide geographic areas in a single generation. Local catastrophes (via the geological record), are unlikely to eliminate a species over its entire geographic range, and larvae from other, persistent populations will replenish populations reduced by local extinction. These effects will combine to produce a geologically long-lived species, and lineages characterized by low extinction rates.

Larval shells are useful as index fossils, particularly if they can be assigned to known taxon by means of growth series, or by comparison to adult specimens having well preserved juvenile stages. This has been evident in the large suites of verligers collected, both in the fossil and living series, for the Chlamys, Chesapecten and Placopecten groups.

Distribution of fossil organisms can be useful in reconstructing paleo-currents, as well as salinity content, seasonal growth, parasitic content, symbiotic comparison as well as strontium/calcium isotopic analysis on all counts.

III

'RELIC FAUNAS' - THE FOSSIL RECORD

Edward J. Petuch, 1987, has written extensively on archaic faunas (primarily pockets of living Caribbean mollusca) having living descendants, based on what he terms 'relic pockets; called heterochrony, a designation implying "biogeographical patterns found in near-shore environments that represent the persistence, into the recent, of geologically older faunas". According to Petuch, two types of relic pockets are known to exist; primary relic pockets, where both the genera, and very often the actual geologically old species, have survived into the Recent; and secondary relic pockets, where only the archaic genera have survived.

In secondary relic pockets, some subsequent speciation has taken place, resulting in the production of new modern species of supposedly-extinct genera.

Petuch considers the existence of two relic pockets for the Pliocene/Pleistocene ancestral faunas and breaks these down into two Provinces - the Caloosahatchian Province (for the Caloosahatchee Formation of Florida) based on faunal populations, while the Caribbean region he refers as the Gatunian Province (for the Gatun Formation of Panama and Costa Rica), again, based on the typical faunas of that region.

For our faunal study I would consider the Waccamaw and Yorktown Formations as a single Province - the Carolinian, with their extensive sprinkling of Miocene to Pleistocene pectinidae (as in Gibson, Ray and other authors). We find here in the fossil record a continuum of bivalves of familial grouping, from the St. James River of Virginia, to the Inland Florida Caloosahatchee deposits at Sarasota, Arcadia and LaBelle, as represented by the several taxon of the Chesapeecten group.

IV

CHLAMYS AS A SUBGENUS OF PECTEN

We now come to the fossils themselves (as individuals and in groups representative of population) and taking living forms first we can then take these back in time, to their present 'weathering-out process in-situ'.

But we must begin at the beginning taxonomically, the group of Chlamys islandica is represented in the Fossil Quarterly collection by the following:

Superfamily PECTINACEA

Family PECTINIDAE

Superfamily PECTININAE

Genus Chlamys Bolten, 1798

Type by subsequent designation, Hermannsen, 1846-47.

Pecten islandicus (Linnaeus) = Ostrea islandica

Gmelin in Linnaeus, Syst. Nat. Edition 13, p. 3326, 1791, Pecten islandicus Muller, Prodr. Zool. Dan. p. 248, 1776, Chlamys Bolten, Mus. Boltenianum, p. 161, 1798.

Grant and Gale, 1931. Mem. San Diego Society Natural History, vol.1, pp. 161-163, pl.11, figs.1 a-b. Moore, 1984, U.S.G. Prof. Papers 1228-B, pp.18-29, pls. 3-7 (for subspecies C. hastata, jordani, opunita and rubida).

Chlamys islandica ranges from Denmark Strait, the waters off Iceland - around the coast of Greenland, flowing northwards along Davis Strait, into Baffin Bay, where the waters swings westward across the Beaufort Sea, Meeting the Bering Sea, heading south of Siberia, finally reaching the Santa Barbara coast. Here the Pliocene/Pleistocene sediments deposited the taxa and various subtaxon of this singular Chlamys.

MacNeil, as recently as 1967 stated that the "typical C. islandica is not regarded as a living Pacific subspecies", continuing, MacNeil states, "the species probably descended..... from the stock of C. picoensis chinkopensis Masuda and Savada, 1961, and C. imanishii Masuda and Savada, from the early Pliocene of Japan, however this may be purely oriental fantasy and C. islandica is to be found in beds of earlier Pliocene age in Iceland.

Our collection contains several well preserved specimens from the early Holocene of central Greenland (C-14 dated at 6185 years B.P. to 8210 years B.P.) the latter specimen valves having a greater dimension than recent New England off-shore deeper water forms.

Apparently during medial Pliocene times, larvae of Chlamys islandica migrated from the waters of Denmark Strait, merging with the east Greenland current. Upon reaching the tip of Greenland, the larvae-bearing plankton, swung into the northwest flowing current (where today living Chlamys populations are harvested as far north as Tasiusq, Greenland, see figure 10), and crossing Baffin Bay, these dormant larvae reached the Berings Strait, hitting the Gulf of Alaska waters flowing southwards to end up along the Santa Barbara coast of Pliocene/Pleistocene time.

Such a living survivor of the Chlamys islandica group, very similar in shell morphology, plus geographically isolated faunas did attain a dispersal in time, expanding their range from colder Icelandic waters to warmer (neotropical) Pacific seas during past Tertiary of Early Neogene time. This vast dispersal of C. islandica leaving isolated pockets of 'relic' populations surviving in the northern Atlantic and Greenland/Icelandic waters of today.

For the Pliocene ancestry in Santa Barbara, California, we find several polytypic species, the most typical subspecies being:

1. Chlamys hastata (Sowerby, 1843), Early Pleistocene, Timm's Point Silt. San Pedro, CA.
2. Chlamys picoensis (Waterfall, 1929) Pleistocene, Pico formation, Ventura County, CA.
3. Chlamys anapleus (Woodring, 1946), Pliocene, Lomita Marl Member, San Pedro Formation, San Pedro, CA.

4. Chlamys rubida, (Hinds, 1844), (a variety of sub-taxon from Rincon Hills, Santa Barbara, CA).
5. Chlamys hindsii (Carpenter, 1887) Early Pleistocene, Lomita Marl Member, San Pedro Formation, Palos Verdes Hills, CA.
6. Chlamys islandica jordani (Arnold, 1903) Upper Pliocene/Lower Pleistocene Santa Barbara Formation, Santa Barbara, CA.
7. Chlamys opuntia (Dall, 1898), Pliocene/Pleistocene, Santa Barbara Formation, Rincon Hills, Santa Barbara County, CA.

Surviving members of the Chlamys islandica group of subspecific rank relevant to this discussion are:

8. Chlamys zelandiae (Gray, 1843), Pliocene/Pleistocene, Mosston Sand, New Zealand.
9. Chlamys farreri nipponensis (Kurada) Pleistocene, Narita Formation, Japan.

Asiatic/Oceanic species 8 and 9 appear more closely related to C islandica, than to the distinctive California subspecies. The living C islandica is then to be accepted as a true 'relic' form of the taxa/taxon no matter where it is found fossil (Pliocene) since it did disappear from the fossil record during those transient Pliocene/Pleistocene seas to reappear in Recent times, along the Continental Shelf, where the shells have been commercially harvested as taken up in dredging operations.

So today this taxa/taxon is to be found abundantly from Denmark Strait off Iceland, to the cool waters off Cape Cod, reaching this area via the Labrador current, which in season reach Virginia during the winter, but extend only as far as Cape Cod during the summer months.

v

A SECOND 'RELIC' TAXA/TAXON

Fossil collectors visiting the classic Lee Creek Mine of the Texasgulf Chemical Company at Aurora, North Carolina, have seen abundant evidence of the pectens to be collected from the spoil piles in the sedimentary zones there. A second 'relic' assemblage occurs here in the Yorktown Formation (Pliocene), in the pectid Placopecten magellanicus (Gmelin, 1791), a large saucer-shaped scallop, closely resembling its associated index-form Placopecten clintonius. Placopecten magellanicus has the distinction, according to Dall (1898), of being the ancestral form of the living P magellanicus of the North Atlantic Ocean.

Trawler collections of living P. magellanicus from the George Bank at depths of 79 meters provided a large assemblage of comparable specimens, including many hundreds of verliger forms. A side by side comparison of fossil versus living P. magellanicus little morphological differences in spite of the break in time-evolutionary development.

VI

FAMILIAL GROUP

Familial groups of fossils exist within any given taxa which has a population distribution point (radiation center), at a given time (geologically speaking), said taxa and taxon appearing at a number of wide-spread locations, remnants of larger biofaunas of undifferentiated seas, in a larger Pliocene context.

For the purpose of this paper, based on our collection, I have selected the fossil bivalve (Mollusca: Pectinidae) Chesapecten, (Ward and Blackwelder, 1975), (U.S.G.S. Professional Paper 861). The species is C. jeffersonius (Say, 1824), a common enough form to be found fairly abundantly, within the Pliocene, averaging five inches in width, and occurs as a vibrant population within other taxa/taxon assemblages.

Collecting at Pliocene outcrops, from Florida to North Carolina has produced study material, as follows:

- A. Chesapecten jeffersonius (Say, 1824) Pliocene: Pinehurst Formation; Macasphalt Quarry, east of Sarasota, Florida, (occurs at numerous other localities in Florida).
- B. Pliocene: Dublin Formation; spoil piles off Highway 701, Conway, South Carolina.
- C. Pliocene: Dublin Formation; (Raysor Unit). Martin Marietta Quarry at Cross, South Carolina.
- D. Pliocene: Yorktown Formation; Lee Creek Mine, Aurora North Carolina.

Now if we wish to continue the 'familial' lineage of pectid populations on a more world-wide scale, by selecting comparable individuals retaining similar/different biounits (Darwinian divergence), and keeping to the taxonomy of Moore and Teichert, 1969, we find in our collection the following taxa/taxon which correspond favorably with 'familial' populations as described.

- E. Pecten humphreysii (Conrad, 1842), Miocene: Fungo River Formation; Lee Creek Mine, Aurora, North Carolina.

- F. Pecten beudanti (Mossberg, 1891), Miocene:
Burdigalien; Saucats, Gironde, France.
- G. Nanaochlamys nutteri (Arnold, 1906). Pliocene:
Purisima Formation; Capitola State Beach, California
- H. Chesapecten septenarius (Say, 1824). Pliocene:
Yorktown Formation; Lee Creek Mine, Aurora, North
Carolina.
- I. Pecten novaezelandiae (Reeves, 1853).
Pliocene/Pleistocene: Boundry uncertain. Teinui
Shellbed, Wanganui, New Zealand.
- J. Pecten albicans (Schroter). Pleistocene:
Schimoosa Group, Narita Formation; Hikida, Ichihara
City, Chiba Prefic., Japan.
- K. Pecten bellus (Conrad, 1837). Plio/Pleistocene:
Santa Barbara Formation; Transit Dump Hill, Santa
Barbara, California.

SUMMARY

What do all these fossils tell us? Primarily the evidence that stages of living veliger or planktonic larvae, could and were able to cross vast bodies of oceanic-water at varying periods of geologic time. For example, Caribbean waters carried veliger flowing into the Pacific due to equatorial currents, but this east-west flow, covering a shallow sea a few hundred feet deep, could change direction with climatic/tidal variation. Authors believe a land barrier may have existed during the Noogene due to an almost complete lack of common species. Populations communicating between the Pacific/Atlantic waterway, note that as early as the Mesozoic there were "windows" for the passage of biofaunas, through Mexico, also a Costa Rican faunal "window" was known to exist, but they (uncited authors) were considering Mediterranean/Caribbean faunas which do not interest us at this point. Anyway, such paleogene "windows" closed during Miocene times.

Pliocene molluscan populations might have crossed the Isthmian Corridor, down from the Santa Barbara reigon, crossing into western Caribbean, leaving isolated 'pockets' (for Petuch to write about), then flowing northward to the Floridian Province - becoming classic Caloosahatchee (Pinehurst - Tamiami marls) around the tip of Florida - staying just west of the Gulf Stream - leaving the neotropical currents to become the Dublin/Waccamaw seas, as well as the Yorktown/St.Mary'y seas of Virginia/Maryland, (also noted in Hallam, 1972).

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ACKNOWLEDGEMENTS

In appreciation for their sharing of photographs, specimens and suggestions, as well as valued publications, I wish to thank:

Mrs. Rita McDaniel, Surfside Beach, South Carolina.

Mr. William Ray, Simpsonville, South Carolina.

Mr. William L. Stafford, Santa Barbara, California.

Mr. John E. Johnson, San Jose, California.

Mr. Frank Peska, Jr., Long Beach, California.

Miss Sanda Roberts, Port Republic, Maryland.

David and Lucille Grabda, Myrtle Beach, South Carolina.

Dr. Linda A. Deegan, Woods Hole, Massachusetts.

Mr. Gary Lumannick, Miami, Florida.

Dr. Sren Anker Pedersen, Copenhagen, Denmark.

Museum of Comparative Zoology, Harvard University,
Cambridge, Massachusetts.

Dr. Junji Itoigawa, Nagoya, Japan.

Mr. Roy K. Sharp, Auckland, New Zealand.

Mr. Micheal Reagin, Pensacola, Florida.

Mr. Jim Reynolds, Maudlin, South Carolina.

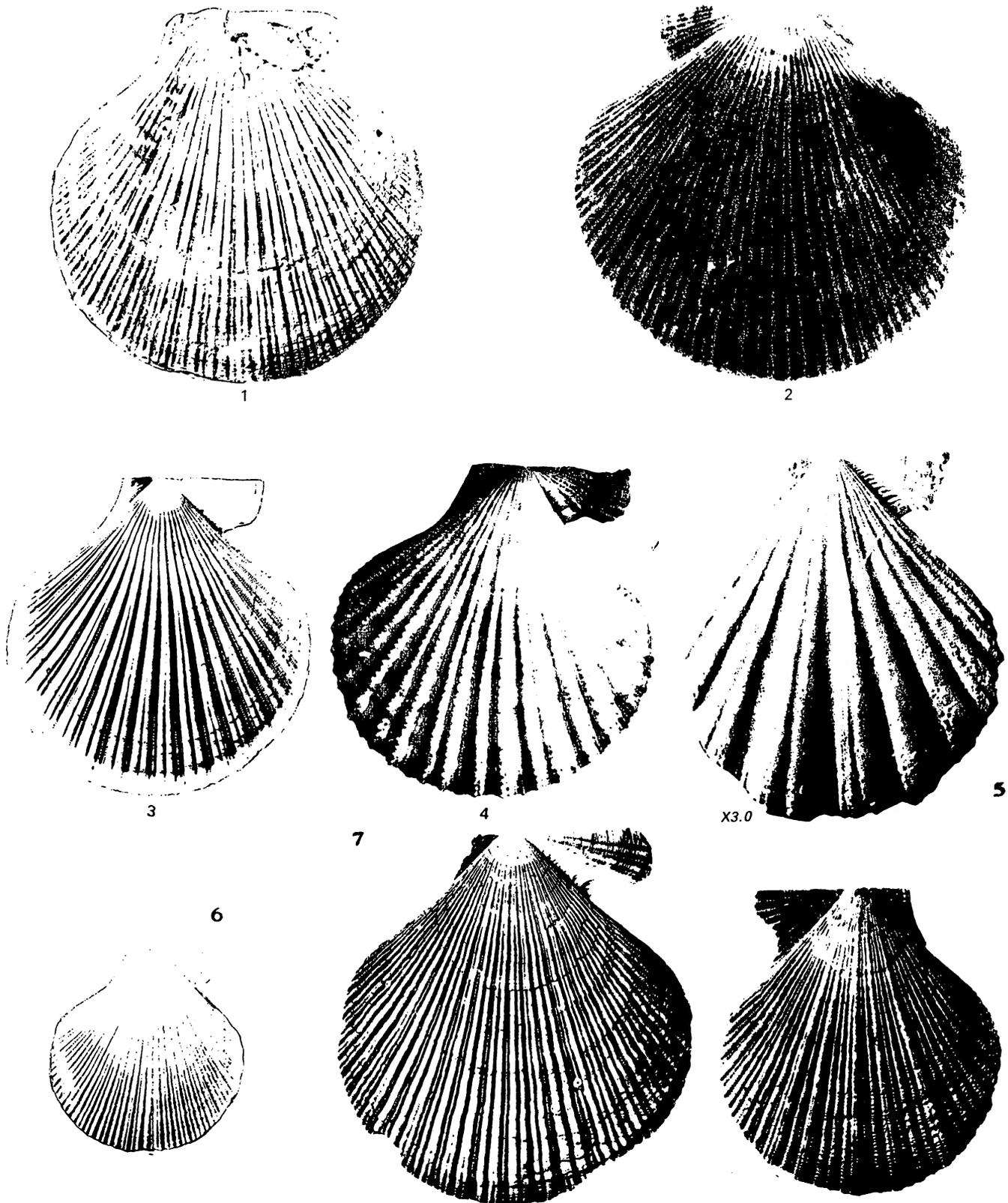


Fig. 1-2 *Chlamys picoensis* (Waterfall); 3. *Chlamys rubida* (Hinds); 4. *Chlamys hastata* (Sowerby); 5. *Chlamys anapleus* (Woodring); 6. *Chlamys opuntia* (Dall); 7. *Chlamys islandica* (Muller).

Illustrations courtesy U.S. Department of the Interior, Geological Survey.

8

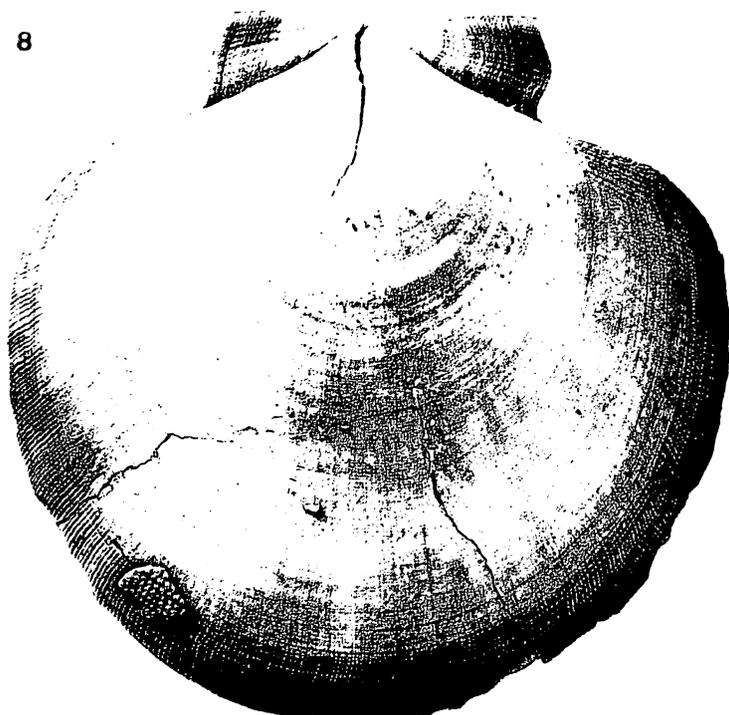


Fig. 8. *Placopecten magellanicus* (Gmelin)
Pliocene, Yorktown formation, Lee Creek
Mine, Aurora, N.C.

9

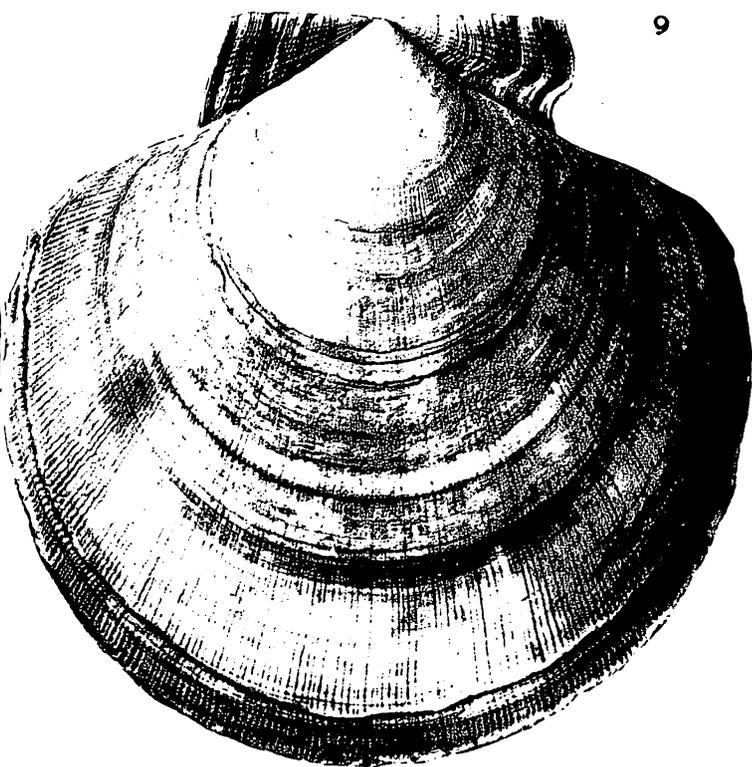


Fig.9. *Placopecten magellanicus*
(Gmelin), Recent - Waters off
Atlantic Shelf.

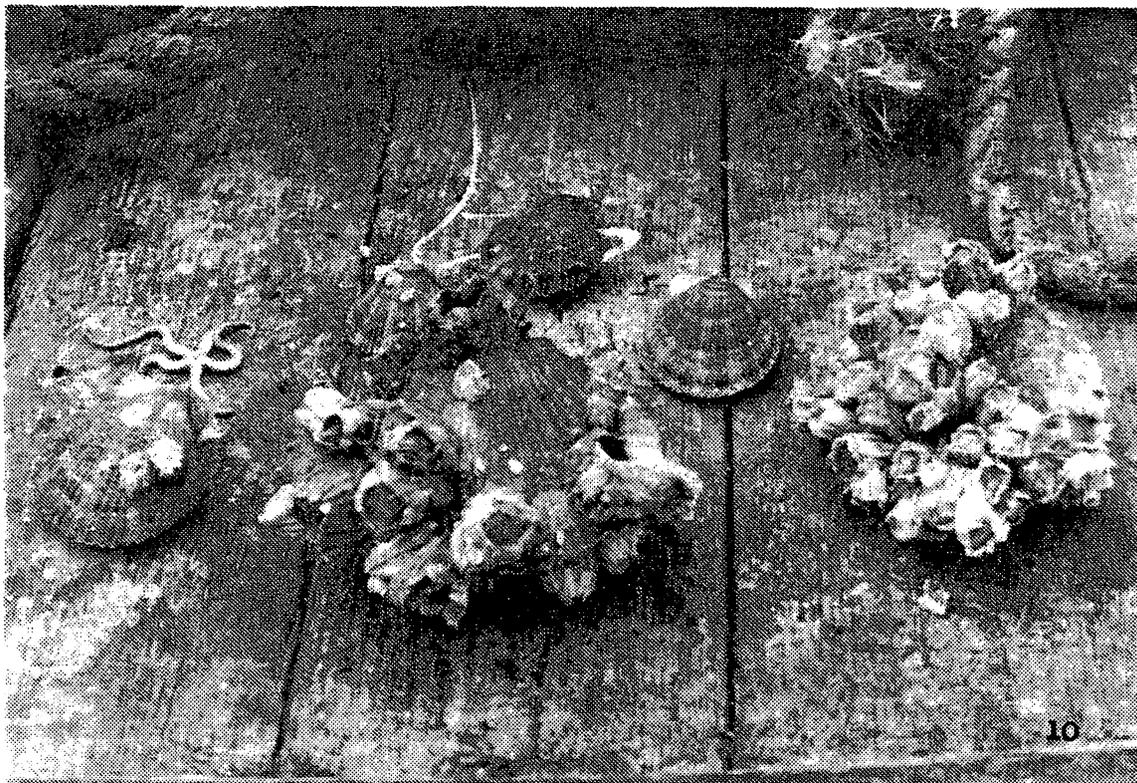
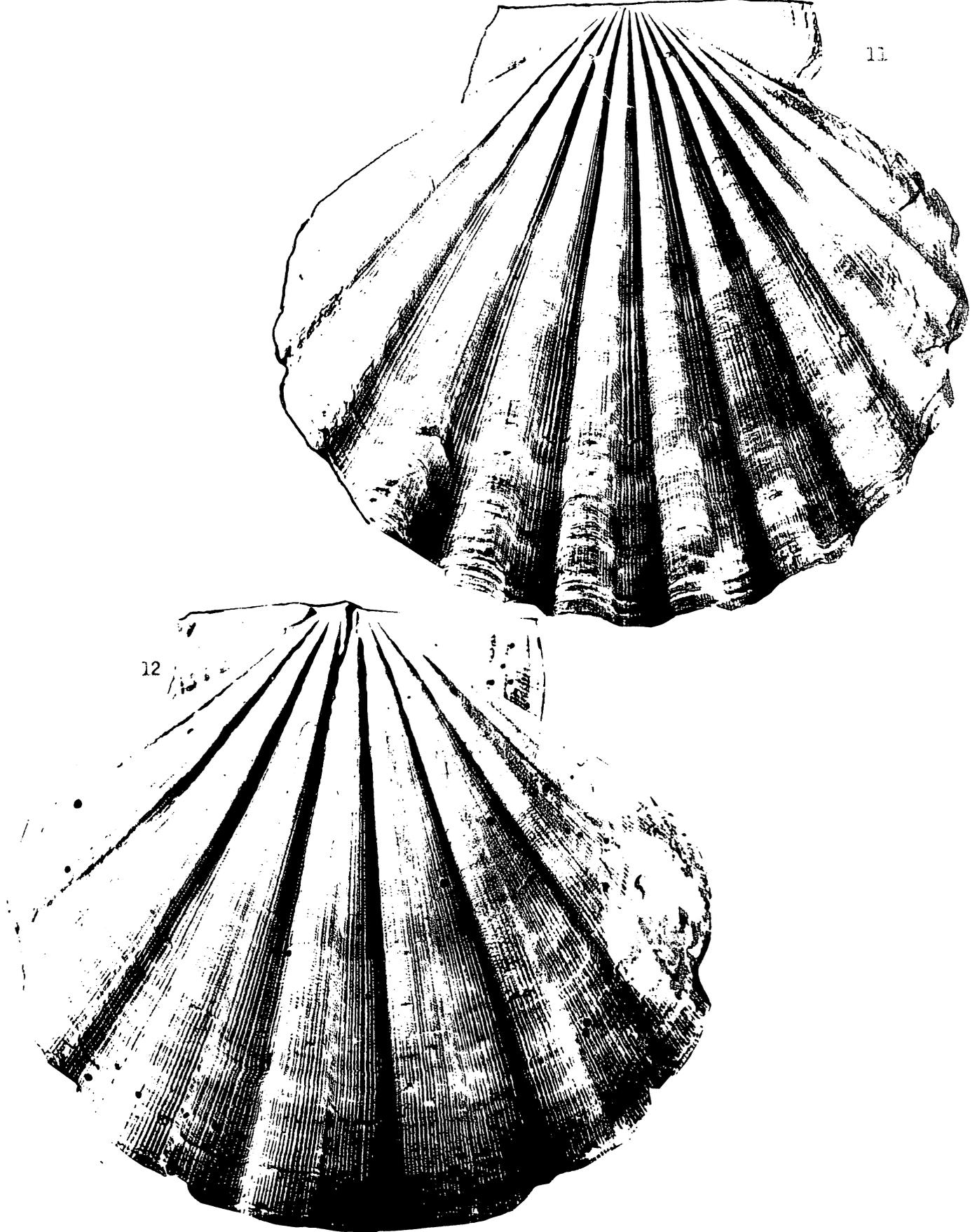


Fig. 10. *Chlamys islandica* dredged from Greenland waters. From Pedersen, 1988,
'Kammuslinger, Chlamys islandica, Ved Vestgrnland, Copenhagen.



Figs. 11 - 12. *Chesapeakecten jeffersonius* (Say). (9 thru 11 ribbed variety)
Pliocene, Yorktown formation. Lee Creek Mine, Aurora, N.C.
Illustrations courtesy, Smithsonian Institution, U.S. National Museum.

* * MAZON CREEK MOLLUSCS * *

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Before discussing the molluscs of Mazon Creek, I will first lay down a foundation for those who are not familiar with the Mazon Creek Area of Northern Illinois. The area is approximately 50 miles (80 km) southwest of Chicago. It stretches from Essex on the east to Ottawa on the west. For over 150 years exquisitely detailed plant fossils of great diversity have been collected in the area and are known world wide. These fossils are preserved in siderite concretions, also known as ironstone nodules. They are middle Pennsylvanian (Desmoinesian) which correlates to the Westphalian C of Europe and are in the Francis Creek Shale Member of the Carbondale Formation. The early collecting was done along the banks of Mazon Creek (on most Illinois maps it is shown as Mazon River) near the town of Morris. Later collecting was done in abandoned coal strip mines near the towns of Braidwood, Coal City and Morris. Some collecting was done near the town of Ottawa but since only clams were found it was dismissed as a poor collecting area by the amateur collectors of that time period, since ferns and associated plants were the main object. On occasion an animal fossil was found and these animals were determined to be either terrestrial or fresh-water species.

