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