Around 1960 a new area near the town of Essex, known as Pit 11 of the Peabody Coal Company, was discovered. Then in 1963 a small abandoned mine a few miles west of Morris was discovered. Because of the abundance of clams in this area it was given the name Chowder Flats. These new areas, unlike the older locations where plants are the dominant form of life, are dominant in animal life. Also, the animal life was shown to be dominant in marine rather than terrestrial/fresh-water species. It was established that there was a definite distinction between the two communities and in 1966 Johnson and Richardson^① formally designated the marine biota as the Essex Fauna and the terrestrial/fresh-water biota the Braidwood Fauna. Subsequent multidisciplinary studies have made it possible to

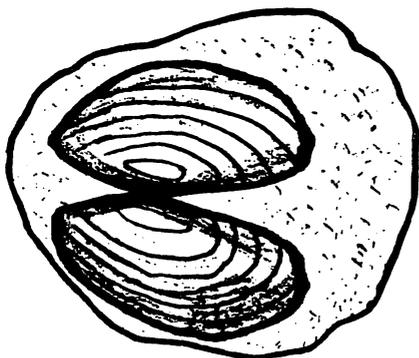
accurately trace the primeval shoreline. Further investigation has determined the existence of a lagoon and a delta.

The molluscs are represented in both the Essex and the Braidwood Faunas. In fact, numerically, molluscs are very important members of the Mazon Creek biota and also of the normal Pennsylvanian clear-water marine fauna of other mid-western locations.

BIVALVIA (PELECYPODA)

The bivalves are without a doubt the most prevalent molluscs in the Mazon Creek biota. In one report alone, over 12,000 specimens were examined by the investigator. To my knowledge, at last count there were 17 genera represented. The fresh-water group, the Braidwood Fauna, is typified by two myalinids - Anthracanuata sp. and Anthraconaia sp.. However, the most common fresh-water bivalves are clams that have not as yet been described.

The marine group, the Essex Fauna, is represented by 15 genera, only one of which is represented by more than one species. The most abundant of these is the clam Edmondia sp..



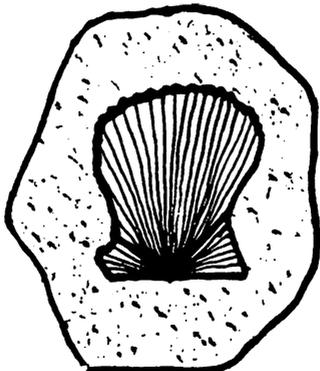
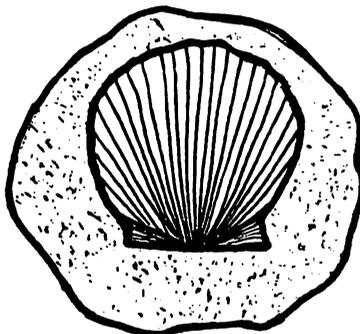
EDMONDIA SP.

It is not only the most common, but also encompasses the largest geographic area of all the molluscs. Specimens have been collected from the southern end of Pit 11 (1 mi. W. of Essex) to Chowder Flats to Ottawa. This is a total distance of about 40 miles (64 km). Occasionally nodules containing specimens of Edmondia sp. are found with a corresponding trail or burrow.

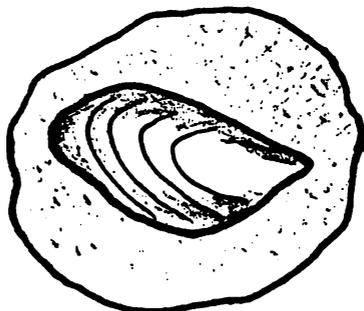
A recently discovered 'Essex' assemblage in Missouri was found to contain Edmondia. This certainly broadens the range of this genus. It is my understanding that the Edmondia of the Mazon Creek Area is being restudied and may possibly be reclassified.

The pectens are also well represented by three genera. In order of abundance they are Aviculopecten mazonensis, Dunbarella sp. and Euchondria sp.. According to one author⁽²⁾, pectens are the most abundant animal at the Chowder Flats

location. Dunbarella is easily distinguished from Aviculopecten by it's less pronounced auricles and lack of auricle notch. Euchondria, which is the smallest of the three and exhibits crosshatching, is very rare.

AVICULOPECTEN MAZONENSISDUNBARELLA SP.EUCHONDRIA SP.

The myalinids are represented by two genera in the Essex Fauna - Myalina wyomingensis and Septimyalina perattenauta. They are fairly common at the Pit 11 location.

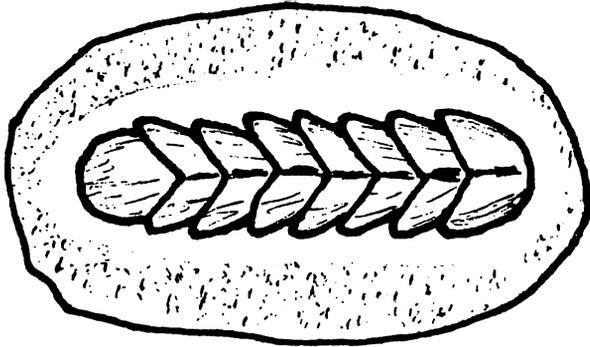


MYALINID

Astartella concentrica is a common clam found in Pennsylvanian deposits throughout the United States. It is found in the Essex Fauna, although not in abundance. Other genera found here are Schizodus, Solemya, Paleolima, Unio, Leptodesma, Yoldia, Streblochondria and Nuculana. These genera have been identified by just a few specimens. The genus that is represented by more than one species (2) is Leptodesma. Careful scrutiny of the many genera of bivalves shows a great diversity of feeding habits.

POLYPLACOPHORA

In a 1956 monograph Eugene S. Richardson, Jr.^② described a polyplacophoran or chiton from a single specimen. This was one of the earliest descriptions of marine invertebrates from the Mazon Creek Area. In describing the various features, he described a radula which as it turned out was the first radula described from the Paleozoic Era. In his original description, Richardson assigned it to the genus Helminthochiton, but it has



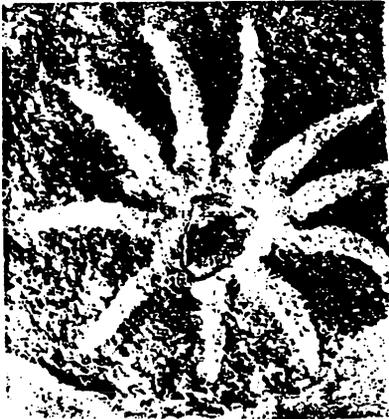
GLAPHUROCHITON CONCINNUS

SHOWN IN COMMON POSITION OF PRESERVATION. UNSHADED AREA IS THE GIRDLER.

since undergone several revisions and the classification has been changed to Glaphurochiton concinnus (Richardson). Several hundred specimens have subsequently been recovered from the area. The specimens are preserved in a dorso-ventral position and are articulated, with most showing all eight valves as well as the girdle. In most of the specimens the radula is preserved and is very much like the radula of modern chitons. It appears as a long, flat ribbon of about 100 rows with 17 teeth per row. Unlike present day chitons which inhabit a hard substrate, Glaphurochiton inhabited a soft, muddy bottom. On Aug. 15 & 16, 1967 while collecting at Pit 11 with my wife and son we recovered 19 chitons from one hill. One other instance of a 'Chiton Hill' has been reported. This would indicate that, like modern chitons, G. concinnus was a gregarious creature.

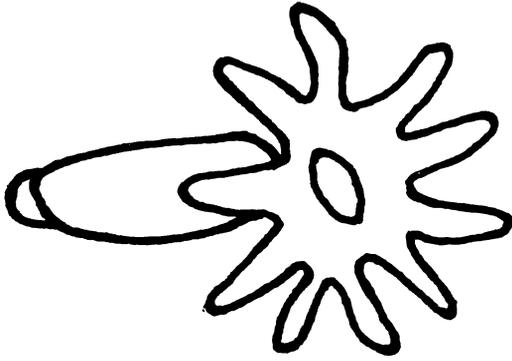
CEPHALOPODA

Although cephalopods are represented in the Mazon Creek biota, they are a rare member. Relatively few specimens of cephalopods have been recovered and none is complete. However, they exhibit a great diversity - nautiloids, ammonoids, coleoids and bactritoids are represented. Three genera, Stearoceras,



JELETZKIA DOUGLASSAE
HOLOTYPE

Titanoceras and Paleocadmus, constitute the nautiloids. Paleocadmus has been described from radular molds only. Two genera, Wiedeyoceras and Schistoceratid indet., make up the ammonoids. The bactritoids are represented by a single genus, Bactrites. Undoubtedly the most spectacular specimen is that of the coleoid Jeletzkiia douglassae. This is the oldest squid-like organism known.



**RECONSTRUCTION OF JELETZKIA
WITH PORTION OF SHELL AS SEEN
IN X-RAY RADIOGRAPH**

x-ray radiographs (Johnson & Richardson, 1968, pg. 527, figs. 3, 4.)." Since the original description, approximately ten additional specimens have been recovered. Preservation of various organs, body parts and shell combined in these specimens produced much needed information to better reconstruct the beastie. Beastie was a popular term used by the late Dr. Eugene S. Richardson, Jr.. The radula, which was not preserved in the holotype, has been found in two additional specimens. Another specimen has the complete shell preserved and an x-ray radiograph of another specimen revealed an ink sac with accompanying ink cloud.

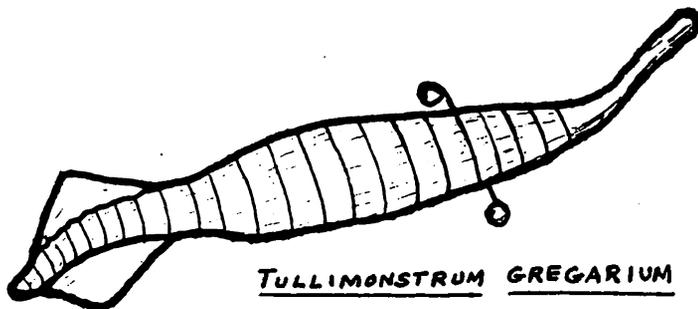
Like the chiton, the description of Jeletzkiopsis was based upon a single specimen. "The holotype is an impression of ten radially arranged tentacles. Arm hooks are preserved within the outline of the arms, in some cases in distinct double rows. A portion of the shell (pen, rostrum or gladius?) is buried within the concretion which contains the holotype, and is discernable in

GASTROPODA

Undoubtedly the gastropods are the least important and unheralded molluscs in the Mazon Creek biota. This may be an ambiguous statement and will be explained later. The Mazon Creek gastropods lack both diversity and good preservation. Commonly the gastropods are preserved as external molds and appear as cavities in the nodule. Infilling of these cavities by secondary minerals such as kaolin, calcite, sphalerite and pyrite does occur. Poor preservation of all but a few specimens has made it impossible to make assignment beyond the genus level. No soft parts have as yet been found preserved. To my knowledge, gastropods have been found only in the Essex fauna. Five genera have been identified and as you will note, the abundance is very unevenly distributed. The bellerophon

Euphemites richardsoni comprises over 2/3 of the gastropod assemblage. In almost all cases they appear individually in the nodules. Next in abundance is Strobeus sp.. Unlike the Euphemites, they usually occur in clusters within the nodules (two to five in a tight cluster) and frequently specimens are found in association with the jellyfish Essexella asherae. The aggregate occurrence along with the association with jellyfish suggests that the Strobeus of Mazon Creek was a scavenger. Strobeus sp. resembles Strobeus primigenius, but due to the poor preservation of the studied specimens this cannot be specifically determined. The genus Straparollus has been identified from two specimens. Hypselentoma sp. and Naticopsis sp. have been identified from single specimens. The Naticopsis specimen had a color pattern of light and dark stripes preserved, but in the process of making a latex mold this feature was destroyed.

Now let us assess the possible ambiguity of my initial statement concerning the gastropods. In 1966 Dr. Eugene S. Richardson, Jr.⁽⁵⁾ described an enigmatic creature from the Essex Fauna - Tullimonstrum gregarium. Without a doubt the Tully Monster, as it is commonly referred to, is the most intriguing organism in the Mazon Creek biota. The affinities of this



bizarre creature were perplexing and it was suggested to be anything from a worm to a Loch Ness Monster. It was classified
 PHYLUM: unknown
 CLASS: unknown.

In a 1979 report Merrill W. Foster⁽⁶⁾ suggested that the Tully Monster is a mollusc. To be more specific, a heteropod - a shell-less gastropod. He made comparisons with modern heteropods. His arguments are very strong however, the jury is still out. As is the case with most revolutionary concepts, he has received some supporters and many skeptics.

So, are the gastropods the least important and unheralded molluscs in the Mazon Creek biota? Not if the Tully Monster is a gastropod.

This capsule commentary should give the reader some insight into the molluscs of Mazon Creek. It should also evoke some questions. The first that comes to my mind - why is it that the gastropods were so poorly preserved when other organisms with bodies of varying hardness and different kinds of chemical composition were so well preserved? Worms, insects, spiders, shrimps, vertebrates, etc., are preserved with excellent detail. Give it some thought.

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The Coral Ridge Fauna

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Introduction

The Coral Ridge member of the New Providence Formation (Osagean, Lower Middle Mississippian) provides a fascinating array of mollusks, echinoderms and other creatures. Yet, because of the paucity of collecting localities coupled with the low abundance, the fauna consists of predominately undescribed and tentatively described species. This article will acquaint readers with the depositional environment, faunal abundance and collecting tips for the fossils which may be preserved in exquisite detail.

The Coral Ridge member and fauna were first described by Conkin (1957) from the Coral Ridge quarry of the General Shale and Brick Company, Jefferson County, Kentucky. There are only four documented localities where this fauna occurs; one is in Clark County, Indiana. The type locality has the most diverse fauna. More than 80 percent of the fossil species are mollusks. Indeed, over 70 percent of the fossils belong to a single species!

Stratigraphy and Paleogeography

According to Conkin (1957, 1972) the New Providence Formation consists of three members (in ascending order): the Coral Ridge member, Button Mold Knob member, and the Kenwood Siltstone member. The formation is part of the Borden Group (see figure 1). Some geologists list the Borden at formational level and assign the New Providence a ranking of member. The Coral Ridge and Button Mold Knob members are not differentiated because their lithology is similar (see figure 2). The Coral Ridge fauna is considered to be of the earliest Middle Mississippian age.

During the early Middle Mississippian, sedimentation in the east-central United States was dominated by deltaic deposition. Called the Borden delta, the sedimentary rock show evidence of conditions on the basin floor, the prodelta or foot of the delta, the delta slope, and the delta platform or top. Each portion of

* This paper is dedicated in memory of Franklin Hadley, member of *
* M.A.P.S. and an expert on brachiopods. *

the delta had a different environment which supported various faunas.

The Coral Ridge fauna is associated with the basin at the base of the Borden delta. During the earliest Mississippian, the environment was anaerobic (lacking dissolved oxygen) forming black shale. Conditions gradually changed to an oxygen-poor sea floor, as indicated by bioturbated greenish clay shale. This allowed for life to exist in patchy communities where conditions were best-suited under a less-than-ideal situation.

Pyritic steinkerns are the most common fossils. Trace fossils of animals that burrowed in the mud may be preserved as pyrite in three-dimensions. The occasional fossil with the external shell ornamentation preserved shows incredible detail. The oxygen-poor conditions were likely anoxic beneath the top few centimeters of sediment (Kammer, 1985) allowing microenvironments for the sulfate-reducing bacteria. They react with detrital iron to in-fill the empty aragonite exo-skeletons with pyrite. In addition to pyritic preservation, Coral Ridge fossils can be altered to marcasite, siderite, goethite ("limonite") and quartz. Fossils may be found partially geodized.

Paleoecology

The Coral Ridge fauna does not have the diversity of other Osagean faunas. The communities were likely of low abundance or only an extremely low number of exo-skeletons were preserved. The fossils are dominated by small individuals. Stunting is thought to be the primary mechanism. This cannot be proven in most mollusks, but can be seen in the goniatites. With the exception of the corals, the bulk of the fossils are smaller than one cubic centimeter. Very rarely larger gastropods, goniatites and nautiloids can be found, these make up less than one percent of the those taxa. Some examples of exceptional large mollusks: Glabrocingulum - 5 cm., Loxonema - 7 cm., Sinuitina - 5 cm., Michelinoceras - 30 cm.

The Coral Ridge fauna is dominated by epifaunal deposit feeders, animals that move around on the sea floor. Most are archeogastropods (Kammer, 1985) (see table 1). They were likely ingesters of detrital organic material. The actual depth of the basin is unknown. Kammer (1985) indicates that it was likely below the photic zone. The presence of tabulate coral indicate that light was present, though probably at very low levels.

The most abundant archeogastropod is Glabrocingulum ellенае (Conkin), which makes up 72 percent of the fossils found, and 92 percent of the epifaunal deposit feeders! It ranges in size from

one millimeter to about 3 centimeters across. About one in 100 show the external ornamentation.

A less common gastropod is Sinuitina annaea, a monoplacophorean which occasionally shows closely-spaced external ribs. It resembles several of the goniatites, but it is much more elongated. Much rarer is a bellerphont gastropod Bucanella sp. A single platyocerid gastropod was collected by the writer. Conkin (1957) lists the platyocerid Orthynochia sp. This snail is coprophagous, situating itself over the anal opening of crinoids.

Trilobites are uncommon epifaunal deposit-feeders. The Coral Ridge fauna is represented by two species. Phillibole conkini Hessler is the more common variety, but is still very rare. Brachymetopus spinosus (Herrick) is less common.

Epifaunal suspension feeders including brachiopods, corals and echinoderms make up about half of the species found in the Coral Ridge fauna, but comprise less than 13 percent of the of the fossils found (table 1). Apparently circulation permitted enough suspended food into the environment to allow a variety of epifaunal suspension feeders to live, but they did not thrive.

Favosites corals are found surrounding crinoid stems. The soft muddy seafloor would not allow larva to get established. In addition, the elevated colony could feed a few centimeters higher above the basin floor. Colony distribution on crinoid stems is assymetrical, indicating a growth preference, likely facing nutrient-bearing currents.

The tiny Crurithyris? sp. is the most common brachiopod. At one to five millimeters in diameter, this diminutive suspension feeder was the most successful animal living on the seafloor. It is more common than the infaunal suspension feeders which, while buried in mud, fed from essentially the same zone.

Echinoderms are highly diverse, but identifiable plates or calices are very rare. Blastoids with fused plates may be found as a complete head or theca. Crinoid plates are usually bound by soft tissue. Upon death they disarticulate quickly. The depth of the Coral Ridge faunal precluded rapid storm burial, as a result, crinoidal material is typically column sections, single plates, and rarely small arm sections or basal cups. Crinoid holdfasts are the type with cirri spreading away like shallow tree roots, to be expected in a soft, muddy substrate. The longest crinoid column found by this writer is about 20 centimeters.

A substantially smaller number of fossils were infaunal deposit feeders, consisting of at least three genera of clams and

a rostroconch, Hippocardia sp. (table 1). The variety of size and shape of the non-siphonate clams (Ctenodonta sp., Nuculopsis sp. and Phestia) sp. suggest a division of food resources in the sediment (Kammer, 1985). Softbodies infaunal deposit-feeders were likely abundant, as indicated by bioturbation of the shale and numerous pyritized trace fossils, including Scalarituba missouriensis Weller.

Unlike other Borden delta communities, the Coral Ridge fauna is relatively rich in carnivorous cephalopods. Four goniatites and one or two nautiloids have been reported. The small goniatite Ammonellipsites sp. (undescribed) makes up five percent of the fossils found by this writer. An undescribed species of Beyrichoceras sp. from the Coral Ridge is thought to be the oldest known occurrence of the genus in North America (Kammer, 1985). The distance above the sea floor that the cephalopods lived is unknown.

Although the nature of Paraconularia sp. is unknown, it may be found in phosphatic exoskeletons with the Coral Ridge fauna. It is typically associated with siderite nodules and in double cone-in-cone nodules. Nodules may consist of numerous fragments or may contain a single specimen preserved in three-dimensions. The writer has found a specimen with the opercula preserved.

Table 1 Faunal List (Collected by the Writer)

Species/Author/Ft.Note#	Number	Percentage(1)	Feeding(2) Type	Fossil(3) Type
<u>Glabrocingulum ellenae</u> (C) (21)	1034	72.2	ED	MG
Rugose Corals (undiff.) (4)	141	9.4	ES	CR
<u>Ammonellipsites</u> sp. undescr.	79	5.3	C	MC
<u>Sinuitina annae</u> Conkin	42	2.8	ED	MG
<u>Loxonema</u> sp. descr.? (5)	36	2.4	ED	MG
<u>Crurithyris?</u> sp. undescr.? (6)	32	2.1	ES	BA
<u>Michelinoceras</u> sp. undescr.? (7)	16	1.1	C	MC
<u>Merocanites marshallensis</u> (W)	12	0.8	C	MC
<u>Nuculopsis</u> sp. undescr.?(8)	12	0.8	ID	MP
<u>Phestia</u> sp. undescr.?	10	0.7	ID	MP
<u>Hippocardia</u> sp. descr.? (9)	8	0.5	ID	MR
<u>Beyrichoceras</u> sp. undescr. (10)	8	0.5	C	MC
<u>Ctenodonta</u> sp. undescr.?(11)	7	0.5	ID	MP
<u>Granatocrinus kentuckyensis</u> (C) (12)	6	0.4	ES	EB
<u>Rhynchopora</u> sp. (13)	6	0.4	ES	BA
<u>Phillibole conkini</u> Hessler	4	0.3	ED	AT
<u>Punctospirifer? subelliptica</u> (M)	4	0.3	ES	BA

<u>Orbiculloidea</u> sp. undescr.?	4	0.3	ES	BI
<u>Paraconularia</u> sp. (14)	4	0.3	ES?	?
<u>Bucanella</u> sp. undescr.?	3	0.2	ED	MG
Sponge spicules	3	0.2	ES	P
<u>Synbathocrinus dentatus?</u> (15)(16)	2	0.1	ES	EC
<u>Cyathocrinites astralus</u> Kammer (16)	2	0.1	ES	EC
<u>Magnumbonella</u> sp. undescr.?	2	0.1	ES	BA
<u>Orthonychia</u> sp.	1	0.1	ED	MG
<u>Favosites?</u> sp. (17)	1	0.1	ES	CT
<u>Hadroblastus</u> sp. undescr.? (18)	1	0.1	ES	EB
<u>Taxocrinus</u> sp. (16)	1	0.1	ES	EC
<u>Barycrinus</u> sp. cf. <u>B. sculptis</u> (16)	1	0.1	ES	EC
<u>Catillocrinus?</u> sp. (16)	1	0.1	ES	EC
<u>Platycrinus hemisphericus</u> (16)	1	0.1	ES	EC
<u>Dielasma?</u> sp. (19)	1	0.1	ES	BA
<u>Eumetria</u> sp.	1	0.1	ES	BA
<u>Brachymetopus spinosus</u> (H) (20)	1	0.1	ED	AT

Crinoid stems, traces fossils are not included in survey.

Notes:

(1) Percentage differs somewhat from Kammer (1985), this writer: N = 1497, Kammer: N = 628 specimens.

(2) ED = Epifaunal deposit feeder; ID = Infaunal deposit feeder; ES = Epifaunal suspension feeder; IS = Infaunal suspension feeder; C = Carnivore

(3) MG = Mollusca, gastropoda; MP = Mollusca, pelecypoda; MC = Mollusca, cephelapoda; MR = Mollusca, rostroconchia; CR = Cnidaria, rugosa; CT = Cnidaria, tabulata; BA = Brachiopoda, articulata; BI = Brachiopoda, inarticulata; EC = Echinodermata, crinoidea; EB = Echinodermata, blastoidea; AT = Arthropoda, trilobita; P = Porifera

(4) Ranking abundance: Amplexus fragilis (Worthen & St. John), Trochophyllum verneiullianum (Milne-Edwards & Haime), Hapsiphyllum sp.

(5) Conkin (1957) lists Loxonema delphicola

(6) Additional examination reveals 30 percent of these brachiopods maybe related to Cyrtina.

(7) Kammer (1985) lists an unidentified orthocone nautiloid

(8) Nuculopsis is in substantially lower numbers than shown here, due to misidentification by the writer in early collecting. Later counts indicate this genus is 66 percent less common than Phestia. Clusters of either can be found, skewing small number counts.

(9) Conkin (1957) lists Hippocardia cancellata

(10) The largest goniatite, Conkin and Kammer list Imatoceras?, which is larger than this genus.

(11) Additional collecting of this genus has revealed larger numbers, slightly below Phestia.

(12) Conkin (1957) lists two other species from the Coral Ridge, including G. coralridgensis (Conkin) and G. oppelti (Rowley)

(13) Conkin (1957) lists as R. beecheri (Greger), this writer notes the similarity. Additional species of Rhynchopora also occurs, represented by a specimen resembling R. persinuata (Winchell), a second is unknown, more elongated from front to back.

(14) Commonly associated with siderite nodules, often broken into numerous fragments.

(15) S. cf. S. dentatus according to Conkin (1957), found as basal cups

(16) Additional collecting indicates the following abundances (in decreasing order): Barycrinus, Cyathocrinites, Platycrinites, Synbathocrinus, Taxocrinus, Catillocrinus

(17) Conkin (1957) lists Favosites divergens, other tabulate corals listed include Striatopora sp. and Michelinia sp. This variety of Favosites typically grows attached to crinoid stems, placing it higher above the muddy sea floor.

(18) Hadroblastus is listed in Conkin (1957) as Codaster jessieae, in Conkin & Conkin (1976) as Hadroblastus sp. A third blastoid genus, Xenoblastus sp. also added in second reference.

(19) Represented by a single poorly preserved specimen. Conkin lists a specimen of Girtyella.

(20) B. spinosus (Herrick) found in siderite nodule, consisting of fragments that may be more than one specimen.

(21) Kammer (1982)(1985) lists Treprospira from the Clark Co., Indiana locality. This writer has several gastropods which have not been positively identified to this genus, but are more elongated than G. ellenae. This form makes up about 0.5 percent of the archeogastropods.

For collectors, there is only one fossil that can be considered abundant among this fauna - Glabrocingulum ellenae. (This excludes the pyritized trace fossils which have not been included in the survey, but are slightly more abundant. A single Scalarituba missouriensis Weller may weather into a half-dozen or more pieces.) Corals, as a group, are relatively common. The goniatite Ammonellipsites sp. is somewhat less. Two snails, Sinuitina annaea and Loxonema are considered uncommon. Everything else is either rare or very rare. Multiple visits to the Coral Ridge quarry does not change the percentages of the eight most common fossils. Those that are rarest (percentages <0.5 percent) have the most collecting variety from trip to trip. It is these fossils that add "spice" to collecting trips!

Collecting the Fauna

There are only four collecting localities documented in the literature (Conkin, 1957, Kammer, 1985). This writer has

collected from the active quarry at Coral Ridge and the abandoned Louisville Cement Shale quarry near Sellersburg, Clark County, Indiana. The latter locality does not have the species variety of the former, though it contains Beyerichoceras in greater abundance than at Coral Ridge.

The sparse and patchy nature of this fauna means collectors must be very thorough. Without a systematic sweep of the outcrop, it is quite easy to miss the only Granatocrinus, Phillibole, which has weathered out. It is also easy to miss a cluster of mollusks. The soft greenish shale weathers rapidly. Unlike some formations where a single collector can "rape" an outcrop for decades with one visit, the nature of the lithology is self-sustaining. A couple of months (or a couple of good downpours) between collecting trips is sufficient to reconcentrate the fossils.

The quarried areas with Coral Ridge fauna consist of five areas separated from each other by haulage roads. Extensive collecting has revealed that the smaller exposures average one Granatocrinus blastoid and one Phillibole trilobite per year. The larger areas have twice that abundance. Where the fauna occurs, there seems to be a very uniform distribution of rare fossils. The mollusks tend to have a clustered distribution.

Site access is somewhat touchy. Collecting can only be done during work hours. Weekend collecting is strictly forbidden. University groups are allowed, but amateur club trips are not. Small groups (three or four) may be allowed. A liability release form must be filled out. The site is relatively safe, but heavy equipment operates in the collecting area. Please contact the author for current collecting status. The Coral Ridge fauna is sparse, so if you are not familiar with the collecting areas, it very easy to walk right over it without noticing anything!

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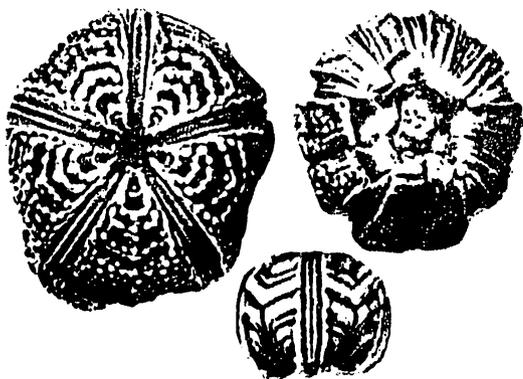
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Granatocrinus kentuckyensis (12mm) (Conkin 1957)



Hadroblastus sp. (19mm high)



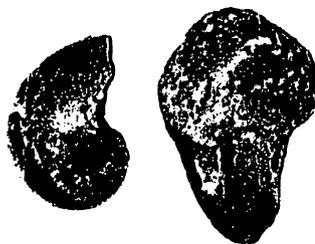
Merocanites marshallensis (Winchell)



Phillibole conkini



Beyerichoceras sp. (16mm)



Sinuitina anaeae (Conkin 1957)



Merocanites marshallensis suture pattern

STRANGE FOSSIL MOLLUSKS AND MOLLUSCAN-LIKE FOSSILS

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Early Paleozoic fossils, which of course represent early Paleozoic life forms, are often peculiar when compared to the shells and hard parts of modern animals. Cambrian fossils in a number of ways often seem to be the most bizarre, and mollusks are no exception to this! Many Cambrian mollusks are peculiar and some do not fit into classification systems which are based upon living animals. During the immense span of geologic time through which life has evolved, body plans have appeared which for one reason or another were not successful, such is the case with mollusks. The molluscan classes living today represent a set of molluscan body plans (classes) which survived the "pruning" of the distant geologic past and for one reason or another survived while the classes represented by fossils discussed here went extinct.

Mollusks are today represented by the pelecypods (clams, oysters, scallops etc.); gastropods (snails and slugs); cephalopods (squid, nautilus and octopus); polyplacophorans or chitons; scaphopods, the rare aplacophora and monoplacophora.

What makes a mollusk a mollusk? The most obvious feature is that a mollusk possesses a shell which has a characteristic molluscan structure. Mollusks also have a muscular foot and distinctive organs such as a mantle which secretes the mother of pearl shell. Some of the living mollusks such as clams and gastropods have undergone an immense amount of speciation since the end of the Paleozoic era and today are represented by a great number of genera and species. One has only to look at the diversity of recent shells as might be in a shell collection from Florida or the Caribbean, to gain insight into the breadth of this diversity. In the early Paleozoic however, a number of fossils which are obviously mollusks (because of their calcareous shells, growth lines and other molluscan "signatures") are known which really don't fit into the existing "modern" classes of mollusks. It is becoming more and more evident that a lot of evolutionary "experimentation" went on during the late Pre-Cambrian and the early Paleozoic that many of these "experiments" were ultimately met with extinction. Some of this extinction was at the end of the Cambrian Period, some at the end of the early Cambrian and some later in the Paleozoic Era, particularly at the Permian extinction event at the end of the era. These "strange fossil mollusks" can be relatively common in the right places and are strange in comparison to these molluscan classes of today.

MOLLUSCAN CLASSES WHICH WERE "PRUNED"

ROSTROCONCHS: These are bivalved mollusks, originally confused with pelecypods and placed within that molluscan class. Unlike pelecypods, Rostroconchs have what looks like two shells fused together to form a single valve. Pelecypods in contrast, have a flexible hinge which separates the two valves. Rostroconchs may have been the stock which gave rise to both pelecypods and scaphopods.

MATTHEVIA: Puzzling shells or valves first described by C. D. Walcott from late Cambrian, black limestone in New York State have been considered as representatives of an extinct molluscan class by Yochelson, 1978. Matthevia was almost certainly a multi-plated mollusk. However without articulated specimens the manner in which the plates went together and the number of plates which occurred on the animal is quite difficult to determine. Yochelson's reconstruction of Matthevia has this mollusk's massive valves with their two distinct openings highlighted by a canopy of smaller valves which extend over the midpart of the animal. Other paleontologists consider Matthevia to be an early type of chiton or polyplacophoran, Runnegar et. al. 1979. Matthevia is known from the latest Cambrian and the early-most Lower Ordovician which in the European stratigraphy terminology is still the Cambrian.

HEMITHECELLA: Thick, arrowhead-shaped valves, probably arranged in some imbricate manner characterizes this group of mollusks. Like the case with Matthevia, Hemithecella is probably a multiplated mollusk but the manner in which the plates fitted together and how many there were is basically unknown. Hemithecella is considered by some paleontologists (see Runnegar et. al. 1979) along with Matthevia as a peculiar early chiton.

HYOLITHS: One of the best known and the most widely distributed of problematic mollusks, Hyoliths are often common fossils in Cambrian rocks all over the world. Shoehorned into the gastropods under a group of small, free swimming forms, the (Pteropods) in earlier paleontologic literature, the taxonomic position of Hyoliths, like many of the forms presented here remains an enigma. Hyolith shells are usually straight, elongate and closed at one end. Some have a triangular or trapezoidal outline, most are oval or oval with a flattened top. The shells are usually relatively thin and most forms have a shelf or projection at the base of the aperture. Many or perhaps all hyoliths had a peculiar "toilet seat" like trapdoor cover the shells aperture. In exquisitely preserved specimens, two "guide-wire-like" structures called helens extend sidewise from the trapdoor-like aperture cover. Some paleontologists consider hyoliths and related forms not to be mollusks, but rather representatives of some extinct animal phylum.

POLYLOPIA: Elongate, slightly tapered, straw-like shells in which larger shells are telescoped or nested within smaller ones, constitute this peculiar group of mollusks.

Polylopia, like some hyoliths, superficially resemble the shells of scaphopods. Scaphopod shells are thicker, open at the smaller end (Polylopia is closed), and have other characteristics which set them apart from other elongate shells, molluscan or otherwise. Polylopia is primarily known from the lower Middle Ordovician of central Tennessee where it can occur in clusters on limestone slabs.

PLAGIELLA: These are usually small, snail-like shells which occur in the Cambrian in various parts of the world. Unlike gastropods, Plagiella comes in both right and left handed varieties. The shell of Plagiella is also particularly un-snail like, particularly when one compares Plagiella to undoubted gastropods of the late Cambrian and Early Ordovician. Plagiella is "shoehorned" in the Treatise of Invertebrate Paleontology, (I Mollusca 1) under the gastropods. The forms and related shells found in Cambrian strata are suggested by some paleontologists to be a coiled-shell molluscan body plan which evolved independently of gastropods, however in the absence of information on internal soft parts this cannot be proven. Possibly related to Plagiella are a variety of left-handed coiled snail-like fossils of Cambrian age which in comparison to undoubted gastropods of Cambrian age are strange. These representatives of the gastropod family Onychochidae include such genera as Materella, Scaevogyra and Kobayashiella.

STENOTHECOIDES: An asymmetrical mollusk-like fossil which has muscle scars suggestive of a monoplacophoran. Stenothecoides is placed with the monoplacophorans in the vol. Mollusca 1 of Treatise of Invertebrate Paleontology, the most comprehensive work on fossils without getting onto the primary literature of paleontology. Stenothecoides has also been suspected of being allied with the arthropods or possibly is a representative of some extinct phylum. Like many of these enigmas, Stenothecoides and related forms are found in the Lower Cambrian.

BELLEROPHONS: Classified as an extinct superfamily of gastropods, bellerophons have planispirally coiled shells which suggests the coiled shell of a cephalopod but unlike them. Bellerophons do not have chambers or septa. Bellerophons span the entire Paleozoic era and few forms are known from the Triassic Period. Bellerophons characteristically have a slit in the aperture (the opening through which the animal extends from the shell). This slit is represented by a keel which forms a plane of symmetry around the bellerophon shell. The earliest bellerophons lack the slit, but have rather a simple indentation in the outer lip of the aperture.

The asymmetrical shell of almost all gastropods is allied with torsion. Torsion is a condition in which the post larval gastropod animal twists in its shell and then consequently loses one of a pair of internal organs. In the bellerophons this did not take place, rather the untorted animal produced the same amount of shell on both sides of a bilaterally symmetrical animal; resulting in the symmetrical bellerophon shell in which the right side is a mirror image of the left one. This planar symmetry is a characteristic also of the monoplacophorans and some paleontologists have suggested that either some or all of the bellerophons may be monoplacophorans. Multiple muscle scars suggestive of monoplacophorans have been found on some bellerophons to support this position.

MONOPLACOPHORANS: Considered to be the probable ancestor of most of the living molluscan classes, monoplacophorans, along with the multivalved shell of the polyplacophora (chitons) exhibit elements of segmentation or related metamerism. Segmentation, derived from a repeated "cloning" of the body of an early ancestor in which the "clones" did not separate, is characteristic of both the trilobites (an early and primitive arthropod) and the segmented worms such as the earthworms. Segmentation however, is not normally associated with the mollusks. Living molluscan classes have entirely lost this repetitious pattern except in the eight valves of chitons and in the partially segmented body of the monoplacophorans.

Monoplacophoran fossils often exhibit a set of multiple muscle scars which correspond to the partial segmentation of the animals body. Muscle scars on other mollusks are an elongate oval or a curved band. Those on monoplacophorans form a horseshoe-shaped set of scars. Monoplacophorans were first recognized as being distinct from other mollusks fossils. In the 1950's living monoplacophoran animals were dredged from the depths of the ocean in oceanographic exploration. The animals dredged up from depths of over four miles showed a spoon-shaped shell much like the previously known fossils. Inside this shell was a partially segmented animal with seven sets of gills, seven sets of kidneys and muscle attachment areas. These attachment muscles, make the horseshoe-shaped series of muscle scars seen on the fossils. Monoplacophorans are true "living fossils" which like the Ginkgo and Metasequoia tree were discovered as fossils previously to their being discovered in the living condition.

CRICOCONARIDS (TENTACULITES): These elongate shells, 1-2 cm in length, have a series of flanges or transverse ridges perpendicular to the length of a gently tapering shell. Tentaculites are best known from the Devonian, but they also occur in the Silurian and first appeared in the Middle Ordovician. Variously considered as the tubes of worms (annelids) or as aberrant gastropods, these attractive shells remain a molluscan enigma? A good discussion of

these little fossils, which are often found together in clusters, is presented in part W (Miscellanea, small conical shells) of the Treatise of Invertebrate Paleontology.

FALAENIGMA: An enigmatic (as the name implies) quadrat cone with truncated top set upon four "legs" characterize this Lower Ordovician fossil. Looking like an early 20th Century (1900's Edwardian) British-Empire Mailbox, Falaenigma is a Paleontological puzzle. Some paleontologists have considered it a fragment of a larger mollusk such as part of a cephalopod or other shell fragment broken in some peculiar and distinctive manner.

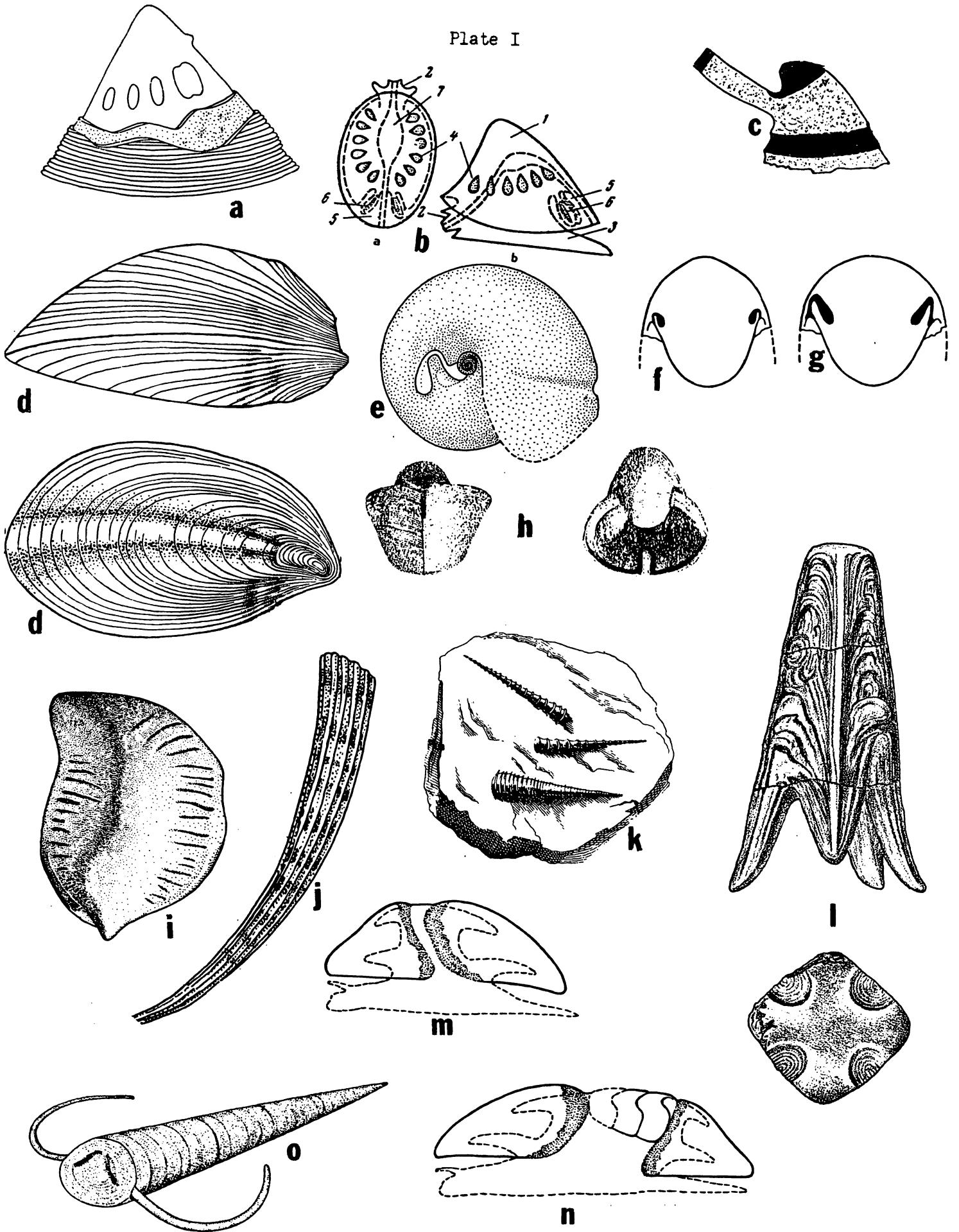
SALTERELLA and VOLBORTHELLA: Narrow cones made up of fine grained sediment particles embedded in calcium carbonate constitute the "shells" of Salterella. These shells can occur in immense numbers when they occur in Lower Cambrian strata of the North American province of the Cambrian. A somewhat similar form called Cloudina is known from the Lower Cambrian of the southern hemisphere.

Volborthella is like Salterella but has chambers somewhat like those of a cephalopod and it, like Salterella is limited to the Lower Cambrian. Vorborthella is best known from the Atlantic Lower Cambrian province, its particularly abundant in Latvia and Estonia.

The agglutinated composition of the "shells" of both of these forms has led some paleontologists to consider these fossils to be something other than mollusks. If that were the case they have no taxonomic home except in the "worms", that is they would be some type of tube secreted by one of the "worm-like" phyla. This "worm phyla" and "worm tract" designation for puzzling fossils has been the "garbage can" of paleontology. When fascinating fossils like Salterella have been relegated to the "worm" they usually become forgotten. Yochelson, 1977 has proposed these fossils as representative of an extinct phylum, the Agmata and hence they would not be mollusks.

TOMMOTIAN SHELLY FAUNA: A variety of small, often phosphatic shells and sclerites occur in limestone beds below strata containing "normal" Cambrian fossils. One of the dominant "normal" Cambrian fossil is the trilobite, and Tommotian fossils appear to predate the appearance of trilobites. These pre-trilobite fossiliferous horizons are known in only a limited number of areas of the world and are currently the subject of much paleontologic research. These fossils are strange, usually unlike those of later Cambrian. There is a good possibility most of them are not mollusks but rather represent strange forms of other phyla or perhaps are the hard parts of extinct phyla. Plagiella is one such Tommotian fossil which, unlike many of them occurs higher in younger Cambrian strata associated with trilobites. One attractive and puzzling Tommotian fossil is Microdactyon.

Plate I



this has been recently found to represent sclerites small mineralized structures which occupied the side of an Onchophoran; they are fat worm-like animals with fat stubby legs which are still living in an adapted forest environment in South American rain forests.

STRANGE AND PUZZLING FOSSIL MOLLUSKS

Plate I

a, Hypseloconid monoplacophoran with shell partially removed to show multiple scars. b, dorsal (top) and side view of monoplacophoran showing position of animal within shell. Anterior (front) of the animal is at top of left view. c, small Lower Cambrian monoplacophoran with snorkel. d,i, Stenothecoides, Lower Cambrian. e,f,g,h, bellerophon gastropod. e,f,g, showing muscle scars, h, showing slit in symmetrical bellerophon shell. j, modern scaphopod of genus Dentalium. k, group of Tentaculites from Devonian. l, Palaenigma, Lower Ordovician. m,n, reconstructions of Matthevia m, without intermediate valves, n, with intermediate valves. o, Hyolith with operculum and helens, Middle Cambrian.

Plate II

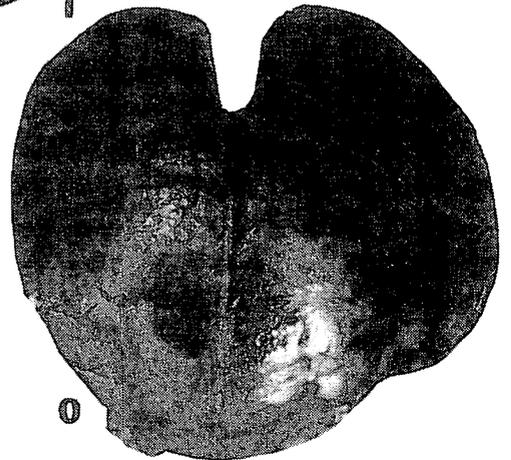
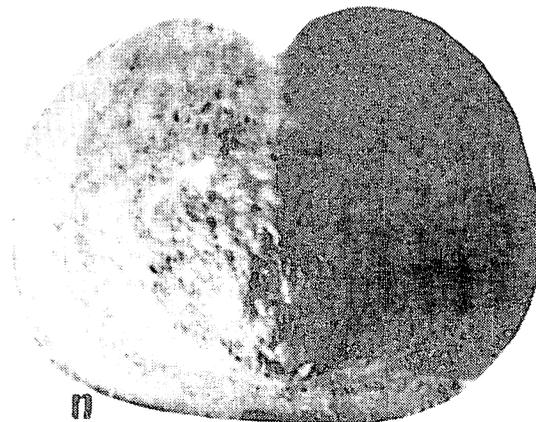
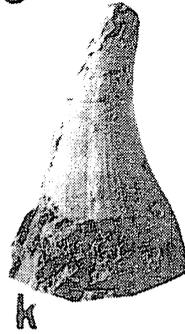
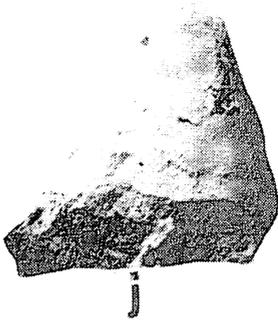
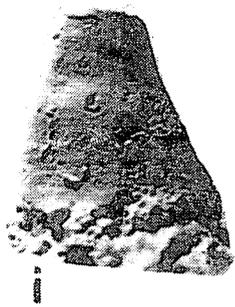
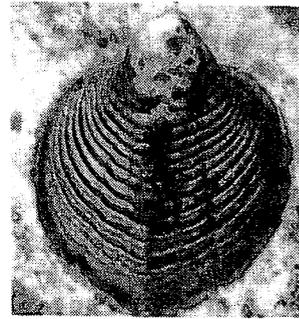
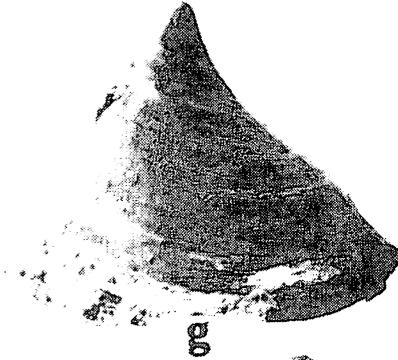
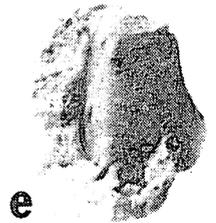
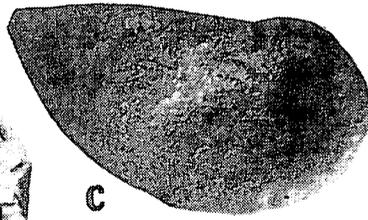
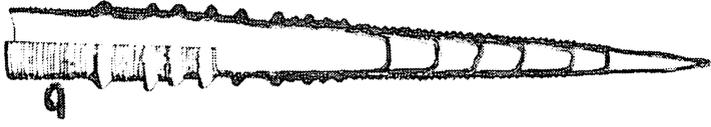
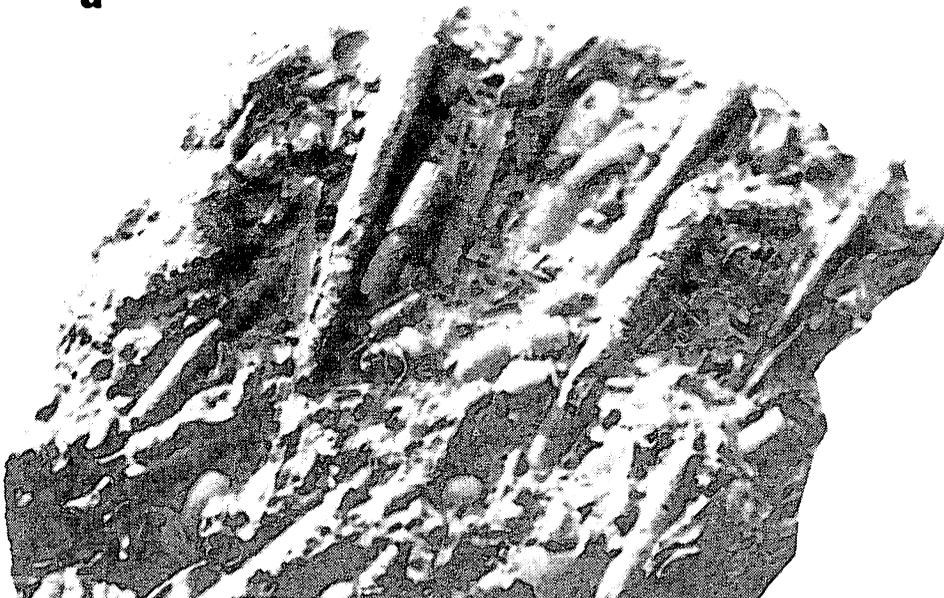


Plate II

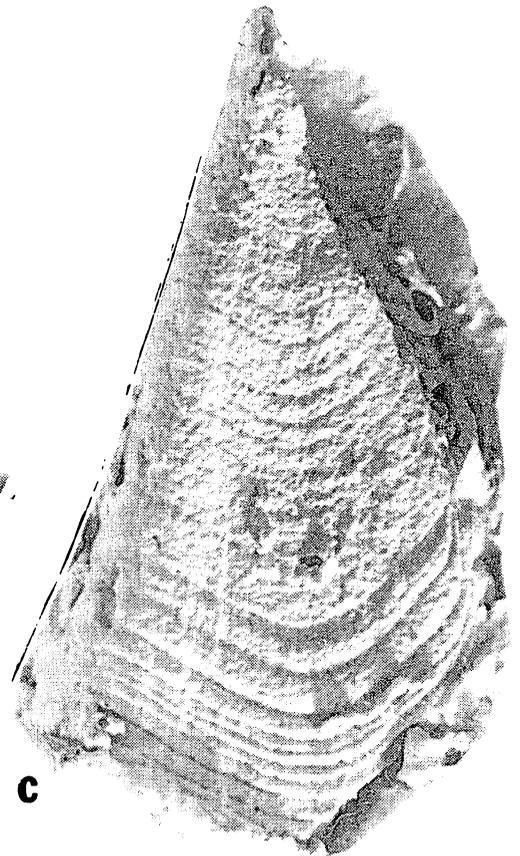
a, Tentaculites, Ordovician, Maquoketa Fm., Iowa. X1. b. Internal mold of Hemithecella expansa, Lower Ordovician, Gasconade Fm., Missouri, X1. c, Flagiella, Upper Cambrian, Franconia Fm., St. Croix Falls, Minnesota, X1. 2. d, Monoplacophoran with multiple muscle scars, Gasconade Fm., Sullivan, MO., X1. e, Monoplacophoran? with multiple musculature, same as d. f, Matthevia, internal mold showing two cavities distinctive of this form, Eminence Fm., U. Cambrian, Missouri. g, monoplacophoran Cambrioconus expansus, Cambrian, Eminence Fm., Mo. The validity of the name of this genus has been questioned as Cambrioconus has also been used for the genus of a snail of a small con-shaped fossil from the L. Cambrian of China, X1. h. Rostroconch, Osagian chert outlier, Rolla, MO., X1. One of a number of unusual faunal elements which come from isolated outcrops of fossiliferous rock surrounded by older strata (outliers). These outliers often have a large molluscan fauna typical for the rest of the midwest U.S.A. i, Monoplacophoran genus Shelbyoceras, Eminence Fm., U. Cambrian, Mo., j, M. genus Archeoconus, Eminence Fm. U. Cambrian, MO. k, M. genus Hypseloconus, same as i, and j. l, Bellerophon gastropod, genus Bellerophon sp. St. Genevieve Fm., Middle Mississippian, X .75. m. Stenothecoides. note peculiar multiple muscle scars on this fossil, compare with muscle of an undoubted monoplacophoran such as d. n, Bellerophonid gastropod? Note apertural notch and flat, patelliform shape of this fossil. Dresbachian Fm., U. Cambrian, Wisconsin. o, Bellerophon showing distinct apertural notch, characteristic of the bellerophons. M. Pennsylvanian, St. Louis Co. MO. X .75. p, Hyolith, genus Hyolithes sp. Dresbach Fm., U. Cambrian, Wisconsin. q, Tentaculites, showing cross-section of shell, Devonian. r, Salterella, cross-section of this distinctive shell. L. Cambrian, Nevada, X10.

Plate III

- a. Slab of Cambrian limestone covered with a typical group of Hyolithes. Upper Cambrian, Missouri, x 1.
- b. Polylophia, chert slab covered with oriented Polylophia shells and ostracodes. Middle Ordovician, Murfreesboro Limestone, Murfreesboro Tennessee, xl.
- c. External surface of hemithecellid, Hemithecella expansa showing pronounced growth lines characteristic of external shell surfaces of mollusks. Gasconade Fm., Southern Mo. X3.

**a****b**

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**c**

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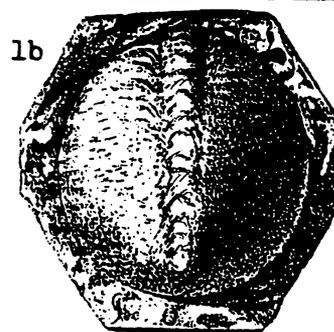
GASTROPODA



1a

GENUS PLATYCERAS, (CONRAD 1840)

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149 E. Main Street
Shelby, Ohio 44875



1b

Platyceras (*Orthonychia* ?) *lodiense*, Meek - Shell rather small, non-spiral, or merely having the form of a rapidly expanding cone, with a backward obliquity that brings the apex nearly over the posterior margin; lateral slopes nearly straight or slightly concave, and converging to the apex at an angle of about 80 degrees. Posterior side vertical and decidedly concave in outline. Anterior slope a little more than twice as long as the height of the posterior side, moderately convex in outline, and provided with a ridge or obtuse carina along its entire length. Aperture oval-suborbicular, being slightly longer than wide; lip more or less sinuous at the middle of the anterior side, on one or both sides of the termination of the central ridge of the anterior slope, which ridge terminates in a little tinch on the anterior slope, where they curve backward as they approach the mesial ridge, and then abruptly forward in crossing the ridge; extremely faint traces of minute radiating striae apparently also exist; apex rather abruptly pointed and directed backward without any lateral obliquity.

Length, measuring obliquely from apex, 0.97 inch; breadth, 0.82 inch; length from anterior to posterior margin, 0.90 inch; height of apex, 0.44 inch.

This species is remarkable for its regular, depressed, obliquely conical form and non-spiral apex, which is merely obtusely pointed and directed backward without the slightest lateral curve. It therefore departs widely in form from the typical species of *Platyceras*, and agrees more nearly with an *Oriskany* shell described in the third volume of the *Paleontology of New York*, under the name *Cyrtolites expansus*, except that its apex is not so attenuated and produced. Although probably not a true *Platyceras* it seems to be more nearly allied to the section of the same, for which the name *Orthonychia* has been proposed, than to *Cyrtolites*, which was founded on a very different type (*C. ornatus* Con.), with a peculiar style of ornamentation. In its surface markings our shell agrees with *Platyceras*, being merely marked with fine lines of growth, more or less undulated on the anterior slope, while the traces of very fine radiating striae indicate relations to the section *Orthonychia*, with the shell also agrees more nearly in its non-spiral form. It therefore bears the same relations to the elongated forms of *Orthonychia* that those depressed, rapidly expanding species of *Platyceras*, such as *P. calanticum* and *P. obesum*, bear to the typical forms of the latter genus. This description of the *Platyceras*(*Orthonychia* ?) *lodiense* Gastropod from the Lodi, Ohio area of the Waverly group of Lower Carboniferous formations.

Specimens 1a - lateral view, 1b - top view, shows one variation of these unique marine animal fossils.

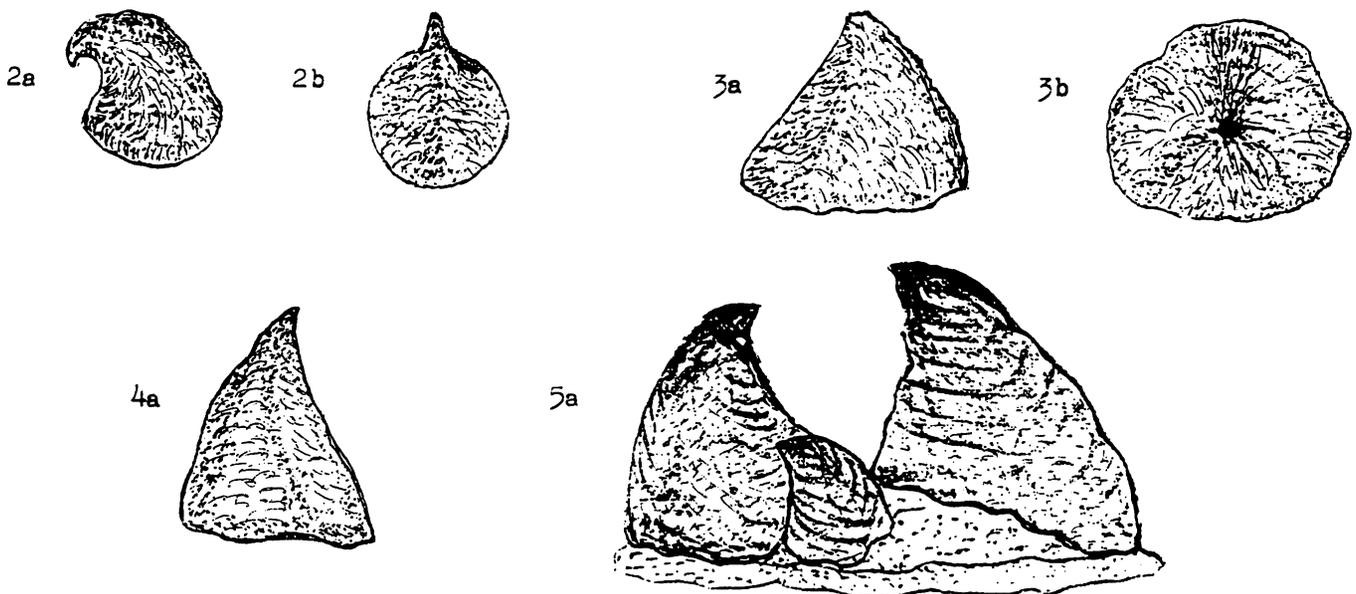
Variety #2 is a small non-spiral form with a rapidly expanding cone, with a backward obliquity that brings the tip of the snail out past the posterior margin. Lateral slopes slightly concave till near crest, where they turn convex to the tip. With the snail resting on the aperture, the measurement from the tip which is now pointing straight down, to the anterior margin 1 and 3/16 inch, and from the tip around the sharply concave surface to the posterior margin is 3/16 inch. The one lateral side vertically from margin to crest of ridge measure 5/8 inch, while the opposite side measures 1/2 inch, giving the fossil the appearance of leaning to the left when viewed from the posterior position; fig. 2a illustrates a lateral view, while fig. 2b is a view from the top of variety #2 specimen.

Variety #3 is a medium size non-spiral form of a rapidly expanding cone, with the apex almost directly over the center of the aperture; the anterior edge along the low ridge from aperture margin to the apex is slightly convex. The lateral side from aperture margin to the apex is practically straight, while the side from the posterior margin to the apex is slightly concave.

The tip of the fossil was replaced by sphalerite, and in cracking open the ironstone concretion that enclosed the fossil, the crystalline sphalerite shattered, resulting in loss of 1/8 inch of tip; aperture measures 1 inch from posterior to anterior margins, and 1 1/4 inch from side to side margins, and 1 inch in height. fig.3a illustrates a lateral view, while 3b is a top view of variety #3.

Variety #4 is a medium size non-spiral form with slowly expanding cone, with a slightly backward obliquity that brings the apex mid way between the posterior margin and the center of the aperture, resulting in a tall, thin cone shaped shell.

The posterior slope from aperture margin to apex is slightly concave, the anterior and lateral sides are slightly convex from aperture margin to the apex; making an irregular oval aperture, which measures 1 inch from posterior to the anterior margin, and 3/4 inch from side to side margins. The height is 1 1/4 inch from base to apex. fig. #4a illustrates a lateral view of variety #4



Variety #5 was removed from a large, lumpy, very heavy ironstone concretion that contained a group of 23 of these fossil snails "JACKPOT" in various sizes. The mature one is a large non-spiral form with rapidly expanding cone shape, with a backward obliquity that brings the apex nearly over the posterior margin; similar to variety #1, but larger, and from a Cuyahoga formation 60 miles to the south. Posterior side decidedly concave, anterior and lateral sides convex from aperture margin to apex, posterior side $\frac{3}{4}$ inch from margin to apex, anterior side is $1\frac{1}{2}$ inch from margin to apex. Aperture measures 1 inch from posterior to anterior margins, and $1\frac{1}{4}$ inch from side to side margins. Fig. 5a illustrates the lateral view of variety #5:

Variety #6 is the "odd-ball" of this group, with the lateral sides being parallel for about $\frac{1}{3}$ of the way from the apex toward the aperture margins, then expanding rapidly into a convex shape to the margins, this flat portion averages about $\frac{1}{8}$ inch in diameter side to side, but expanded to $\frac{1}{2}$ inch in diameter between the posterior and anterior sides, with more rapid expansion of the body cavity; bringing the apex out past the aperture margin. The posterior side being concave measures $\frac{3}{4}$ inch from apex to the aperture margin, anterior slope is convex and measures $1\frac{1}{2}$ inches from apex to aperture margin, lateral sides near apex are convex, then parallel, then with a short area concave, then rapidly expanding convex portion to the margins.

This unusual and unique shape has been found in several other specimens from the Cuyahoga formation. I would appreciate any comments or ideas as to whether this group of fossil snails is just variation, due to the local environment, or if some of these differences are part of the process of evolution into different species. Possibly some of you people that specialize in the study of gastropods might shed some light on these critters variations in shape or sizes. Fig. 6a illustrates a lateral view and 6b an anterior view of variety #6



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Illustrations:

2a through 6a, drawn by author from fossils he has collected from the Waverly Group Formations of the Mississippian Period, in the north central portion of Ohio.

MIOCENE MOLLUSCS FROM THE LOWER GATUN FORMATION,
PANAMA

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In this paper, the collections from three fossil sites in Panama are described. The sites are in the lower Gatun formation of the middle Miocene.

The Miocene mollusca of the Gatun Formation in Panama provide a fascinating example of the use of fossils to reconstruct portions of geological history. The Gatun fossils are an extensive group of marine fossils related to other Miocene fossils from the Caribbean and adjacent areas of North and South America. The Gatun fauna, however, is closely allied to the existing Pacific shells. The current Caribbean shell population shows some remnants of the Miocene, but in general, reflects invasion, survival and development of a different fauna.

The rise of the land bridge between North and South America was the occurrence which separated the Pacific and Caribbean fauna after the middle Miocene. The development of the separate molluscan populations indicates that the Atlantic and Pacific have not been connected through Central America since that time.

The fossils of the Miocene Gatun Formation were first described and extensively collected during the construction of the Panama Canal. Large collections were deposited at the Natural History Museum of the Smithsonian Institution and other museums. These were exhaustively studied by W. F. Woodring of the U.S. Geological Survey. He published the results in Geology and Paleontology of Canal Zone and Adjoining Parts of Panama, USGS Professional Paper # 306 (Parts A to F) during the years 1967 to 1982.

The Gatun fauna is extensive, and thus provides a clear picture of the diversity of the Miocene marine mollusks in the Caribbean. Although many of the species and forms have been described from fossil sites in Jamaica, Trinidad, Costa Rica and Colombia, no other sites provide such a rich selection of specimens. Woodring describes 396 species and subspecies from the Gatun Formation.

The author was working on a project from 1968 to 1973 which involved 21 trips to the Canal Zone. During these visits, three sites were found which exposed the lower Gatun formation. Specimens collected (in the author's collection and the stock of Ecoresources)

were diverse, and in some cases exceeded size limits and quality of the specimens figured in Woodring's monograph.

Cativa I is a factory site on the south side of the Trans-Isthmusian highway, at the intersection of the road to the Payardi Island refinery. It is a few hundred feet from the town of Cativa, Republic of Panama. At the site, a shelf was bulldozed and leveled from a small hill to hold a factory building. Fossils were weathering from the cut bank and the material leveled for the building site. The site is identical with (or within 100 yards) of Woodring's sites # 138, 138a and 138b.

The site identified as Cativa II is a factory site on the east side of the road to the Payardi Island refinery. This road intersects the Trans-Isthmusian Highway immediately east of Cativa. It corresponds to Woodring's sites # 138c & 138d.

The site identified as Cativa III is a clearing on the east side of the road to the Payardi Island refinery, which intersects the Trans-Isthmusian Highway immediately east of Cativa. At the time this site became available to the author, it consisted of soil over a large area which had been bulldozed/harrowed. No cut exposed the formation. The few specimens collected here were primarily megafossils which were durable enough to survive the mechanical preparation and weathering at the site. It does not correspond to any of the Woodring sites.

Collectors visiting Panama should take the opportunity to check the Cativa area (close to the Atlantic port of Colon) for construction sites. The tropical climate and rampant vegetative growth accelerates the destruction of exposed fossils. Over several years, the author collected many good fossils at the Cativa sites, e.g. 320 specimens of Cymatophos veatchi veatchi. When visiting the sites several years later, only six relatively complete mollusc specimens were found. Not even the formerly omnipresent broken shell litter was to be seen.

Woodring reported 384 species and subspecies of molluscs for the Gatun Formation. The 260 collections comprising the initial scope of Woodring's study (Part A published in 1957) included specimens from five lower Gatun Formation sites (plus three sub-sites). Site #138 and subsite #138a were in the Cativa area. By the end of the study (Part F, published in 1982), additional field work and collections examined included 8 additional subsites in the Cativa area (#138b through #138i).

Woodring lists 207 species and subspecies of mollusca from the Cativa localities (Gastr: 143, Scaph: 2, Biv: 62). The author's collections from Cativa I, II, and III contain 103 of these species. As would be expected, the 104 species and subspecies not represented include 79 characterized as Rare or Few (less than six specimens in the collections examined by Woodring).

An important point for amateur collectors is that 64 of the 104 species not found by the author, are 10 mm or less in greatest

dimension. Small gastropods comprise 52 of the 72 not found. This clearly indicates the tendency of the author (and other collectors) to dismiss smaller specimens as immature or of minor significance. Unlike many investigators, Woodring painstakingly examined and characterized the smaller molluscs often found only in residues.

Woodring described 32 species and subspecies from other lower Gatun sites (entered in column X in Table I) not found in the Cativa sites. The author has identified eight of these species and subspecies in his Cativa area collections. In addition, 14 other species and subspecies not previously reported from the lower Gatun fm were identified. These 14 additions are indicated in Table I by an "A" in the column titled NOTES. If validated, they bring the Cativa molluscan fauna to 229 species and subspecies (162 gastropods, 2 scaphopods, and 65 bivalves).

Table I lists the molluscan fossils reported from the lower portion of the Gatun Formation (middle Miocene). Entries in Columns X, Y and Z are Woodring's reports; entries in Columns I, II, and III are occurrences reported by this author. Occurrence at Woodring's non-Cativa sites is shown by an entry in Column X. Occurrence at Woodring's sites 138, 138a, or 138b (= author's Cativa I) is shown by an entry in column Y. Occurrence at Woodring's sites 138c or 138d (= author's Cativa II) and sites 138e,f,g,h, & i is shown by an entry in column Z.

Woodring's symbols for relative frequency are retained for the entries for occurrences:

R = rare	= 1-2 specimens in collections examined
F = few	= 3-5 specimens
C = common	= 6-20 specimens
A = abundant	= more than 20 specimens

In this report, Y and Z categories include more than one Woodring site. The entry in these columns will be the highest number he reported at any of the included sites, e.g. if sites 138, 138a and 138b had entries of F,R, and C respectively, the entry in the column titled Y would be C. In the first part of Woodring's report (Part A, issued in 1967), the codes were not used. The x used therein to indicate occurrence at a specific site is retained in this report.

These frequency symbols are used in columns I, II, and III to indicate the number of specimens collected by the author at these sites. Some of these specimens are of a quality to illustrate features not shown by Woodring's specimens, and are described and figured in this report. An entry of Q in the NOTES column of Table I indicates such a specimen. An entry of S in the NOTES column indicates a size greater than that reported by Woodring. The largest dimension (in mm) found in the author's specimens follows the dash after an S entry.

TABLE I. MOLLUSCAN OCCURRENCES AT LOWER GATUN FM SITES

Name	Notes	Woodring Sites			Author's Sites		
		X	Y	Z	I	II	III
(X = non-Cativa)							
.....							
<u>GASTROPODA</u>							
<u>Acteocina elachista</u> Woodring		-	C	-	-	-	-
<u>Acteocina rusa</u> Gardner		-	-	R	-	-	-
<u>Acteon punctostriatus</u> (C.B.Adams)		-	F	C	-	-	-
<u>Agaronia testacea hadra</u> Woodring		-	R	-	-	R	-
<u>Agaronia testacea mancinella</u> (Olsson)		-	R	R	-	R	R
<u>Agladrillia acaria ectypha</u> Woodring		-	C	C	-	-	-
<u>Agladrillia characta</u> Woodring		-	R	F	-	-	-
<u>Agladrillia enneacyma</u> (Brown & Pilsbry), <u>ssp.</u>		-	R	-	-	-	-
<u>Agladrillia isthmica</u> (Brown & Pilsbry)		-	F	F	F	-	-
<u>Alabina asperoides asperoides</u> (Gabb)		-	C	-	-	-	-
<u>Alabina asperoides canaliculata</u> (Gabb)		-	C	-	-	-	-
<u>"Alvania" aff "A." epulata</u> (Pilsbry & Johnson)		R	-	-	-	-	-
<u>Anachis sp</u>		-	-	R	-	-	-
<u>Anachis mira fugax</u> Brown & Pilsbry	S-18	-	F	R	-	R	-
<u>Anachis mira mira</u> (Dall)	QS-13	-	-	C	-	R	-
<u>Anachis stibara</u> Woodring		F	-	-	-	-	-
<u>Ancilla pinquis</u> (Guppy)	QA	-	-	-	-	-	R
<u>Anticlimax gatunensis</u> Pilsbry & Olsson		-	F	-	-	-	-
<u>Antillophos candei gatunensis</u> (Toula)		-	C	A	F	A	-
<u>Aphera islacoloni</u> s (Maury)		-	R	R	-	-	-
<u>Architectonica nobilis nobilis</u> Roding		-	C	-	A	R	R
<u>Bailya crossata</u> Woodring		R	-	-	-	-	-
<u>Balcis aulaca</u> Woodring		-	R	-	-	-	-
<u>Balcis cetia</u> Woodring		-	-	F	R	R	-
<u>Balcis jacululum</u> (Maury)		-	R	R	-	-	-
<u>Balcis lipara</u> Woodring		-	F	F	-	-	-
<u>Bittium nugatorium</u> Brown & Pilsbry		-	C	-	-	-	-
<u>Bulla umbilicata</u> Roding, "small form"		R	-	-	-	-	-
<u>Bursa caelata amphrites</u> Maury		-	F	-	F	C	-
<u>Caecum cf C. regulare</u> Carpenter		-	R	-	-	-	-
<u>Calophos ectyphus</u> Woodring		-	C	A	F	A	F
<u>Calyptraea centralis</u> (Conrad)		-	x	-	F	-	-
<u>Cancellaria acalypta</u> Woodring		R	-	-	-	C	-
<u>Cancellaria aff C. macneili</u> Mansfield		R	-	-	-	R	-
<u>Cancellaria anomomia</u> Woodring		-	-	F	-	R	-
<u>Cancellaria barystoma</u> Woodring		-	R	F	-	-	-
<u>Cancellaria cibarcicola cibarcicola</u> Anderson		-	F	A	R	A	F

TABLE I. cont'd

<u>Cancellaria codazzi</u> Anderson		-	R	A	C	A	-
<u>Cancellaria dinota</u> Woodring		-	R	A	F	A	-
<u>Cancellaria epistomifera dariena</u> Toula	Q	-	F	A	C	A	R
<u>Cancellaria terryi</u> Olsson		-	-	C	F	-	-
<u>Carinodrillia zooki</u> (Brown & Pilsbry)		-	R	-	-	-	-
<u>Clathrodrillia aff C. lelandi</u> (Olsson)		-	-	C	A	-	-
<u>Clathrodrillia cf C. islalindae</u> (Maury)		-	-	F	-	-	-
<u>Clathrodrillia gatumensis</u> (Toula)		C	-	F	-	R	-
<u>Conus acolus</u> Woodring		-	-	F	-	R	-
<u>Conus aemulator aemulator</u> Brown & Pilsbry	QS-54	-	R	R	-	A	-
<u>Conus bravoii</u> Spieker	Q	-	-	C	-	A	-
<u>Conus burkhardti harrisi</u> Olsson	S-45	-	R	C	R	C	-
<u>Conus consobrinus consobrinus</u> Sowerby		-	-	R	-	-	-
<u>Conus imitator imitator</u> Brown & Pilsbry		-	-	C	-	-	-
<u>Conus molis</u> Brown & Pilsbry		-	-	C	-	A	-
<u>Conus multiliratus multiliratus</u> Bose	Q	-	C	C	C	C	-
<u>Conus spurius</u> Gmelin	QAS-50	-	-	-	-	R	R
<u>Conus symmetricus</u> Sowerby	QA	-	-	-	-	R	-
<u>Crassispira consors consors</u> (Sowerby)	QS-45	-	R	C	F	A	-
<u>Crepidula cf C. maculosa</u> Conrad	Q	-	x	-	-	R	-
<u>Crepidula plana</u> Say	QS-18	-	x	-	R	C	-
<u>Crucibulum spinosum</u> (Sowerby)	Q	-	-	R	-	R	-
<u>Crucibulum springvaleense</u> Rutsch		-	x	-	F	C	-
<u>Cyclotremiscus pentagonus</u> (Gabb)		-	x	-	-	-	-
<u>Cylichnella atacata stibara</u> Woodring		-	A	A	-	-	-
<u>Cymatium pileare henicum</u> Woodring		R	-	-	-	-	-
<u>Cymatophos veatchi veatchi</u> (Olsson)		-	A	A	F	A	F
<u>Cymia cheloma</u> Woodring	QS-78	F	-	-	-	R	-
<u>Cytharella? cf C. compsacosta</u> Gardner		-	-	R	-	-	-
<u>Daphnella sp</u>		-	R	-	-	-	-
<u>Daphnella? sp</u>		-	R	-	-	-	-
<u>Distorsio decussata gatumensis</u> Toula		-	R	-	F	F	R
<u>Dolostoma anorhepes</u> Woodring		-	F	R	-	-	-
<u>Drillia rioqurabonis eurysona</u> Gardner		-	-	R	-	-	-
<u>Enaeta economia</u>		-	R	-	-	-	-
<u>Engina turbinella</u> Kiener		R	-	-	-	-	-
<u>Episcynia megalia</u> Woodring		-	R	-	-	-	-
<u>Epitonium cf E. foliaceicostum</u> (d'Orbigny)		-	R	-	-	-	-
<u>Epitonium sp</u>		-	R	-	-	-	-
<u>Euclathurella eucharis</u> Woodring		-	F	C	-	-	-
<u>Eulima nobilis</u> Guppy		-	F	C	-	-	-
<u>Eulima sarissiformis</u> (Pilsbry & Johnson)		-	F	R	-	-	-
<u>Eupleura cf E. nitida</u> (Broderip)	QA	-	-	-	-	C	-
<u>Eupleura thompsoni</u> Woodring		-	R	-	R	A	R
<u>Fasciolaria gorgasiana</u> Brown & Pilsbry		-	-	F	R	-	R
<u>Gemmula machapoorensis</u> (Maury)		-	-	R	-	-	-
<u>Gemmula vaningeni</u> (Brown & Pilsbry)		-	-	R	-	-	-
<u>Glyphostoma allodapum</u> Woodring		-	-	R	-	-	-
<u>Glyphostoma dentiferum</u> Gabb		-	-	R	-	R	-
<u>Heliacus stonemanae</u> (Maury)		-	R	-	-	-	-
<u>Hipponix cf H. pilosus</u> (Deshayes)	QA	-	-	-	-	R	-
<u>Ithyocythara cf I. elongata</u> (Gabb)		-	-	R	-	-	-

TABLE I. cont'd

<u>Ithycythara defuniak</u> Gardner		- - R	- - -
<u>Kurtziella habra</u> Woodring		- R -	- - -
<u>Kurtziella pagella</u> Woodring		- F C	- - -
<u>Kurtziella sp</u>		- - R	- - -
<u>Lepicythara heptagona</u> (Gabb)		- R -	- - -
<u>Malea camura</u> Guppy	Q	- R -	R A R
<u>Melongena cf M. colombiana</u> Weisbord	QA	- - -	- R -
<u>Melongena cf M. propatula</u> Anderson		R - -	- - -
<u>Melongena melongena consors</u> (Sowerby)		- R F	F C -
<u>Metula gabbi</u> Brown & Pilsbry		- - R	- - -
<u>Microdrillia trina</u> Mansfield		- R R	- - -
<u>Mitra dariensis</u> Brown & Pilsbry	QS-41	- - C	R F -
<u>Mitra longa longa</u> Gabb	Q	- R R	- C -
<u>Mitrella aff M. fenestrata</u> (C.B.Adams)		- R R	- - -
<u>Murex polynematicus</u> Brown & Pilsbry		- C -	R A -
<u>Murex recurvirostris recurvirostris</u> Broderick		- R -	R C -
<u>Nassarius paraprustus conatus</u> Woodring		- A A	- - -
<u>Nassarius praeambiguus</u> (Brown & Pilsbry)		- C -	- - -
<u>Natica bolus</u> Brown & Pilsbry		- x -	R - -
<u>Natica stenopa</u> Woodring		- x -	- - -
<u>Neverita helicoides</u> (Gray)		R - -	- - -
<u>Neverita reclusiana xena</u> Woodring		x - -	R - -
<u>Nicema amara</u> Woodring		- R R	R C -
<u>Niso mesata</u> Woodring		- R A	- - -
<u>Northia ?</u>		R - -	- - -
<u>Oliva gatunensis</u> Toula		- C A	C C F
<u>Olivella terryi</u> Olsson		- A A	- F -
<u>Paziella gatunensis</u> (Brown & Pilsbry)	QA	- - -	- C -
<u>Persicula couviana stenygra</u> Woodring		R R -	- - -
<u>Petalococonchus sculpturatus</u> H.C.Lea	QS-33	- - R	F F -
<u>Pleurofusua fusinus fusinus</u> (Brown & Pilsbry)	QS-56	- C A	R A -
<u>Pleuroliria aff P. oxytropis</u> (Sowerby)	A	- - -	R R -
<u>Pleuroliria tenagos</u> (Gardner)	Q	- R A	R C -
<u>Polinices canalizonalis</u> Brown & Pilsbry		x - -	- - -
<u>Polinices stanislasmeyneri</u> Maury		- x -	C A F
<u>Potamides suprasulcatus</u> (Gabb)	A	- - -	- R -
<u>Prunum gatunense</u> Brown & Pilsbry		- - C	- - -
<u>Pterynotus textilis</u> (Gabb)		- - R	- - -
<u>Rictaxis oryza</u> (Gabb)		- - R	- - -
<u>Ringicula semistriata</u> d'Orbigny		- F F	- - -
<u>Roxania chipolana</u> (Dall)		- - R	- - -
<u>Scobinella morieri</u> (Cossman)		- R -	- - -
<u>Semicassis reclusa</u> (Guppy)	QS-43	- x -	- F -
<u>Serpulorbis papulosus</u> (Guppy)	QAS-97	- - -	- R -
<u>Sinum euryphedra</u> Woodring		x - -	- - -
<u>Siphocypraea henekeni</u> (Sowerby)		- F -	- C -
<u>Solariorbis hyptius hyptius</u> Woodring		- x -	- - -
<u>Solariorbis strongylus</u> Woodring		- x -	- - -
<u>Solenosteira dalli dalli</u> Brown & Pilsbry		- - C	R F -
<u>Solenosteira dalli protera</u> Woodring		- C A	F C R
<u>Spiratella inflata elevata</u> (Collins)		F - -	- - -
<u>Stigmaulax guppiana</u> (Toula)		- x -	F A -

TABLE I. cont'd

<u>Strioterebrum aff S. raptum</u> (Gardner)		-- R	-- --
<u>Strioterebrum gausapatum</u> (Brown & Pilsbry)		- C -	-- --
<u>Strioterebrum indocayapum</u> Olsson		- A A	F A -
<u>Strioterebrum monidum</u> (Woodring)		-- R	-- --
<u>Strioterebrum oresignum hadrum</u> Woodring		-- A	- A -
<u>Strioterebrum spiriferum</u> (Dall)		- C A	- A -
<u>Strioterebrum wolfgangi</u> (Toula)		F - -	-- --
<u>Strombina cf. S. lissa</u> Gardner		-- R	-- --
<u>Strombina amphidyma</u> Woodring		-- R	-- --
<u>Strombina lessepsiana</u> Brown & Pilsbry	QS-37	- C A	R A -
<u>Strombina pleurica</u> Woodring		-- R	-- --
<u>Strombinophos mimicus</u> Woodring	QS-17	- F C	-- --
<u>Strombus gatumensis</u> Toula		- R -	R C R
<u>Sulcoretusa sulcata lipara</u> Woodring		- R F	-- --
<u>Teinostoma andrium</u> Woodring		x - -	-- --
<u>Teinostoma anquatum trochalum</u> Woodring		- x -	-- --
<u>Teinostoma pycnum</u> (Woodring)		- x -	-- --
<u>Teinostoma stemonium</u> Woodring		- x -	-- --
<u>Terebra aff T. taurina</u> (Lightfoot)	A	-- -	R - -
<u>Terebra concurrupiensis</u> Dinomikado	QS-93	- C A	F C -
<u>Terebra subsulcifera cembra</u> Olsson	QS-56	- - C	C A -
<u>Terebra subsulcifera subsulcifera</u> Brown & Pilsbry		- F C	-- --
<u>Trachypollia aneureta</u> Woodring		- R -	-- --
<u>Trigonostoma cf T. scalatella</u> (Guppy)		R - -	-- --
<u>Trochita spirata</u> Forbes?		R - -	-- --
<u>Turritella abrupta</u> Spieker	QS-90	- - R	R A R
<u>Turritella altilira altilira</u> Conrad	Q	- x -	R A F
<u>Turritella altilira praecellens</u> Pilsbry & Brown	Q	x - -	- F -
<u>Turritella bifastigata</u> Nelson	QS-87	x - -	F C -
<u>Turritella gatumensis gatumensis</u> Conrad	QS-62	- x -	C F -
<u>Turritella gatumensis rhytodes</u> Woodring	QA	- - -	C A -
<u>Turritella matarucana</u> Hodson		- x -	- R R
<u>Typhis alatus obesus</u> Gabb	QS-30	R - -	- R -
<u>Typhis eucteanus</u> Woodring		- C C	-- --
<u>Volvulella oxytata</u> (Bush)		- C C	-- --
<u>Volvulella phoinicoides</u> (Gardner)		- - R	-- --
<u>Xancus dodonaius praelaevigatus</u> (E.H.Vokes)	Q	- - F	- F -

SCAPHAPODA

<u>Cadulus epetrium</u> Woodring		- A A	-- --
<u>Dentalium armillatum armillatum</u> Toula		- - C	-- --
<u>Dentalium dissimile</u> Guppy		R - -	-- --
<u>Dentalium pyrum</u> Pilsbry & Sharp		R - -	-- --

TABLE I. cont'd

BIVALVIA

<u>Aequipecten plurinominis</u> (Pilsbry & Johnson)		- R R	- - -
<u>Agripoma gatumensis</u> (Dall)		- R C	- F -
<u>Alveinus rotundus</u> Dall		- A A	- - -
<u>Anadara chavezi</u> (Engerrand & Urbina)		- C A	F C -
<u>Anadara dariensis dariensis</u> (Brown & Pilsbry)		- C A	F A -
<u>Anadara eumeces</u> Woodring		- - R	- - -
<u>Anadara fissicosta</u> (Spieker)	S-43	- F A	C A -
<u>Anadara sechurana</u> (Olsson)	S-46	- A A	C A -
<u>Anadara veatchi veatchi</u> (Olsson)		- R -	- - -
<u>Anomia simplex</u> d'Orbigny		- - R	- - -
<u>Arca imbricata</u> Bruguiere		R - -	- - -
<u>Arcinella arcinella</u> (Linne), "small form"		- R C	R F R
<u>Atrina aff. A. serrata</u> (Sowerby)		R - -	- - -
<u>Bellucina actinus</u> (Dall)		- A A	- - -
<u>Bothrocorbula gatumensis</u> (Toula)		- A A	C A -
<u>Caryocorbula oropendula stena</u> Woodring	S-18	- A A	F - -
<u>Caryocorbula prenasuta</u> Olsson	S-20	- R C	R - -
<u>Chama berjadinensis</u> F. Hodson		- R F	- - -
<u>Chione tegulum</u> Brown & Pilsbry	S-51	- C A	F A -
<u>Clementia dariena dariena</u> (Conrad)		- R A	C C R
<u>Crassinella martinicensis</u> (d'Orbigny)?		- F C	- - -
<u>Crenella divaricata</u> (d'Orbigny)		- - C	- - -
<u>Cyclinella cyclica</u> (Guppy)		- R F	- F R
<u>Cyclopecten oligolepsis</u> (Brown & Pilsbry)		R - -	- - -
<u>Diplodonta homalostriata</u> Woodring		R - -	- - -
<u>Dosinia delicatissima</u> Brown & Pilsbry		- - R	F - -
<u>Ervilia valhosierr</u> Gardner		- A A	- - -
<u>Eucrassatella classa</u> Woodring	S-50	- A A	C A R
<u>Flabellipecten gatumensis gatumensis</u> (Toula)		- F C	F - -
<u>Glycymeris carbasina</u> Brown & Pilsbry		- - R	- - -
<u>Glycymeris secticostata schencki</u> Nicol		- R -	- - -
<u>Gouldia costaricensis</u> (Olsson)		- - A	- - -
<u>Harvella elegans elegans</u> (Sowerby)		C - -	- - -
<u>Hytissa haitensis</u> (Sowerby)		- - C	R - -
<u>Laevicardium laevigatum</u> (Linne)		- R -	- - -
<u>Lamelliconcha cora</u> (Brown & Pilsbry)		- F C	- C -
<u>Leptopecten ecnomius</u> Woodring		- A A	F C -
<u>Limatula asymbleta</u> Woodring		- R -	- - -
<u>Lirophora falconensis</u> (H.K. Hodson)	S-33	- R A	C - -
<u>Lirophora mactropsis</u> (Conrad)	S-50	- F A	C A -
<u>Lopha frons</u> (Linne)		- - R	- - -
<u>Lucinisca bocasensis</u> (Olsson)		- - R	- - -
"Lucinoma" sp		- - R	- - -
<u>Macrocallista maculata</u> (Linne)	S-57	- C A	C A R
<u>Mactronella alata</u> (Spengler)	A	- - -	F - -
<u>Martesia sanctipauli</u> Maury		- - R	- - -
<u>Mulinia aff. M. lateralis</u> (Say)		- R C	- - -
<u>Noetia reversa macdonaldi</u> (Dall)		- R C	- C -

TABLE I. cont'd

<u>Panopea parawhitfieldi</u> (Gardner)		-- R	-- C
<u>Pitar centanulatus</u> Brown & Pilsbry		-- R	--
<u>Psammacoma gatumensis</u> (Toula)		- R F	--
<u>Pteria inornata</u> (Gabb)?		- R C	--
<u>Sacella acrita epacra</u> Woodring		- F A	--
<u>Sacella balboae</u> (Brown & Pilsbry)		- R C	--
<u>Semele laevis costaricensis</u> Olsson	S-76	- R F	- A F
<u>Solecurtus broggii gatumensis</u> Toula		-- R	--
<u>Solen obliquus rudis</u> C.B.Adams		-- F	--
<u>Tagelus divisus</u> (Spengler)?		-- R	--
<u>Tellina</u> ?		-- R	--
<u>Tellina anaxia</u> Woodring		R --	--
<u>Tellina angulosa costaricana</u> Olsson		- R F	--
<u>Tellina punicea</u> Born		- R C	- R --
<u>Temblornia virgata</u> (Gardner)		R --	--
<u>Tivela mactroides</u> (Born), "small form"		-- F	--
<u>Trachycardium bairerum</u> Woodring		- F A	F --
<u>Trachycardium dominicense dominicense</u> (Gabb)		F --	R --
<u>Trachycardium stiriatum</u> (Brown & Pilsbry)	A	--	R --
<u>Trigoniocardia aminensis</u> (Dall)		- A A	F --
<u>Varicorbula disparilis</u> (d'Orbigny)		- R F	--
<u>Venericardia aversa</u> Pilsbry & Johnson		-- R	--

The molluscan additions to the lower Gatun formation are listed in Table II. As would be expected, nine of the fourteen are extensions of the range of middle Gatun formation fossils. Investigation of the affinities of the three unfigured gastropods and the bivalves is continuing, and will be reported at a later date. The additions bring the total molluscan fauna for the lower Gatun formation to 253 species and subspecies (178 gastropods, 4 scaphods, and 71 bivalves.

The specimens with noteworthy features are illustrated in Plates I to VI. Comments on these specimens are:

Turritella gatunensis gatunensis Conrad

Plate I, Figure 1

Turritella gatunensis rhytodes Woodring

Plate I, Figures 2a,b

The posterior constriction and axial waves in these subspecies vary as indicated by Woodring. However, the increase in strength of the secondary spiral posterior to the posterior primary spiral on the later whorls, and the resultant modification of the profile provides a diagnostic character for separating the numerous specimens found at both Cativa I and II.

Specimen 1 has unmodified primary spirals and is identified as Turritella gatunensis gatunensis. Specimen 2a shows a doubled posterior primary, while specimen 2b illustrates a typical specimen with both posterior and anterior spirals doubled. These are assigned as Turritella gatunensis rhytodes and added to Woodring's list of species and subspecies occurring in the lower portion of the Gatun formation.

Turritella abrupta Spieker

Plate I, Figure 3

As Woodring indicated in Part D, p. 430, better examples of this species were found at the later Cativa sites. This specimen was collected at Cativa II, is 92mm in length and has 8-1/2 whorls.

Turritella bifastigata Nelson

Plate I, Figures 4a,b,c,d

Specimen 4a (Cativa II) is mature ; specimen 4b (Cativa II -with some of the protoconch preserved) consists of the early whorls ; and specimen 4c (Cativa I) consists of the early and middle whorls. Specimens 4b and 4c were originally identified as T. mimetes, a middle Gatun gastropod, or T. matacaruna. Comparison with the complete specimen 4a showed them to be segments of the early and middle whorls of T. bifastigata. Specimens with only the early whorls preserved are not easily distinguished as T. bifastigata.

TABLE II. FAUNAL ADDITIONS TO LOWER GATUN FM

<u>GASTROPODA</u>	<u>OTHER OCCURRENCES *</u>
<u>Ancilla pinguis</u> (Guppy)	Middle Gatun
<u>Conus spurius</u> Gmelin	Middle Gatun
<u>Conus symmetricus</u> Sowerby	Middle Gatun
<u>Eupleura cf E. nitida</u> (Broderip)	Recent (Pacific)
<u>Hipponix cf H. pilosus</u> (Deshayes)	Miocene (Dom Rep)
<u>Melongena cf M. colombiana</u> Weisbord	Miocene (SA & Trinidad)
<u>Paziella gatunensis</u> (Brown & Pilsbry)	Middle Gatun
<u>Pleuroliria aff P. oxytropis</u> (Sowerby)	Recent (Pacific)
<u>Potamides suprasulcatus</u> (Gabb)	Miocene (SA, Carib & Pan)
<u>Serpulorbis papulosus</u> (Guppy)	Middle Gatun
<u>Terebra aff T. taurina</u> (Lightfoot)	Middle Gatun
<u>Turritella gatunensis rhytodes</u> Woodring	Middle Gatun
 <u>BIVALVIA</u>	
<u>Mactronella alata</u> (Spengler)	Middle Gatun
<u>Trachycardium stiriatum</u> (Brown & Pilsbry)	Middle Gatun

* = Except for Eupleura nitida, occurrences cited were extracted from Woodring's Prof Paper 306.

Turritella atilira atilira Conrad

Plate I, Figures 5a,b,c,d,e,f

Turritella atilira praecellens Pilsbry & Brown

Plate I, Figure 6

Woodring's discussion of turritella atilira atilira in Part A was based on two specimens from a Cativa I site (183a). The first was considered typical. For the second, he stated: "... has a non-flanged posterior primary; that is, it combines characters of the typical form and T. atilira praecellens, with which it is associated." From the specimens available, he indicated the T. atilira praecellens is predominant in the lower, but occurs in the middle, and that T. atilira atilira is predominant in the middle, but occurs in the lower.

Specimen 5a was collected at the Cativa I site. Specimens 5b,c,d,e,f, were collected at Cativa site II. All of these specimens illustrate the anterior primary to be more flanged and less nodose than the posterior primary. All of them except specimen 6 illustrate the weakly nodose anterior primary on the early whorls, strongly nodose anterior primary on the central whorls, and weakly nodose anterior and posterior primaries on the mature final whorls. Specimen 6 shows the single specimen of the B6 collected at Cativa II which displays anomalous characteristics. The taper is markedly less. Based solely on the somewhat ambiguous distinction that the secondary spirals appear later, this is assigned as T. atilira praecellens.

Petalococonchus sculpturatus (H. C. Lea)

Plate II, Figure 7

This specimen shows the typical form and sculpture shown by the middle Gatun fm specimens illustrated by Woodring.

Serpulorbis papulosus (Guppy)

Plate II, Figure 8

This is a longer specimen than the middle Gatun examples illustrated by Woodring.

Crucibulum spinosum Sowerby

Plate II, Figure 9

On Conus bravoii. Although the interior is inaccessible, the exterior ornamentation is well preserved although worn.

Hipponix cf. H. pilosus (Deshayes)

Plate II, Figure 10a,b

Like the Culebra formation example described by Woodring, this is a single specimen. The interior is well preserved and the muscle scar well shown.

Crepidula plana Say

Plate II, Figure 11a,b,c

Specimens 11a and 11b are backward curved (attached to interior of shell). Specimen 11c shows the undistorted form.

Crepidula cf. C. maculosa Conrad

Plate II, Figure 12

The fragility of this somewhat worn specimen has prevented cleaning matrix from under the deck. Thus, the presence of the characteristic muscle scar cannot be verified.

Semicassis reclusa (Guppy)

Plate III, Figure 13

Outer lip incomplete, but anal canal and fasciole are preserved.

Malea camura Guppy

Plate III, Figure 14

Complete specimen, including all apertural features.

Cymia cheloma (Woodring)

Plate III, Figure 15

All apertural features preserved.

Eupleura cf. E. nitida (Broderip)

Plate III, Figures 16a,b,c,d,e

Woodring pointed out that Eupleura thompsoni from the Gatun Fm was the first described Tertiary Eupleura from a locality south of Florida. Eupleura cf. E. nitida becomes the second such species. It reinforces Woodring's thesis (Part A, p219) that the genus is extinct in the Caribbean and survives in the Pacific. The recent Pacific Eupleura muriciformis (Broderip) is a close relative of E. thompsoni; Eupleura nitida (Broderip) is a recent Pacific species.

Five of the seven specimens in the author's collection are illustrated. These specimens (plus three others turned over for examination to the Philadelphia Academy of Natural Sciences) were collected at Cativa II.

From the measurements listed below, specimens 16a and 16b could be considered narrow forms, specimens 16c and 16d considered wide forms, and 16e an immature specimen. The total suite of ten specimens is too small to assign this to other than normal variation. Further, a number of specimens of the Recent E. nitida collected by the author at FarFan Beach, Panama, show an equivalent variation. Therefore, the author concludes that the range in height/diameter ratio is normal variation for the species.

- 16a. Dorsal view, #1814, height = 28 mm, diameter = 18 mm.
- 16b. Ventral view, #1815, height = 24 mm, diameter = 16 mm.
- 16c. Dorsal view, #1818, height = 22 mm, diameter = 17 mm.
- 16d. Ventral view, #1819, height = 24 mm, diameter = 18 mm.
- 16e. Dorsal view, #1820, height = 19 mm, diameter = 13 mm.

Faziella gatumensis (Brown & Pilsbry)

Plate III, Figures 17a,b

Complete specimens from the lower Gatun Fm.

Typhis alatus obesus Gabb

Plate III, Figure 18

Suture from tube to preceding varix well defined.

Ancilla pinquis (Guppy)

Plate III, Figure 19

This specimen is larger than the middle Gatun specimens figured by Woodring. Thus, his conclusion that his specimens were immature is probably correct.

Melogena cf. M. colombiana Weisbord

Plate IV, Figures 20a,b

Woodring discusses M. colombiana, a species occurring in the southern part of the Miocene Caribbean province, in his description of M. consors. The specimens shown conform exactly to his description of M. colombiana.

Xancus dodonaius praelaevigatus (E.H.Vokes)

Plate IV, Figures 21a,b,c

Woodring's rejection of the ICZN's opinion suppressing Xancus for Turbinella is followed in this report.

Mitra dariensis Brown & Pilsbry

Plate IV, Figures 22a,b,c

The specimens figured as 23a and 23b were initially identified as M. longa longa because of their size. Strong radial threads on late whorls, absence of intermediate spiral threads, and turreted outline of the whorls are diagnostic of M. dariensis, however.

Mitra longa longa Gabb

Plate IV, Figure 23

A complete specimen.

Cancellaria epistomifera dariena Toula

Plate IV, Figures 24a,b,c,d (Type I)

Plate IV, Figures 25a,b,c (Type II)

Plate IV, Figures 26a,b,c,d (Type III)

As Woodring pointed out, the variation in this subspecies is large. However, when the suite of 110 specimens were sorted, several consistent varieties were found, and are illustrated. Those shown as Type I are distinctly turreted. On the body whorl, the cancellate pattern changes as the radial threads become wider, more separated, and dominant.

The specimens shown as Type II are slightly turreted at best. The body whorl is a consistently larger part of the height. The cancellate pattern (radial and spiral threads equally strong) continues on the body whorl until a varix occurs. The cancellate pattern resumes after the varix has formed.

The specimens shown as Type III are immature. Since the turreting of Type I occurs most distinctly on the penultimate whorl, and the change in radial threads and varix formation occur on the body whorl, they cannot be assigned to Type I or II by these distinguishing characteristics.

Conus aemulator aemulator Brown & Pilsbry
Plate 5, Figure 27

Although the size would indicate C. molis, the characteristics are typical for C. aemulator aemulator and are readily separable in a group of mixed specimens.

Conus bravoii Spieker

Plate V, Figures 28a,b,c
Specimens showing preservation of color patterns.

Conus burkhardti harrisi Olsson

Plate V, Figure 29
Although larger than other Gatun examples, this specimen is still smaller than Costa Rican and Venezuelan specimens.

Conus multiliratus multiliratus Bose

Plate V, Figure 30
Although worn, the sculptural features are preserved. Protoconch partly present.

Conus spurius Gmelin

Plate V, Figure 31a,b,c
The specimen from Cativa II figured as 31a conforms to the illustration and description by Woodring of a middle Gatun specimen. The specimens figured as 31b (Cativa II) and 31c (Cativa III) show the spots merged into bands and a more typical concave anal fasciole.

Conus symmetricus (?) Sowerby

Plate V, Figure 32
Presumably immature, the body shape does not conform to Woodring's description and illustration of C. symmetricus. Although it has some characteristics of C. tortuostriatus Toulou, the extreme pustulosity of the specimen resulted in the questionable identification as C. symmetricus.

Terebra concurrupiensis Dinomikado

Plate VI, Figures 33a,b
Specimen 33b has a complete lip and aperture.

Terebra subsulcifera cembra Olsson

Plate VI, Figures 34a,b,c
The protoconch is preserved on specimen 34b.

Crassispira consors consors (Sowerby)

Plate VI, Figures 35a,b,c

Three specimens with undamaged lip and showing anal sinus.
Protoconch preserved on specimen 36b.

Pleurofusua fusinus fusinus (Brown & Pilsbry)

Plate VI, Figures 36a,b

Complete pillars, although they do not reach Woodring's estimate of 60 mm. for complete specimens.

Pleuroliria tenagos (Gardner)

Plate VI, Figures 37a,b

Specimens with anal sinus complete.

Strombina lessepsiana Brown & Pilsbry

Plate VI, Figures 38a,b

Largest of the 150 specimens collected at Cativa II, the specimen shown as Figure 38a is damaged on the ventral side.

Anachis mira mira (Dall)

Plate VI, Figures 39a,b

As in Woodring's specimen from the lower Gatun (Loc 138c), the two specimens shown here lack axial sculpture.

Strombinophos mimicus Woodring

Plate VI, Figures 40a,b,c

The outer lip is complete on these two specimens. No notch is present confirming Woodring's conclusion

PLATE I

1. Turritella gatunensis gatunensis Conrad
#1545, Cativa I, h: 62 mm. , d: 16 mm.
2. Turritella gatunensis rhytodes Woodring
 - 2a. #1552, Cativa II, h: 48 mm. , d: 15 mm.
 - 2b. #1554, Cativa I, h: 58 mm. , d: 17 mm.
3. Turritella abrupta Speiker
1528, Cativa II, h: 90 mm. , d: 22 mm.
4. Turritella bifastigata Nelson
 - 4a. #1539, Cativa II, h: 87 mm. , d: 24 mm.
 - 4b. #1564 Cativa II, h: 30 mm. , d: 11 mm.
 - 4c. #1538 Cativa I, h: 45 mm. , d: 16 mm.
5. Turritella attilira attilira Conrad
 - 5a. #1531, Cativa I, h: 60 mm. , d: 14 mm.
 - 5b. #1536, Cativa III, h: 53 mm. , d: 26 mm.
 - 5c. #1533, Cativa II, h: 67 mm. , d: 23 mm.
 - 5d. Cativa II, h: 42 mm. , d: 20 mm.
 - 5e. #1532, Cativa II, h: 67 mm. , d: 20 mm.
 - 5f. Cativa II, h: 32 mm. , d: 11 mm.
6. Turritella attilira praecellens Pilsbry & Brown
#1534, Cativa II, h: 36 mm. , d: 7 mm.

PLATE I.
Figures are 3/4x
unless otherwise indicated

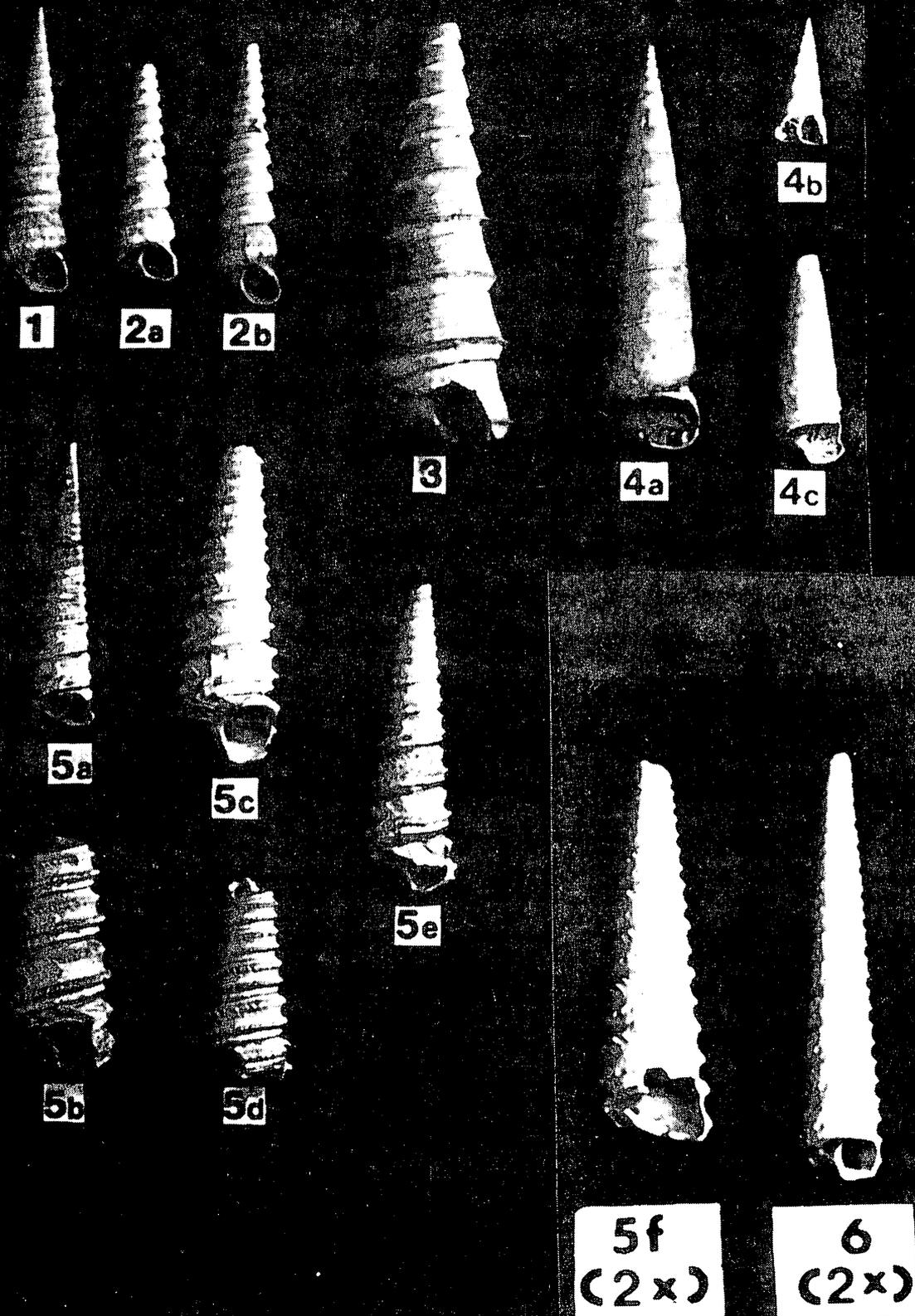


PLATE II

7. Petalocochus sculpturatus H. C. Lea
#1597, Cativa II, h: 33 mm. , d: 17 mm.
8. Serpulorbis papulosus (Guppy)
#1591, Cativa I, h: 97 mm. , d: 12 mm.
9. Crucibulum spinosum (Sowerby)
on Conus bravoii
#1632, Cativa II, h: 13 mm. , d: 27 mm.
10. Hipponix cf. H. pilosus (Deshayes)
#1621, Cativa II, h: 7 mm. , d: 8 mm.
11. Crepidula plana Say
 - 11a. #1626, Cativa II, h: 16 mm. , d: 10 mm.
 - 11b. #1627, Cativa II, h: 18 mm. , d: 13 mm.
12. Crepidula cf. C. maculosa Conrad
#1628, Cativa II, h: 16 mm. , d: 10 mm.

PLATE II.
Figures are 3/4x
unless otherwise indicated



7
(2x)



8



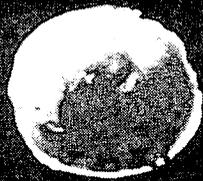
9



11a



10a
(2x)



10b
(2x)



11b
(2x)



12
(2x)

PLATE III

13. Semicassis reclusa (Guppy)
#1772, Cativa II, h: 43 mm. , d: 28 mm.
14. Malea camura Guppy
#1759, Cativa II, h: 83 mm. , d: 49 mm.
15. Cymia cheloma Woodring
#1792, Cativa II, h: 78 mm. , d: 54 mm.
16. Eupleura cf. C. nitida (Broderip)
16a. #1814, Cativa II, h: 28 mm. , d: 18 mm.
16b. #1815, Cativa II, h: 24 mm. , d: 16 mm.
16c. #1818, Cativa II, h: 22 mm. , d: 17 mm.
16d. #1819, Cativa II, h: 23 mm. , d: 14 mm.
16e. #1820, Cativa II, h: 19 mm. , d: 13 mm.
17. Paziella gatunensis (Brown & Pilsbry)
17a. #1786, Cativa II, h: 32 mm. , d: 22 mm.
17b. #1787, Cativa II, h: 35 mm. , d: 24 mm.
18. Typhis alatus obesus Gabb
#1789, Cativa II, h: 30 mm. , d: 23 mm.
19. Ancilla pinquis (Guppy)
#1984, Cativa III, h: 19 mm. , d: 8 mm.

PLATE III.
Figures are 3/4x
unless otherwise indicated



13



14



15



16a
(2x)



16b
(2x)



16c
(2x)



16d
(2x)



16e
(2x)



17a



17b



18



19
(2x)

PLATE IV

20. Melogena cf. M. colombiana Weisbord
20a. #1917, Cativa II, h: 60 mm. , d: 56 mm.
20b. #1918, Cativa II, h: 75 mm. , d: 60 mm.
21. Xancus dodonaius praelaevigatus (E.H.Vokes)
21a. #1987, Cativa II, h: 93 mm. , d: 32 mm.
21b. #1988, Cativa II, h: 65 mm. , d: 21 mm.
22. Mitra dariensis Brown & Pilsbry
22a. #1939, Cativa II, h: 41 mm. , d: 10 mm.
22b. #1940, Cativa II, h: 41 mm. , d: 11 mm.
22c. #1941, Cativa II, h: 31 mm. , d: 8 mm.
23. Mitra longa longa Gabb
#1942, Cativa II, h: 50 mm. , d: 13 mm.
24. Cancellaria epistomifera dariena Toula
TYPE I
24a. #1487, Cativa I, h: 33 mm. , d: 19 mm.
24b. #1488, Cativa I, h: 27 mm. , d: 16 mm.
24c. #1489, Cativa I, h: 21 mm. , d: 13mm.
24d. #1492, Cativa II, h: 32 mm. , d: 17 mm.
25. Cancellaria epistomifera dariena Toula
TYPE II
25a. #1439, Cativa I, h: 33 mm. , d: 22 mm.
25b. #2056, Cativa II, h: 23 mm. , d: 17 mm.
25c. #2060, Cativa II, h: 36 mm. , d: 23 mm.
26. Cancellaria epistomifera dariena Toula
TYPE III
26a. #2036, Cativa II, h: 23 mm. , d: 13 mm.
26b. #2037, Cativa II, h: 22 mm. , d: 14 mm.
26c. #2038, Cativa II, h: 19 mm. , d: 12 mm.
26d. #2039, Cativa II, h: 19 mm. , d: 12 mm.

PLATE IV.
Figures are 3/4x
unless otherwise indicated

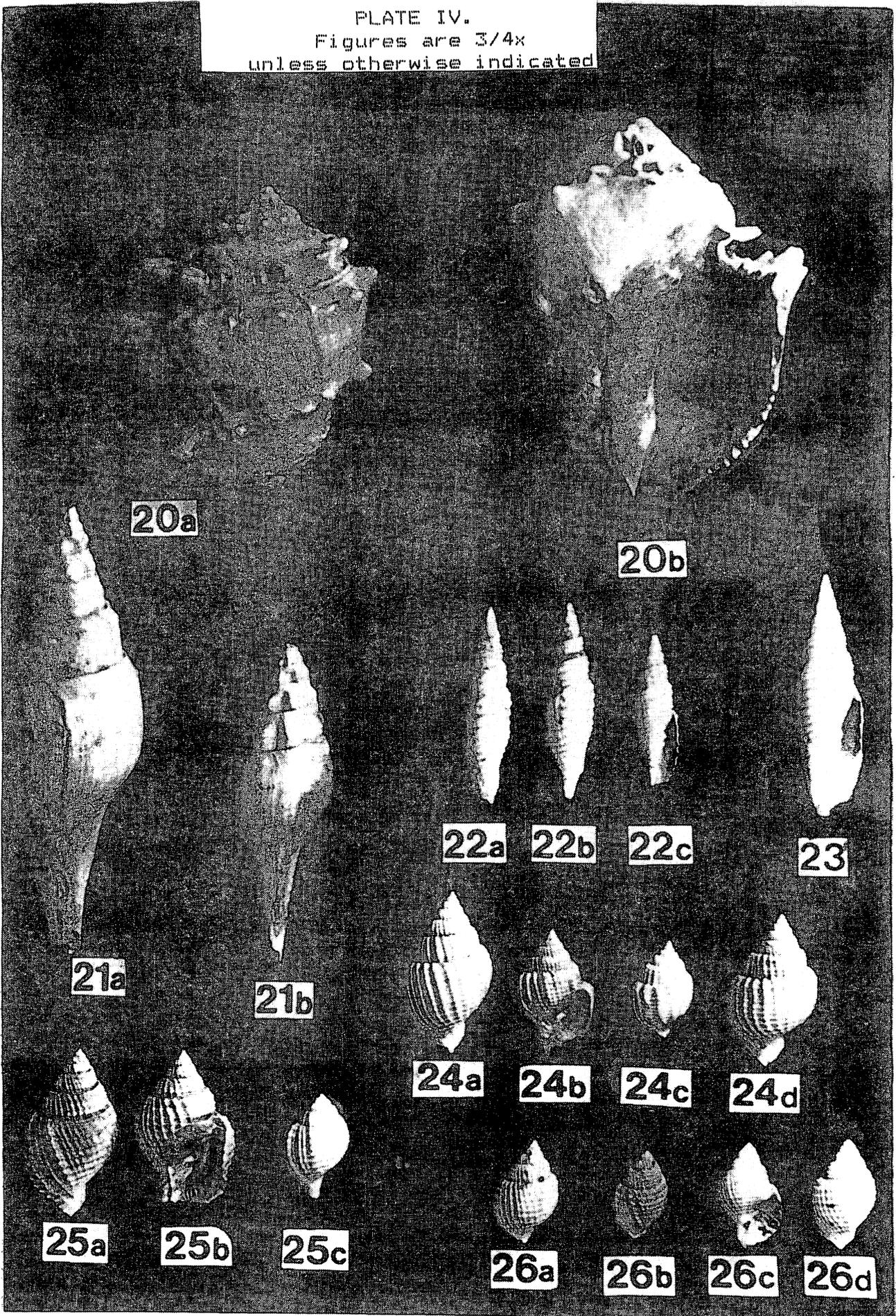


PLATE V

27. Conus aemulator aemulator Brown & Pilsbry
#2069, Cativa II, h: 53 mm. , d: 35 mm.
28. Conus bravoii Spieker
28a. #1439, Cativa I, h: 44 mm. , d: 28 mm.
28b. #2056, Cativa II, h: 42 mm. , d: 24 mm.
28c. #2060, Cativa II, h: 38 mm. , d: 23 mm.
29. Conus burkhardi harrisi Olsson
#2075, Cativa II, h: 43 mm. , d: 15 mm.
30. Conus multiliratus multiliratus Bose
#2088, Cativa II, h: 33 mm. , d: 18 mm.
31. Conus spurius Gmelin
31a. #1475, Cativa III, h: 45 mm. , d: 25 mm.
31b. #1434, Cativa II, h: 50 mm. , d: 28 mm.
31c. #1435, Cativa III, h: 41 mm. , d: 24 mm.
32. Conus symmetricus (?) Sowerby
#1433, Cativa II, h: 16 mm. , d: 9 mm.
33. Terebra concurrupiensis Dinomikado
33a. #1482, Cativa II, h: 83 mm. , d: 22 mm.
33b. #1481, Cativa II, h: 59 mm. , d: 19 mm.
34. Terebra subsulcifera cembra Olsson
34a. #1476, Cativa II, h: 56 mm. , d: 11 mm.
34b. #1478, Cativa II, h: 41 mm. , d: 8 mm.
34c. #2104, Cativa II, h: 55 mm. , d: 10 mm.

PLATE V.
Figures are 3/4x
unless otherwise indicated



35a



35b



35c



36a



36b



37a



37b



38a



38b



39a
(3x)



39b
(3x)



40a
(3x)



40b
(3x)



40c
(3x)

PLATE VI

35. Crassispira consors consors (Sowerby)
35a. #2000, Cativa I, h: 45 mm. , d: 13 mm.
35b. #2001, Cativa I, h: 38 mm. , d: 12 mm.
35c. Cativa II, h: 32 mm. , d: 9 mm.
36. Pleurofusua fusinus fusinus (Brown & Pilsbry)
36a. #2112, Cativa I, h: 51 mm. , d: 13 mm.
36b. #2013, Cativa II, h: 56 mm. , d: 16 mm.
37. Pleuroliria tenagos (Gardner)
37a. #2015, Cativa I, h: 45 mm. , d: 16 mm.
37b. #2019, Cativa II, h: 53 mm. , d: 17 mm.
38. Strombina lessepsiana Brown & Pilsbry
38a. #2955, Cativa II, h: 40 mm. , d: 14 mm.
38b. #1828, Cativa II, h: 37 mm. , d: 14 mm.
39. Anachis mira mira (Dall)
39a. #1824, Cativa II, h: 13 mm. , d: 7 mm.
39b. #1825, Cativa II, h: 13 mm. , d: 6 mm.
40. Strombinophos mimicus Woodring
40a. #1833, Cativa I, h: 18 mm. , d: 6 mm.
40b. #1834, Cativa I, h: 13 mm. , d: 5 mm., dorsal view.
40c. #1834, Cativa I, h: 13 mm. , d: 5 mm., ventral view.

PLATE VI.
Figures are 3/4x
unless otherwise indicated



27



28a



28b



28c



29



30



31a



31b



31c



32
(2x)



33a



33b



34a



34b



34c

SYSTEMATIC OUTLINE OF THE PHYLLUM

MOLLUSCA

BY

CHARLES EDWARD OLDHAM

RIVER CITY GEOLOGICAL SUPPLY

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1992

CLASS: MONOPLACOPHORA - " CAP SHELLS "

ORDER: TRYBLIDIOIDEA - reference genus Pilina

ORDER: ARCHINACELLOIDEA " " Archinacella

ORDER: CAMBRIDIOIDEA " " Cambridium

CHARACTERISTICS; Single shell, either shaped like a cap or a spoon. Some forms are bilaterally symmetrical, while others are curved longitudinally. The internal structures shows segmentation through the pairing of the ctenidia, muscles and associated tissues. The shell composition of most of the fossil forms appears to be an outer layer of calcite and an inner layer of aragonite. Recent forms (Neopilina and others) are composed entirely of aragonite.

DISTRIBUTION; Fossil forms - North America, Europe, Australia and North East Asia. Recent forms - Mexican Coast and the Peru-Chile Trench off Northern Peru.

GEOLOGIC RANGE; Lower Cambrian to Recent. In the Cambrian of North America, monoplacophorans are commonly found in sandstones and limestones. In the Ordovician they are found in dirty crystalline limestones (Ky.), and in dolomites (Mo.). In the Devonian they occur in calcareous shales.

FEEDING CHARACTERISTICS; The monoplacophorans are apparently deposit feeders, ingesting radiolarians, diatoms and undefined detrital material.

ASSOCIATES; In the cambrian the monoplacophorans were associated with trilobites, in the silurian with the coral-stomatoporoid reefs and recent forms with the echinoderms.

BATHYMETRY; Cambrian to devonian forms were located on the shallow continental shelves. Post-paleozoic forms appear to have migrated to much deeper water. Recent forms are found at depths ranging from 11,000 to 18,000 feet below sea level.

POSSIBLE AFFINITIES; Lemche (1957) discovered a living monoplacophora (Neopilina). Neopilina is a segmented form and the nature of segmentation is very similar to that of annelid worms and arthropods. Neopilina also has characteristics that clarify various intermolluscan affinities between the chitons and the nautiloids. This discovery also settled a long debate over the internal anatomy of the monoplacophorans and their position with the phylum mollusca.

CLASS: POLYPLACOPHORA (AMPHINEURA) - THE CHITONS

SUBCLASS POLYPLACOPHORA (chitons)

ORDER: PALEOLORICATA - lacking articulamentum

SUBORDER: CHELODINA - reference genus -
Gotlandochiton

SUBORDER: SEPTEMCHITONINA " "
Septemchiton

ORDER: NEOLORICATA

SUBORDER: LEPIDOPLEURINA " "
Lepidopleurus

SUBORDER: ISCHNOCHITONIA " "
Chiton

SUBORDER: ACANTHOCHITONIA " "
Acanthochiton

SUBORDER: AFOSSOCHITONIA " "
Afossochiton

SUBCLASS APLACOPHORA (lacks a fossil record)

CHARACTERISTICS; Marine, shore to near shore, sluggish bottom dwellers, that live on or under rocks, although some prefer soft silty bottoms. Size range from .25 to 13 or 14 inches, average size 1 to 3 inches. The shell is composed of a girdle made up of eight dorsal calcareous articulate plates that overlap. The plates are usually ornamented with various bumps, spines and bristles. The interior or ventral side has a head, foot, radula and numerous gills. The sexes are separate.

DISTRIBUTION; Fossil forms, particularly Paleozoic forms preferred soft substrates or reef facies (ie. the Permian of West Texas). Recent forms are experiencing an explosive expansion both in habitat and evolution.

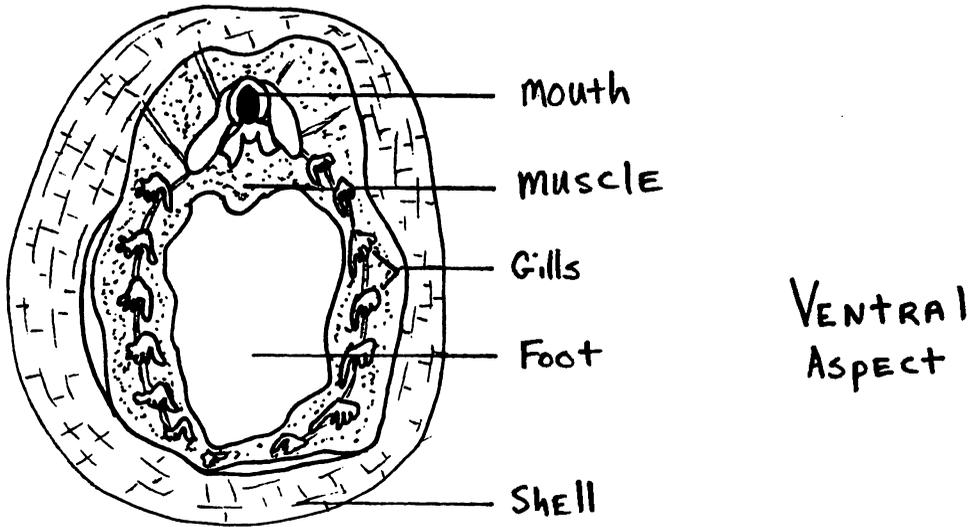
GEOLOGIC RANGE; Upper Cambrian to Recent, 73 Paleozoic species, 31 Mesozoic species, 248 Cenozoic species and well over 500 Recent species.

FEEDING CHARACTERISTICS; Chitons feed at night, and return home to a particular rock using a homing instinct that may be linked to magnetism. The chitons use a radula to feed with, which is very effective for removing algae from rocky surfaces. Some chitons are omnivorous - feasting on bryozoans, young barnacles and hydroids.

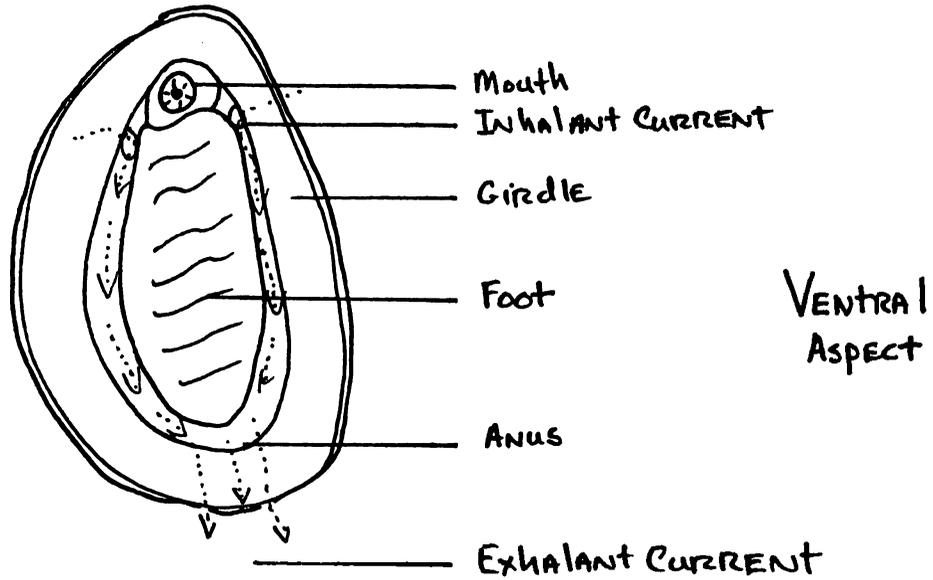
ASSOCIATES; Other mollusks in and around reefs.

BATHYMETRY; Shoreline to 13,800 feet below sea level.

Monoplacophora



Polyplacophora



CLASS: SCAPHOPODA - " TOOTH SHELLS "

FAMILY: DENTALIIDAE (sculptured shell)

GENUS: DENTALIUM - extant (subdivided into 16 subgenera)

GENUS: PLAGIOGLYPTA - extinct

GENUS: PRODENTALIUM - extinct

FAMILY: SIPHONODENTALIIDAE

GENUS: CADULUS - extant

GENUS: ENTALINA - extant

GENUS: SIPHONODENTALIUM - extant

CHARACTERISTICS; Marine, elongate body, bilaterally symmetrical. Tusk-like shell, head and appendages project from the anterior aperture (large end). The posterior (small end) is projected above the sea floor and serves as both the inhalant and exhalant aperture. (these currents serve as both sanitary and respiratory functions). The anterior end contains the head, foot and numerous prehensile structures (not true tentacles) which collect food in the substrate. A radula is present. The sexes are separate, no copulation, production of larva. Shell is calcareous with three layers of aragonite.

DISTRIBUTION; WORLDWIDE

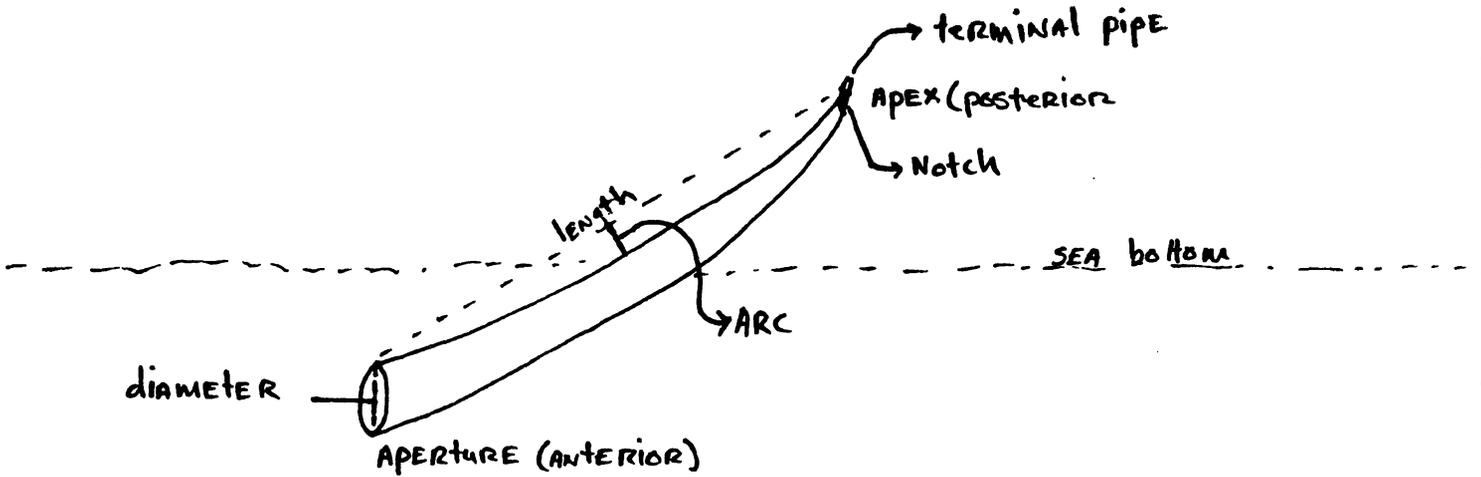
GEOLOGIC RANGE ; Ordovician to Recent. Ordovician forms are known to occur in Russia. However there is a mysterious gap in the record during the Silurian. The Devonian is well represented and there are numerous reports from the Mississippian, Pennsylvanian and Permian in North America. Modern forms appeared in the Cretaceous. Mesozoic and tertiary forms are widespread. The recent expansion is similar to that of the polyplacophorans (chitons). The number of living species exceeds that of all extinct forms.

FEEDING CHARACTERISTICS; Foraminifer appear to form the bulk of the diet of the scaphopods. Scaphopods that are partly embedded in the substrate are deposit feeders and feed on diatoms, foraminifer and a host of other small organisms.

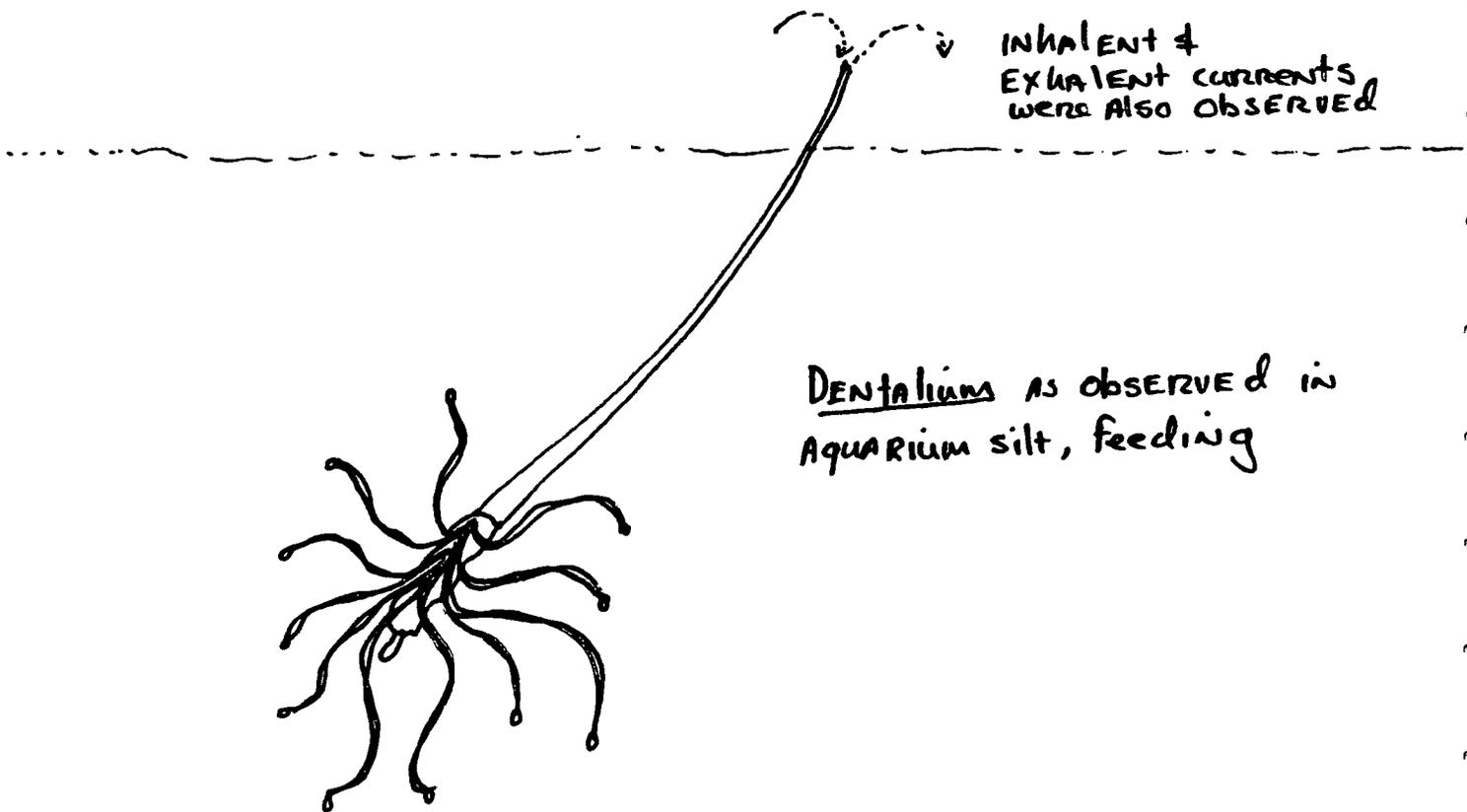
ASSOCIATES; Monoplacophorans and other mollusks.

BATHYMETRY; Scaphopods are benthonic, rarely occupying the littoral zone. Commonly found in the neritic and bathyal zones.

Scaphopoda



Morphological features from which Scaphopods are identified and described.



CLASS PELECYPODA (BIVALVIA OR LAMELLIBRANCHIATA)

SUBCLASS PALEOTAXODONTA - primitive hinge, "all teeth alike"

SUBCLASS PALEOCONCHA - thin shells, without lateral teeth

ORDER: SOLEMYOIDA - aragonite ostracum

ORDER: PRAECARDIODA - reference genus PraecardiumORDER: CONOCARDIODA - reference genus Conocardium

SUBCLASS PTERIOMORPHA - commonly attached to substrate

ORDER: ARCOIDA - two adductor muscles equal in size

ORDER: MYTILOIDA - two adductor muscles unequal in size

ORDER: PTERIOIDA - reference genus AnisomyarianSUBORDER: PTERIINA - reference: PteriinaSUBORDER: OSTREINA - reference: Ostrea

SUBCLASS PALAEOHETERODONTA - long axis of ligament parallel to hinge

ORDER: ACTINODONTOIDA - teeth absent or radial

ORDER: UNIONOIDA - non-marine forms

ORDER: TRIGONOIDA - trigonal marine shells, lateral teeth absent

SUBCLASS HETERODONTA - lateral teeth occur on either side of of the cardinal teeth

ORDER: HIPPURITOIDA - "Coral-like" rudistids

ORDER: VENEROIDA - heterodonts

SUBORDER: LUCININA (ten superfamilies)

SUBORDER: ARCTICINA (five superfamilies)

ORDER: MYOIDA - asthenodonts - teeth obsolete

SUBCLASS ANOMALODESMATA - burrowing habit, without well developed teeth

ORDER: PHOLADOMYINA - primitive hinge, burrows

ORDER: POROMYOIDA - reference genus Verticordia

CHARACTERISTICS; BODY - Bilaterally symmetrical, very compressed laterally. Completely enclosed "head", foot and visceral mass. Head very much reduced - ie. lacking eyes, tentacles and radula. (Exception: stalked eyes of the Pecten, accompanied with sensory tentacles, C.M. Young, 1948).

MANTLE - Three lobes, one adjacent to the shell, produces the shell by secretion. The middle lobe has sensory functions and the innermost lobe is muscular.

DORSAL HINGEMENT AND VALVE CLOSURE -

The two lateral valves are joined dorsally by ligament and hinge. These valves are opened and closed by muscular processes.

NOTE: Hinge teeth, ligament scars, and muscle scars on fossil shell valves are important characteristics used for identification of fossil pelecypods.

FOOT - Wedge shaped, used for slow, ploughing movements through bottom sediments.

GILLS - Two ctenidia occur in the mantle cavity, the cilia create currents and serve as sieving devices for food gathering.

SIPHONS - The mantle is divided into an upper and lower chamber. Each cavity opens and closes respectively creating a continuous flow of water. Water enters the ventral (inhalant) siphon and passes over the gills and exits through the dorsal (exhalant) siphon. NOTE: a mussel approximately five inches long will pass 4.5 pints of water an hour over its gills. A mussel bed with a population of 300,000 mussels will pass appx. 170,000 gallons of water per hour.

SHELL - Bivalved shell of calcium carbonate (Calcite and Aragonite). Tridacna gigas a modern pelecypod from Bikini Atoll when studied for the content of (Strontium 90) a radioactive isotope a curious fact was discovered. Instead of being composed of bands of aragonite the shell was composed of Stontianite.

SIZE - Controlled by temperature.

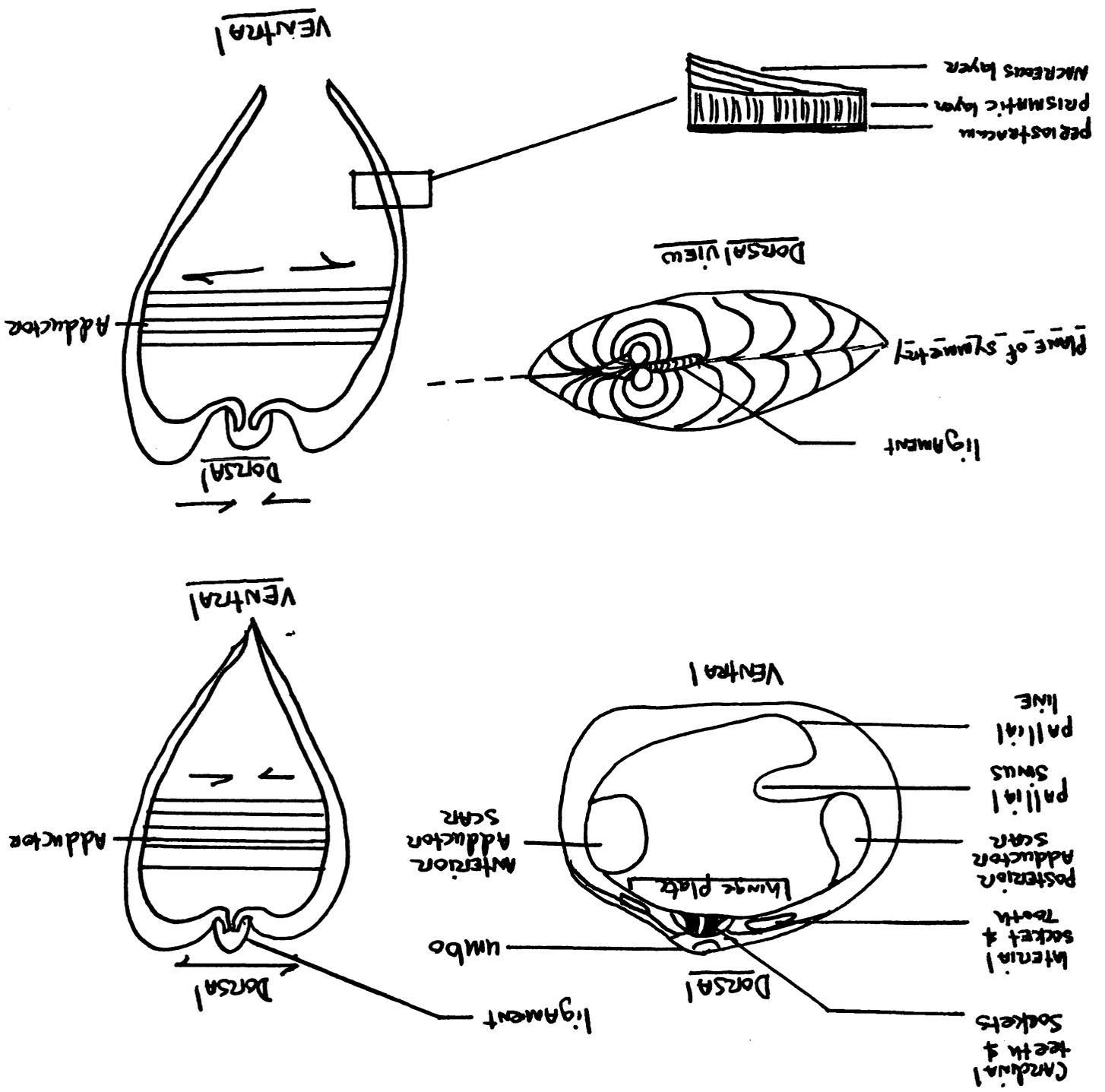
DISTRIBUTION; Worldwide

GEOLOGIC RANGE; Ordovician to recent.

FEEDING CHARACTERISTICS ; Filter feeders

ASSOCIATES ; Other mollusks

Pelecypoda (Bivalvia)



CLASS: GASTROPODA - " SNAILS "

SUBCLASS PROSOBRANCHIA - gill position forward, with torsion

ORDER ARCHAEOGASTROPODA - lacks siphons or proboscis

ORDER CAENOGASTROPODA - siphons usually present

SUBCLASS OPISTHOBRANCHIA - gill position to rear, detorsion

ORDER PLEUROCOELA - shell and mantle cavity obsolete

ORDER UNCERTAIN - no radula

ORDER PTEROPODA - naked or poorly developed shell

ORDER NUDIBRANCHIA - shell usually absent

SUBCLASS PULMONATA - modified hinge

ORDER BASOMMATOPHORA - with shell, eyes and tentacles

ORDER STYMMATOPHORA - shell may be reduced to calcareous granules

CHARACTERISTICS; HEAD - distinct, may be fused to foot. Eyes present, unspecialized tentacles.FOOT - sole-like, modified for creeping.RADULA - normally present.NERVES - ganglia are distinct.TORSION - "coiling" - occurs in most forms or inferred from ancestral forms or occurs in early stages, and not in adult forms.SYMMETRY - varying degrees of bilateral asymmetry.SHELL - when present is a univalve, calcareous, usually spiral, and lacking regular chambers.DISTRIBUTION ; Worldwide.GEOLOGIC RANGE ; Lower Cambrian to Recent.FEEDING CHARACTERISTICS; Although most gastropods are grazers that utilize a radula for scraping algae, some gastropods are predators. Bucher (1938) described a layer of brachiopods from Ohio (*Dalmanella meeki*) whose valves bore a round hole that was drilled by a gastropod (*Lophosira*). In other cases there appears to be a symbiotic relationship between gastropods (*Cyclonema*, *Naticonema*, and perhaps *Platyceras*) and crinoids and cystoids (Bowsher, 1955, 1956) (Treatise, Mollusca I pp. I-239). These gastropods apparently lived on a fecal pellet diet.

Recent gastropods belonging to the family Melanellidae may either live a free existence or be true parasites of echinoderms. Platyceras would affix itself at the larval stage and would feed off the waste of the crinoid host. As the gastropod matured its aperture would completely engulf the anal vent of the crinoid and conform to the irregularities of their crinoid hosts to the extent of uncoiling of the gastropods' shell.

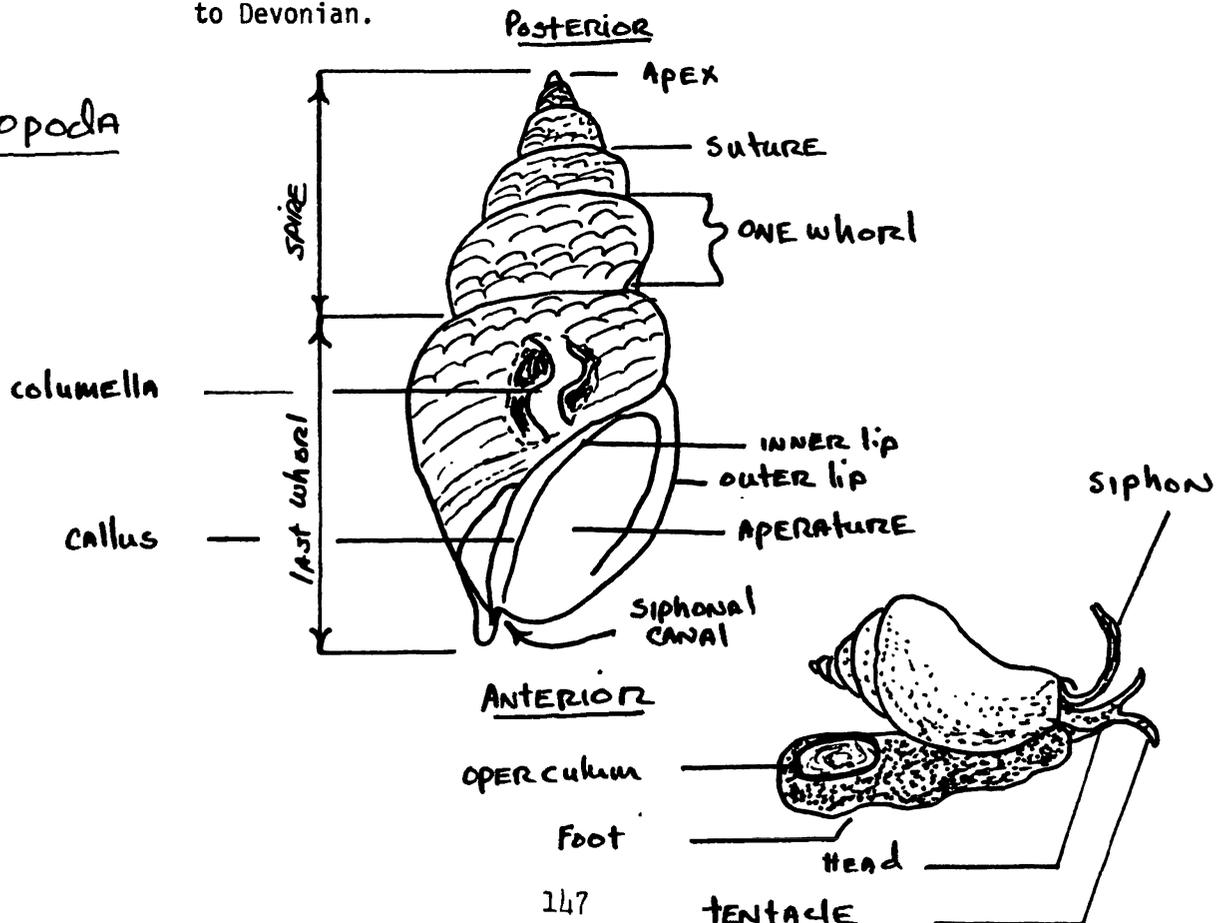
" CLASS " HYOLITHA - operculate mollusks, shell elongate, tapering, apical portion usually separate. Geologic range from Lower Cambrian to Middle Permian.

FAMILY HYOLITHIDAE - contains most of the forms in the " Class Hyolitha ". Geologic range from Lower Cambrian to Middle Permian.

FAMILY ORTHOTHECIDAE - orthoconic shells. Geologic range from Lower Cambrian to Middle Devonian.

FAMILY PTERYGOTHECIDAE - geologic range from Lower Ordovician to Devonian.

Gastropoda



CLASS: CEPHALOPODA

SUBCLASS NAUTILOIDEA - small to large conchs, that maybe straight, cytoconic, or coiled. Siphuncle position variable. Differentiated from subclass Endoceratoidea by the absence of endcones, and from subclass Actinoceratoidea by the lack of complex annular deposits. (approximatly 700 genera)

ORDER ELLESMEROCERIDA - all Cambrian and Lower Canadian

ORDER ORTHOCERIDA - reference genus Cayutoceras

ORDER ONCOCERIDA - reference genus Onoceras

ORDER DISCOSORIDA - reference genus Phragmoceras

ORDER TARPHYCERIDA - reference genus Lituites

ORDER BARRANDEOCERIDA - reference genus Peismoceras

ORDER NAUTILIDA - reference genus Nautilus

SUBCLASS ENDOCERATOIDEA - medium to very large conchs - a specimene residing in the Havard collection is appx. 5800 mm long. Generally the conchs are straight and longiconic, however some are slightly curved and breviconic forms do occur. The siphuncle is medium large, cylindrical, ventral to subventral. Close-packed endcones, cameral deposits are absent.

ORDER ENDOCERIDA - reference genus Chazyoceras

ORDER INTEJOCERIDA - reference genus Evenoceras

SUBCLASS ACTINOCERATOIDEA - medium to large conchs that are generally staight. Siphuncle has septal necks, segments that tend to be wider than long, although there are exceptions. The siphuncle may be subventral to subcentral and annular deposits may fill much of the space.

ORDER ACTINOCERIDA - reference genus Armenoceras

SUBCLASS BACTRITOIDEA - orthoconic to cytoconic conchs. May be either longiconic or breviconic. Siphuncle in contact with the ventral wall. Suture is V-shaped.

ORDER BACTRITIDA

FAMILY BACTRITIDAE - reference genus Pseudobactrites

FAMILY PARABACTRITIDAE - reference genus Parabactrites

SUBCLASS AMMONOIDEA - coiled tightly in one plane, septa form angular sutures that are visible on an internal mold. A small marginal siphuncle.

ORDER ANARCESTIDA - the ancestral stock of the ammonoids

ORDER CLYMENIIDA - dorsally situated siphuncle

ORDER GONIATITIDA - eight lobes

ORDER PROLECANTITIDA - reference genus Prolecanites

ORDER CERITITIDA - very complex sutures

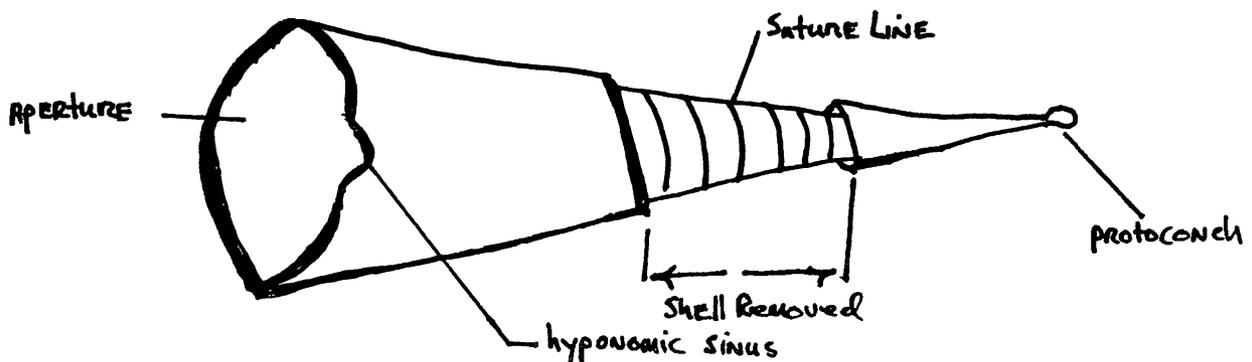
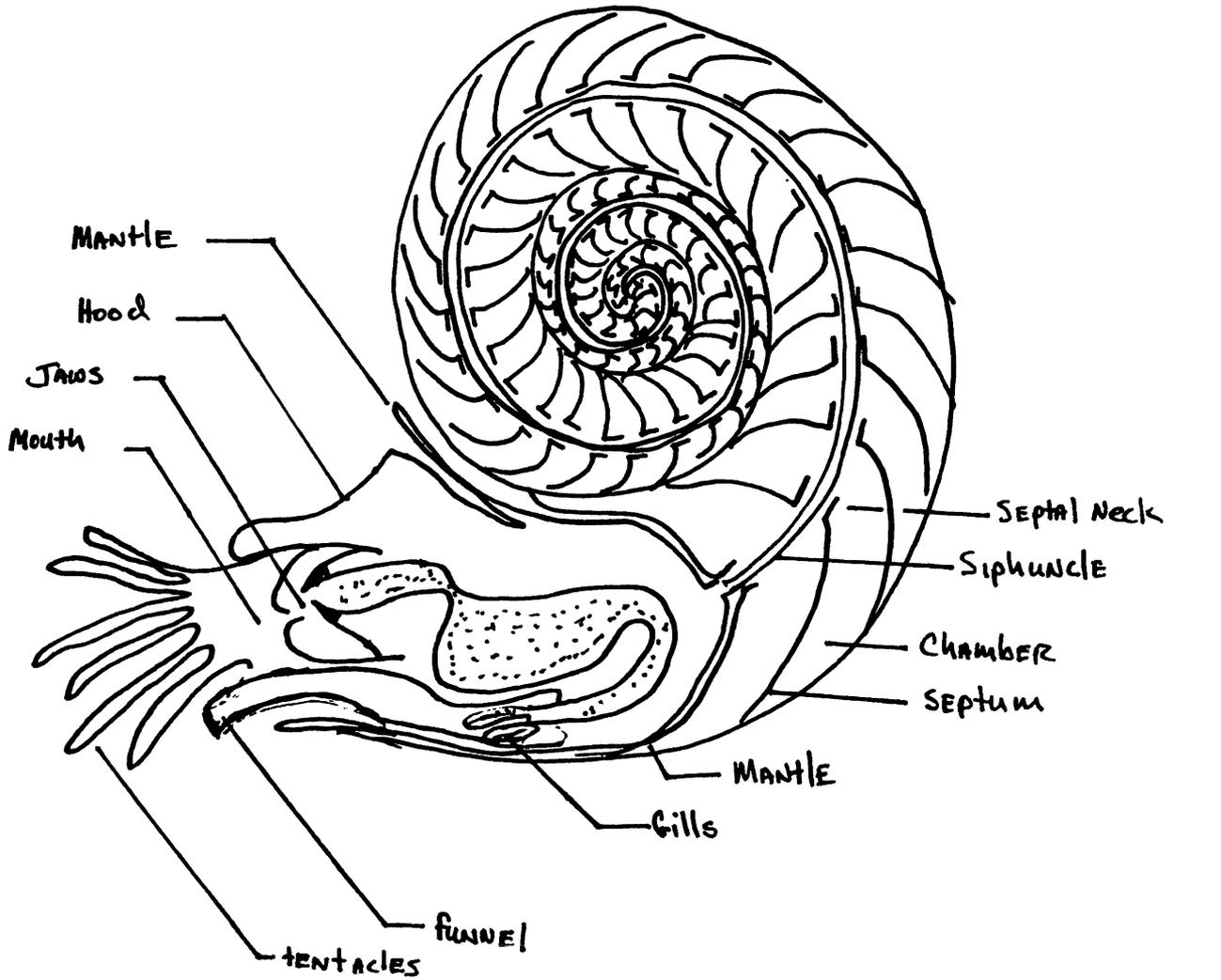
ORDER PHYLLOCERATIDA - leaf-shapped saddle endings

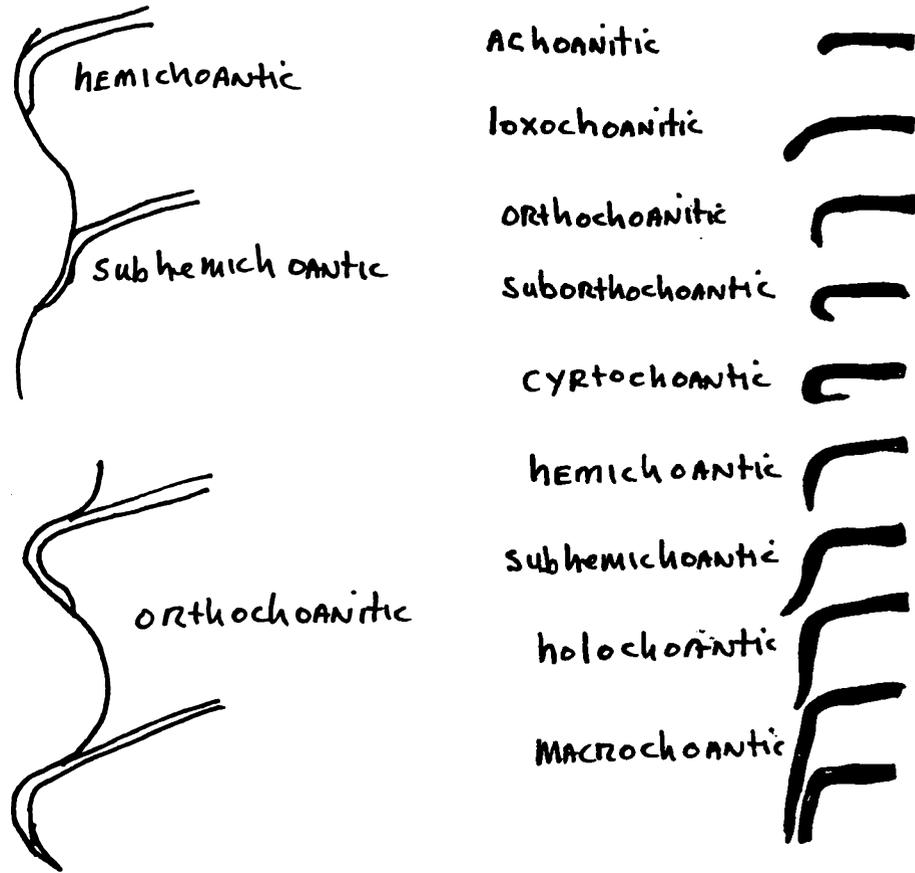
ORDER LYTOCERATIDA - moss-like sutures

ORDER AMMONITINA - thick test, strong ornament

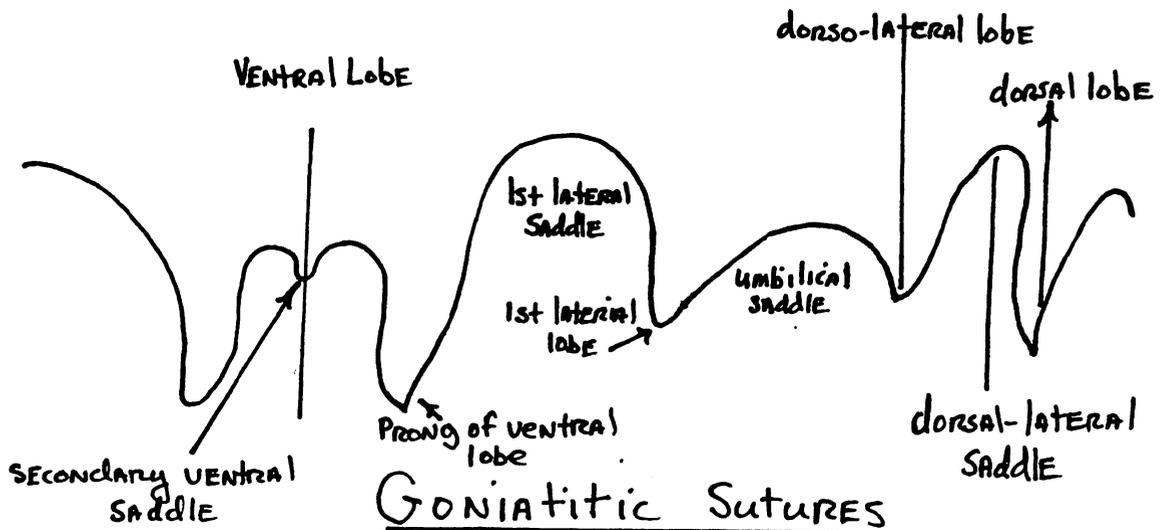
Nautiloid

VENTRAL





Types of septal NECKS



SUBCLASS COLEOIDS - all living cephalopods with the exception of the Nautilus belong to this subclass. This includes squids, cuttlefish, sepioids and octopods. Also the extinct belemnoids are also placed with the coleoids. The coleoids represent a new evolutionary expansion. The chambered shells of fossil cephalopods were constantly evolving to solve the problem of buoyancy versus the predation problems. However the "new" cephalopods have solved part of this problem by decreasing the amount of shell and increased their locomotion (exception Sepia), some have even given up their shell (Octopus). New ecologic niches became available with the loss or reduction of the external shell.

SUBCLASS COLEOIDA - living forms have tentacles (8 or 10), these are specialized for capturing prey and or for reproduction. Shell is internal or external, or absent. Complex eyes are also present.

ORDER DECAPODA - ten arms, internal shell.

SUBORDER BELEMNOIDEA - extinct, internal calcareous shell, buoyant, composed of three parts, a massive rostrum which served as ballast, a phragmacone, the source of buoyancy, and a tongue-like projection of the phragmacone.

Commonly referred to as fossil "cigars". Geologic range from the Mississippian to the Eocene. The suborder has five families.

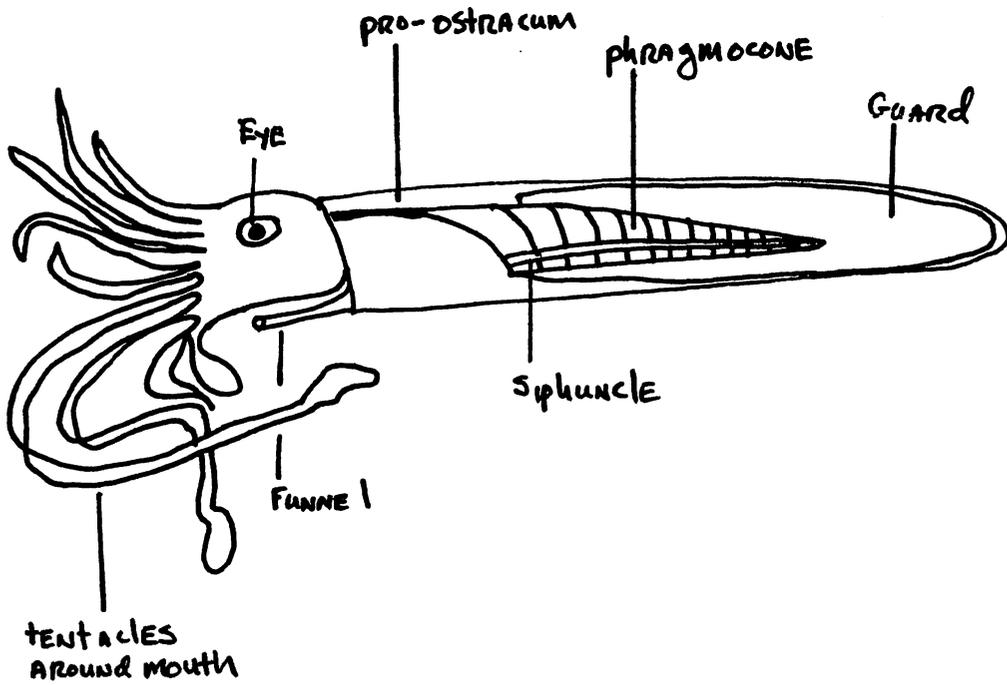
SUBORDER SEPOIDEA - DECAPODS - have an internal calcareous shell, a rostrum, pro-ostracum and a reduced phragmacone which tends to curve. Geologic range is from Jurassic to Miocene.

SUBORDER TEUTHOIDEA - DECAPODS - have a horny internal shell, very reduced phragmacone which is sometimes absent, and the rostrum is either very small or absent. Geologic range is from the Jurassic to the Recent.

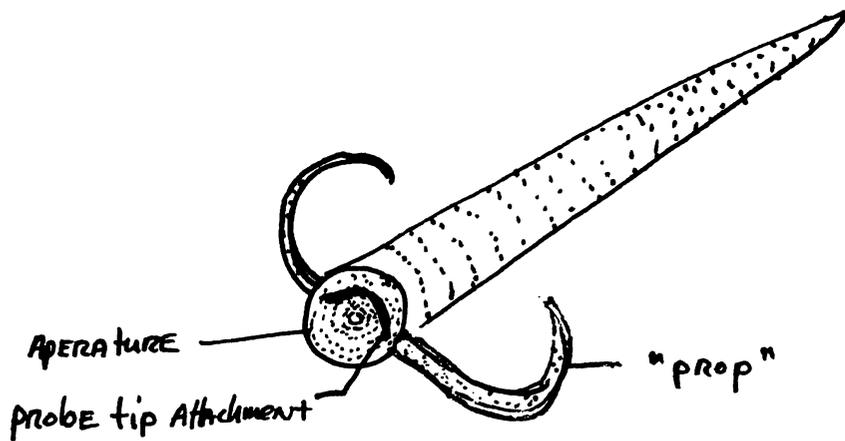
ORDER OCTOPODA - eight arms (longer than the body), Internal shell absent in living forms, but an extremely reduced shell is present in some fossil forms. Certain extant Argonauta females secrete an external shell, (also known in fossil forms).

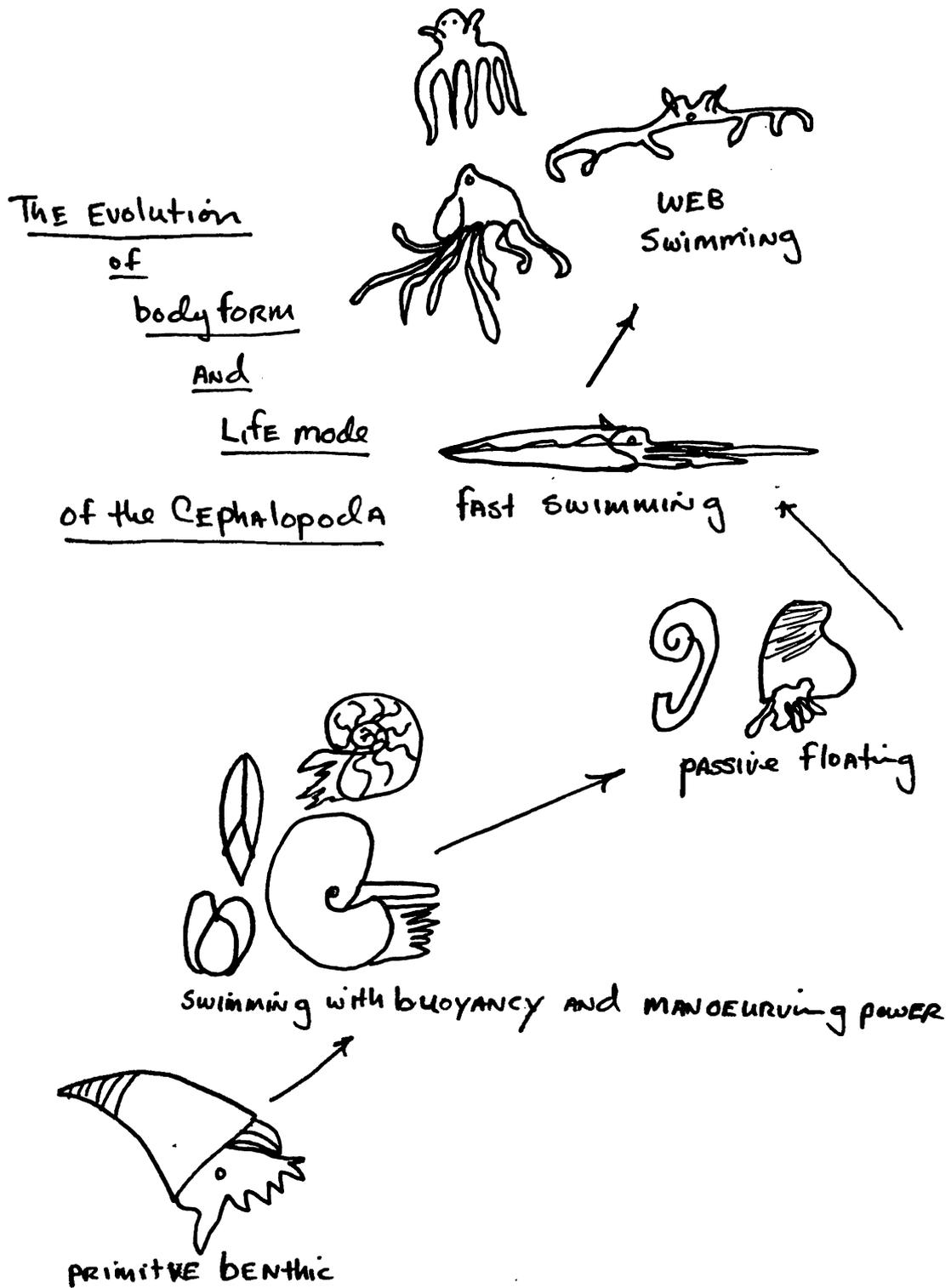
FAMILY CIRRATEUTHIDEA - no fossil record.
FAMILY PALEOCTOPODA - sparse fossil record
FAMILY POLYPODOIDEA - sparse fossil record

BELEMNOIDEA



Hyolitha





THE MOLLUSCAN-BEARING PALEOGENE DEPOSITS OF ALABAMA

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The state of Alabama has often been referred to as one of the most fossiliferous states in the nation. Sediments range in age from Cambrian to Pennsylvanian in the ridge and valley province of the Appalachian Mountains in the north to the Upper Cretaceous sands and limestones of central Alabama and the Paleogene deposits of the Gulf of Mexico Coastal Plain. Of all of these none are as important as the Paleocene and Eocene formations which have been known for their diversity and preservation of mollusks since the early 1800s. The Paleogene deposits are divided into four stages: the Midway, the Sabine, the Claiborne and the Jackson. The type section of all but the Sabine are found within the eastern gulf coast region.

In the Gulf Coastal Plain, the end of the Cretaceous was marked by the emergence of land and the withdrawal of the sea to the south and west. In the western area of the coastal plain (Texas, Louisiana, and Mississippi), the Cenozoic seas advanced and receded many times resulting in the formation of alternating marine and non-marine sediments. However deposits in Alabama to the east are predominately shallow water marine sediments deposited on the continental shelf. The deposits from this time are mainly glauconitic sandy marls of which mollusks are the most common fossil. In limestones, mollusks with calcitic shells such as the oysters and pectens are usually the only shells preserved intact. Most other mollusks are composed of aragonite, the less stable form of calcium carbonate. In limestones, aragonitic shells are usually preserved as casts in molds, however in many of the impermeable glauconitic sand beds found in Alabama, aragonitic shells are so well preserved that they appear to have just recently been collected from the beach.

Since mollusks are the most abundant megafossil found in the Paleogene deposits, they are very useful in mapping the main surface fossil zones. The most important guide fossils are the oysters. During the Paleogene, the oysters underwent a period of rapid evolution of new species. Older species became extinct resulting in a restriction of most oyster species to one specific formation. Other genera of pelecypods that are useful for identification of strata in Alabama include Pecten, Venericardia, and Pitar. Although gastropods are not found in as great of numbers as the pelecypods, they

are much more diversified. Common gastropods used as guide fossils include Turritella, Athleta, Calyptraphorus, Mesalia, Natica, and Pseudoliva.

The Midway Stage which contains the Lower Paleocene deposits of Alabama, is named for Midway Landing on the Alabama River. The oldest deposits are from the Clayton Formation which is equivalent to the Danian Stage of Europe. At the type location in the city of Clayton in Barbour County, the Clayton Formation is a yellow sandy limestone containing abundant casts and molds of Turritella alabamiensis and many Ostrea crenulimarginata. Casts and molds of other aragonitic shells and calcite replaced Turritella aldrichi are found in lesser numbers. An upper clay bed containing complete leaf prints indicate a near shore environment. In southeastern Alabama, the Clayton contains an iron ore bed with typical Clayton fossils and cephalopods replaced by hematite or chalcedony. In central Alabama, two fossiliferous beds are recognized. The lowest, the Pine Barren Member, is a sandy calcareous silt overlain by a sandy crystalline limestone. Outcropping in Lowndes, Butler, and Wilcox Counties, the Pine Barren member in early reports was known as the "Turritella Rock" because of abundant casts and molds of Turritella alabamiensis. The other member is the McBryde Limestone, a light gray marl or clayey chalk which is also known as the "Nautilus Rock" due to the abundant large casts of several species of nautilus, most notably Hercoglossa ulrichi. Outcrops are characterized by bald spots of chalky limestone with a preponderance of cedar trees. A number of other mollusks are found within the McBryde mostly large shells of Ostrea crenulimarginata and numerous molds and casts of aragonitic shells.

The Porters Creek Formation is named for exposures along Porters Creek in Hardeman County, Tennessee. It is a black tough massive marine clay which breaks up upon exposure into roundish conchoidal fragments. The Porters Creek was deposited during a period in which the limestones of the Clayton was succeeded by the deposition of clay. In Alabama this change occurred gradually taking place first in the west and proceeding eastward so that both the Porters Creek and the Clayton are partly of the same age. The lower member of the formation contains many casts and molds of mollusks with Venericardia smithii and Ostrea pulaskiensis being the most abundant. The upper member is the Mathews Landing Marl which outcrops in Wilcox and Marengo Counties. It is a glauconitic marl which is known for its abundant well preserved mollusks.

The Naheola Formation is named for Naheola Bluff on the Tombigbee River in Choctaw County. It is a buff to

pink unfossiliferous thin bedded sand which represents sediments deposited by streams entering into protected lagoons and estuaries. A lower bed, the Oak Hill Member, is named for exposures near Oakhill Post Office in Wilcox County and is generally an unfossiliferous laminated silty clay. The Coal Bluff Marl in the upper Naheola is a fossiliferous glauconitic sand with a fauna similar to that of the Mathews Marl and represents deposits laid down on marshlands after a slight shifting of the Naheola sea. In most exposures it contains only prints and molds in limonitic sandstone. Both the Porters Creek and the Naheola formations are equivalent to the Landenian Stage of Europe.

The formations of the Sabine Stage in Alabama are mostly marine sediments of Lower Eocene age and named for fossiliferous exposures along Sabine River in Texas and Louisiana. Studies of planktonic foraminifera suggest that the Nanafalia and the Tuscahoma Sand could possibly be of Upper Paleocene in age when compared with similar forms in Europe. Formerly called the Wilcox group and the Lignitic Stage by Harris for the beds of lignite found in the Nanafalia Formation and the Tuscahoma Sand, the strata within the Sabine Stage acts as a standard for the correlation of other formations within neighboring states due to the widespread presence of fossiliferous marine beds containing abundantly well preserved mollusks.

The Nanafalia is the lowest formation within the stage and is a marine glauconitic marly sand named for the exposure at Nanafalia Landing on the Tombigbee River which contained many well preserved shells before being covered by backwater from the Coffeeville Dam. The Nanafalia is marked by the presence of large numbers of the oyster Odontogryphae thirsae which first appeared with the invasion of the Eocene sea in Alabama. Found only in the Nanafalia in Alabama, this small, stout oyster is indicative of early Eocene sediments as far west as South Texas and Northern Mexico.

Two subunits are found within the Nanafalia. The lowest is the Gravel Creek Sand Member which represents unfossiliferous non-marine beds which were worked by waves and currents of an advancing sea. The upper unit is the Grampian Hills member, a silty impermeable claystone which is responsible for the high and rugged Grampian Hills in southern Wilcox County. It is very fossiliferous, but both calcitic and aragonitic mollusks are preserved only as external and internal molds.

The Tuscahoma Sand named for Tuscahoma Landing on the Tombigbee River in Choctaw County, is a laminated silty clay containing a few poorly preserved fossils such

as the pecten Chlamys greggi and shark teeth. Logs and splinters of silicified wood indicate a near shore environment. Two fossil beds are found within the Tuscahoma. The lowest, the Greggs Landing Marl, is named for exposures at an old landing on the Alabama River in Monroe County. It is a silty calcareous glauconitic sand and with an abundant, diversified, and well preserved molluscan fauna (fig. 3). Good outcrops of this member with well preserved shells are restricted to two exposures on the Alabama River.

The Bells Landing Marl Member of the Tuscahoma Sand is also named for a landing on the Alabama River in Monroe County. It is a fine grained sand marked by the presence of very large pillow-shaped concretions. The Bells Landing Marl contains many of the same shells as the Greggs, but is less diversified and is known for the presence of very large Ostrea sinuosa, Venericardia aposmithii, Turritella mortoni postmortoni, and Turritella praecincta (fig. 4). Fossils found within both the Nanafalia and the Tuscahoma indicate an equivalent age to the Ypresian Stage of Europe and Africa.

The highest formation within the Sabine Stage is the Hatchetigbee which is named for Hatchetigbee Bluff on the Tombigbee River in Washington County and is equivalent to the Cuisian Stage of Europe. It is a laminated silty clay lithologically similar to the Tuscahoma representing estuarine and deltaic sediments. The Bashi Marl Member is named for Bashi Creek in Clarke County where 15 to 20 feet of glauconitic marl with large pillow-shaped limestone concretions contain abundant well preserved shells. Bashi exposures are superficially similar to those of the Bells Landing Marl, however the Bashi is distinguished by the lack of the large shells found in the Bells Landing Marl and the presence of Turritella gilberti. In Mississippi, Bashi sediments contain a less diverse, thick-shelled molluscan fauna compared to the more fragile thin-shelled fauna of Alabama. This indicates a high energy nearshore environment in Mississippi where thick shells served as ballast and protection and a less turbulent marine shelf environment further east in Alabama. When first exposed in early roadcuts, the Bashi yielded many well preserved shells, especially in west Alabama in the vicinity of a geological uplift known as the Hatchetigbee anticline. However due to the rich quality and slumping of soils derived from the Bashi, most exposures are now overgrown and thus the best exposures are presently found on the Tombigbee River.

The Claiborne Stage is named for the classic exposure at Claiborne Landing on the Alabama River in

Monroe County. It was in the city of Claiborne overlooking the bluff, that the famous paleontologist T.A. Conrad taught the children of a wealthy family to support himself while collecting from the exposed fossil beds. The Claiborne contains three formations which are Middle Eocene in age and equivalent to the Lutetian Stage of Europe. In Alabama the Claiborne represents a comfortable series of marine deposits while in Mississippi alternating deltaic and marine sedimentation occurred.

The Tallahatta Formation was known as the "Buhrstone" in early reports due to the hard quartzite, sandstone, and siliceous claystone which forms the Tallahatta Hills in Choctaw County. The rugged relief of the hills forms a steep escarpment overlooking lower country which in the days before modern roads and travel represented a formidable barrier. These sediments represented a highly destructive wave dominated and channel mouth sand bar system where fossils are rarely found. In west Alabama, lenses of gray sandy clay and glauconitic sandstone occur and contain the oysters, Cubitostrea perplicata and Alectryonia johnsoni which are diagnostic of the Tallahatta. In eastern Alabama, exposures of the Tallahatta along the Conecuh River near Andalusia yield abundant shark teeth.

The Lisbon Formation named for Lisbon Landing on the Alabama River is a marine calcareous glauconitic sand and marl which is abundantly fossiliferous with well preserved mollusks (fig. 5). In the lower part of the Lisbon, Cubitostrea lisbonensis is common while Cubitostrea sallaeiformis is abundant at the top. The middle part of the Lisbon corresponds to the Stone City Beds in Texas.

Fossils shells from the Gosport Sand, named for Gosport Landing on the Alabama River, have been known since 1833 when beautifully preserved shells from Claiborne Bluff were described by Conrad and Lea. The Gosport is a glauconitic quartz sand with an upper leaf bearing clay bed indicating a near shore environment. There is a greater diversity of mollusks within the Gosport than any other Eocene deposit in the Eastern Gulf Coast region with species numbering in the hundreds. Perhaps the most famous fossil exposure in Alabama is the deposit of the Gosport Sand at Little Stave Creek in Jackson County. The deposition of Gosport shells at this locality has been compared to that now occurring at Sanibel Island where a long shallow undersea shelf concentrates the accumulation of live and dead shells. The molluscan fossils at Little Stave Creek have been described by many as the best preserved shells of their age in the United States (fig. 6).

The Jackson Stage represents Upper Eocene deposits and is named for exposures found in and around Jackson, Mississippi. It has an extensive outcrop area stretching from Louisiana and extending to Georgia and Florida. The Jackson also includes the Ocala Group of Florida which is famous for its beautifully preserved echinoids.

The Moodys Branch is the oldest formation found in the Jackson and is equivalent to the Auversian of Europe. In Jackson Mississippi, the Moodys Branch produces a diverse and well preserved fauna of aragonitic shells, however in Alabama, exposures are not as productive. The lower part of the formation in Alabama is a calcareous glauconitic sand and sandy limestone which is designated by large numbers of the echinoid Periarchus lyelli. The only common mollusks are pectens, mostly Chlamys deshayesii, Chlamys spillmani, and Eburneopecten scintillatus. The upper Moodys Branch Formation is less glauconitic and fossiliferous and is marked by the presence of Periarchus lyelli pileussinensis.

The Yazoo Clay is named for the Yazoo River, Yazoo City, Yazoo County, Mississippi and is equivalent to the Bartonian of Europe. In the Yazoo, only calcitic mollusks are usually found intact while aragonitic shells, when present, are preserved as molds and casts. The Yazoo Clay is divided into several members, the lowest being the North Twistwood Creek Clay which is a gray calcareous clay containing only a few fossils, mostly Chlamys danvillensis and Cirostrema danvillense. The next member of the Yazoo is the Cocoa Sand, a yellowish gray calcareous fossiliferous sand that is known more for its marine vertebrate fossils from the type location near the old Cocoa post office in Choctaw County, than for invertebrates. The most common mollusk is Chlamys spillmani clinchfieldensis. The Pachuta marl is a gray glauconitic sandy limestone which is famous as the beds which produce the remains of the primitive whale Basilosaurus cetoides. The Shubuta Clay is a gray sandy glauconitic marl to white sandy limestone which contains Chlamys spillmani clinchfieldensis and Gryphaeostrea vomer plicatella as well as several echinoids also found in the Crystal River Formation of Florida (fig. 7).

Today in Alabama, new exposures of Paleogene deposits are not being uncovered due to the lack of new road building, while many of the older cuts are rapidly weathering away. However most of the creek and river exposures continue to yield large numbers of beautifully preserved shells and will probably continue to do so in the future due to sparse collecting by the local population.

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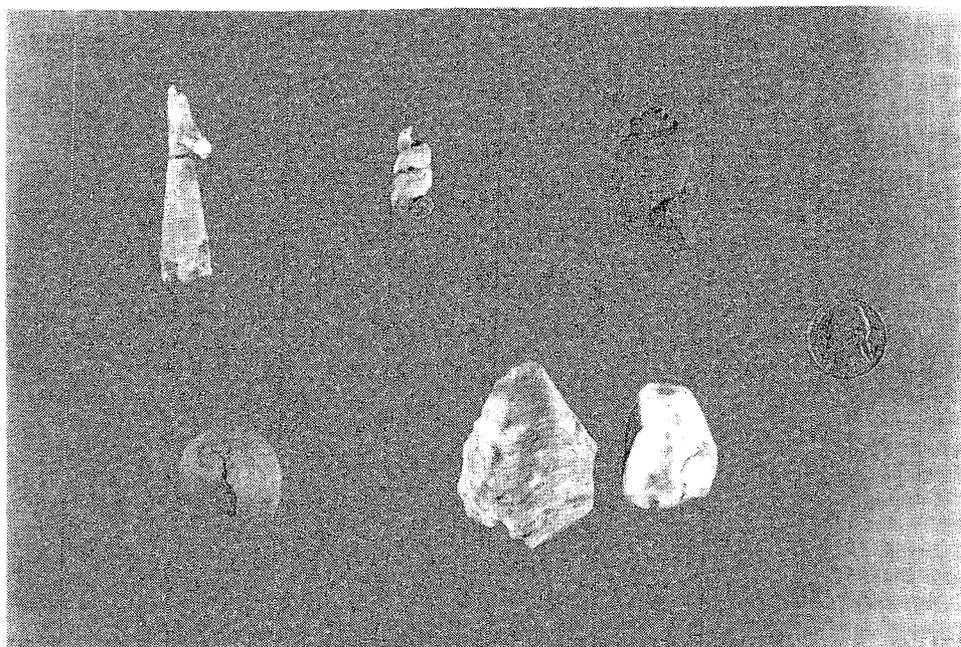


Figure 1. 1. to r. upper: Turritella aldrichi Bowles, Turritella alabamiensis Whitfield, Clayton Formation, Barbour County; Pseudoliva sp., Iron Ore facies, Clayton Formation, Pike County; lower: Cypraea sp., Porters Creek Formation, Lowndes County; Odontogryphaea thirsae (Gabb), Nanafalia Formation, Henry County.

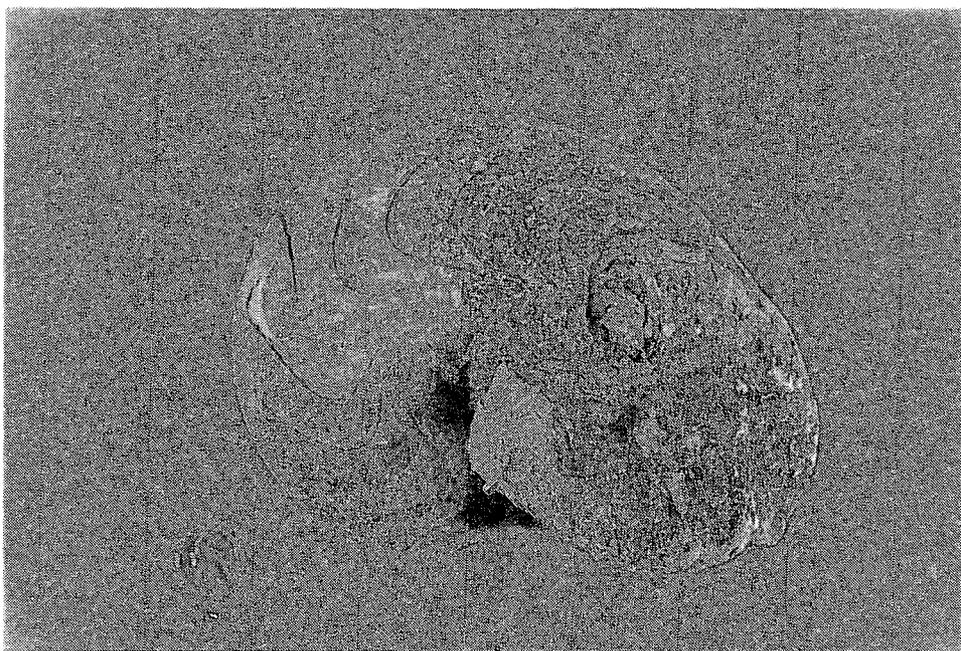


Figure 2. Hercoglossa ulrichi (White). McBryde Limestone Member of the Clayton Formation. Cedar Creek, Butler County, Alabama.

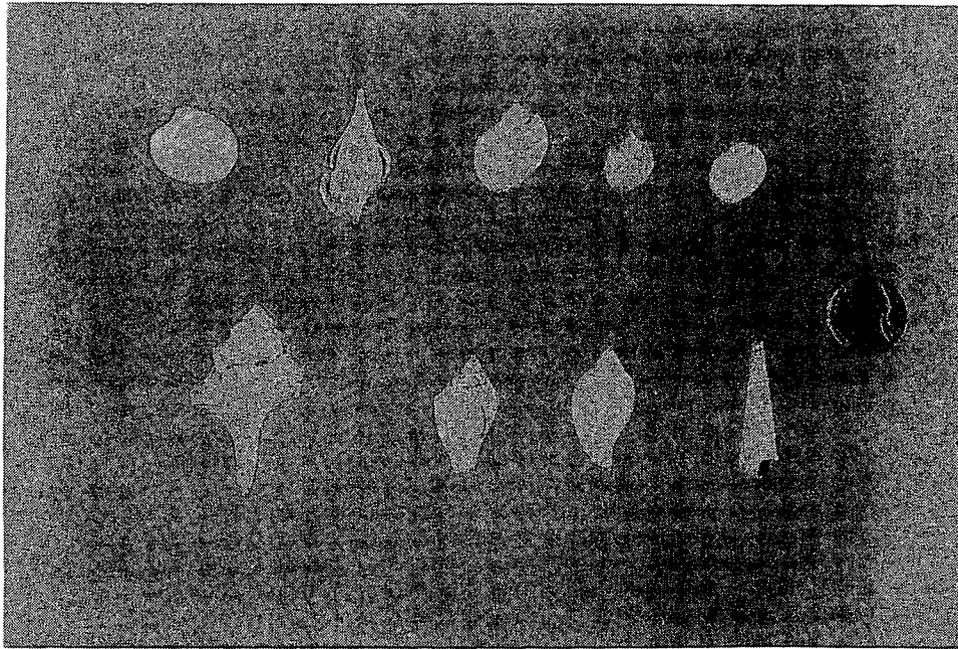


Figure 3. Fossils from the Greggs Landing Marl Member of the Tuscahoma Sand, Alabama River, Monroe Co. Upper: Pitar nuttalliopsis greggi (Harris), Calyptrophorus trinodiferus Conrad, Lacunaria alabamiensis (Whitfield), Lacunaria erecta, Ampullella recurva (Aldrich) var. Lower: Levifusus supraplanus Harris, Athleta tuomeyi Conrad, Caricella sp., Turritella bellifera Aldrich.

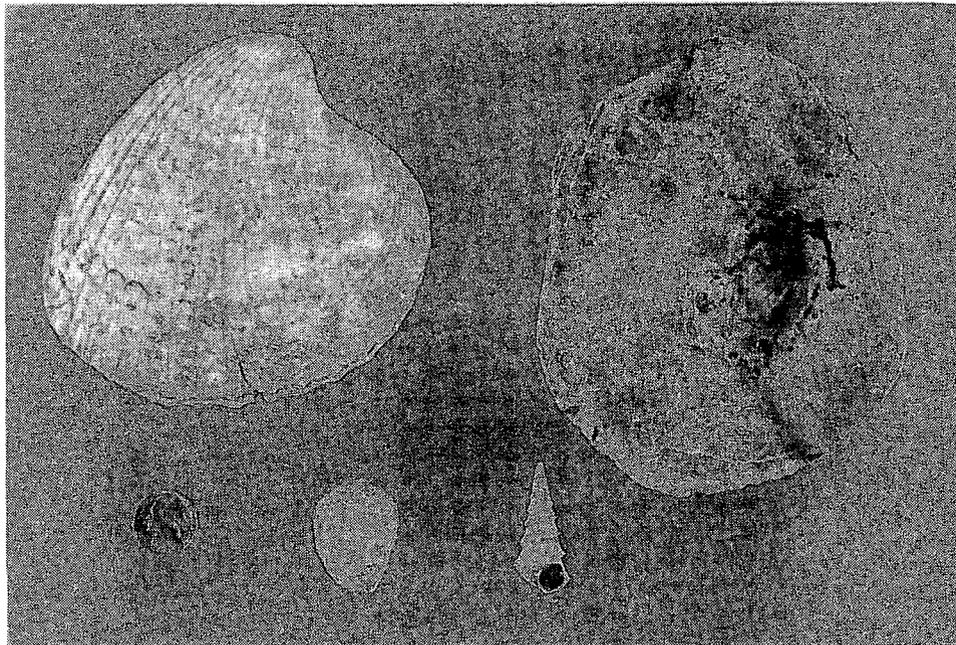


Figure 4. Fossils from the Bells Landing Marl Member of the Tuscahoma Sand, Wilcox County, Alabama. Upper: Venericardia aposmithii Gardner & Bowles, Ostrea sinuosa Rogers & Rogers. Lower: Pseudoliva vetusta (Conrad), Turritella mortoni postmortoni Harris.

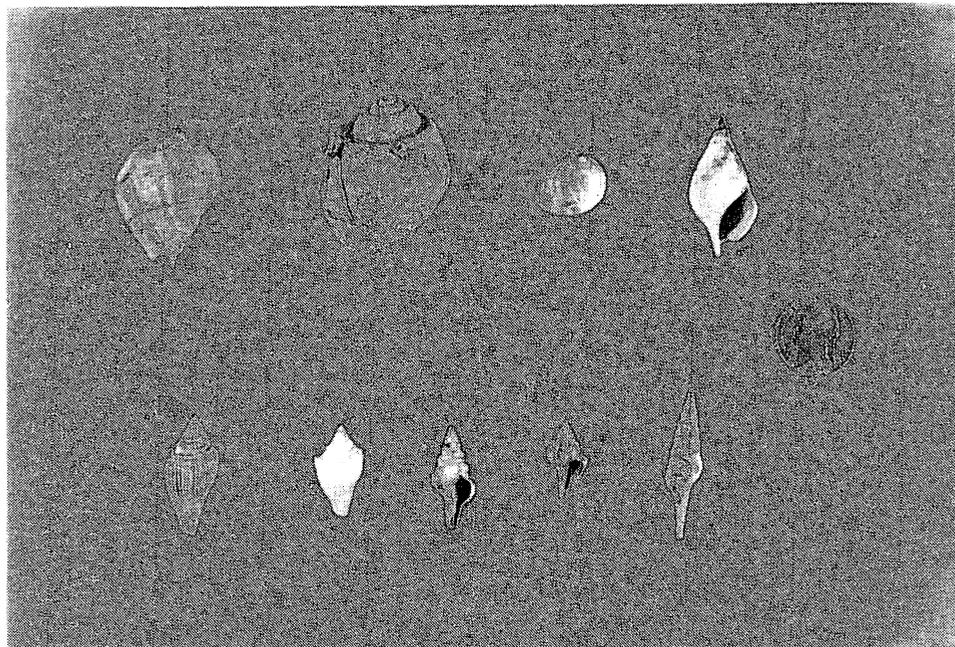


Figure 5. Fossils from the Lisbon Formation, Sowilpa Creek, Choctaw County. Upper: Ampullella recurva (Aldrich), Pseudoliva vetusta carinata Conrad, Polinices aratus (Gabb), Calyptrophorus velatus nodovelatus Palmer. Lower: Athleta haleaunus (Conrad), Athleta petrosus (Conrad), Latirus moorei (Gabb), Levifusus mortonopsis (Gabb), Protosurcula gabbi (Conrad).

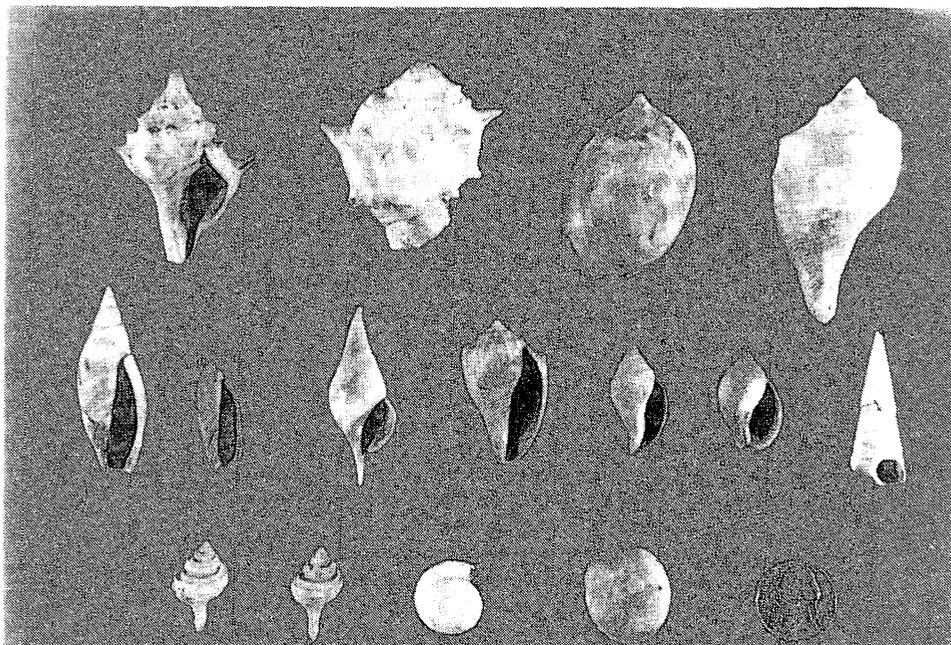


Figure 6. Fossils from the Gosport Sand, Little Stave Creek, Clarke Co. Upper: Papillina papillata, Cornulina armigera, Bullia altilis, Ficopsis penita. Middle: Agaronia alabamiensis, Ancilla staminea, Calyptrophorus velatus, Athleta sayanus, Caricela bolaris, Doliocassis nupera, Turritella carinata. Lower: Lirofusus thoracicus, Levifusus mortonii, Archetectonica elaborata, Neverita limula.

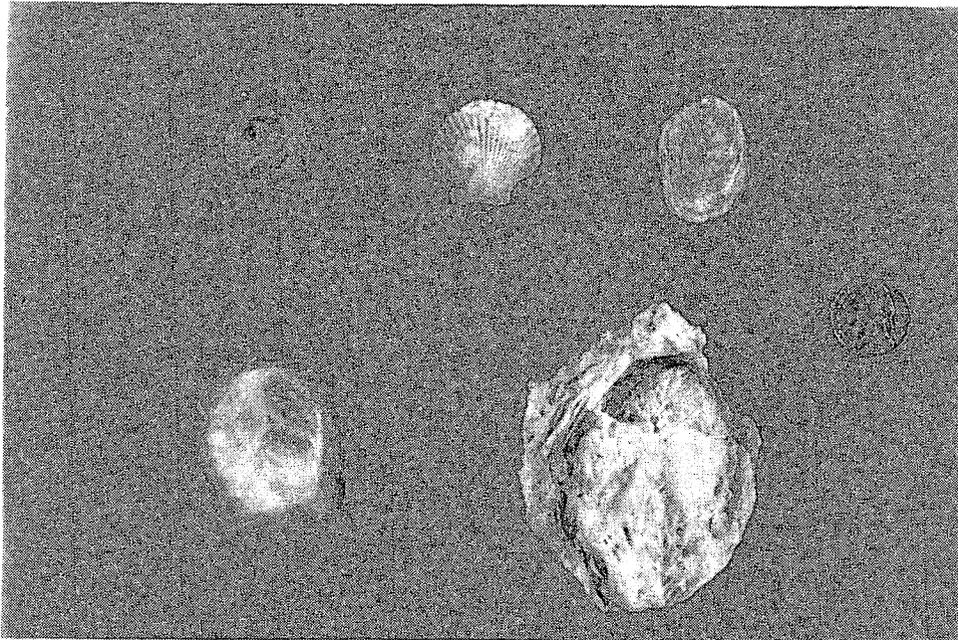


Figure 7. Fossils from the Shabuta Clay Member of the Yazoo Clay, Clarke County, Alabama. Upper: Xenophora sp., Chlamys spillmani clinchfieldensis Harris, Gryphaeostrea vomer plicatella Morton. Lower: Alectryonia vicksburgensis (Conrad) var., Gigantostrea trigonalis (Conrad).



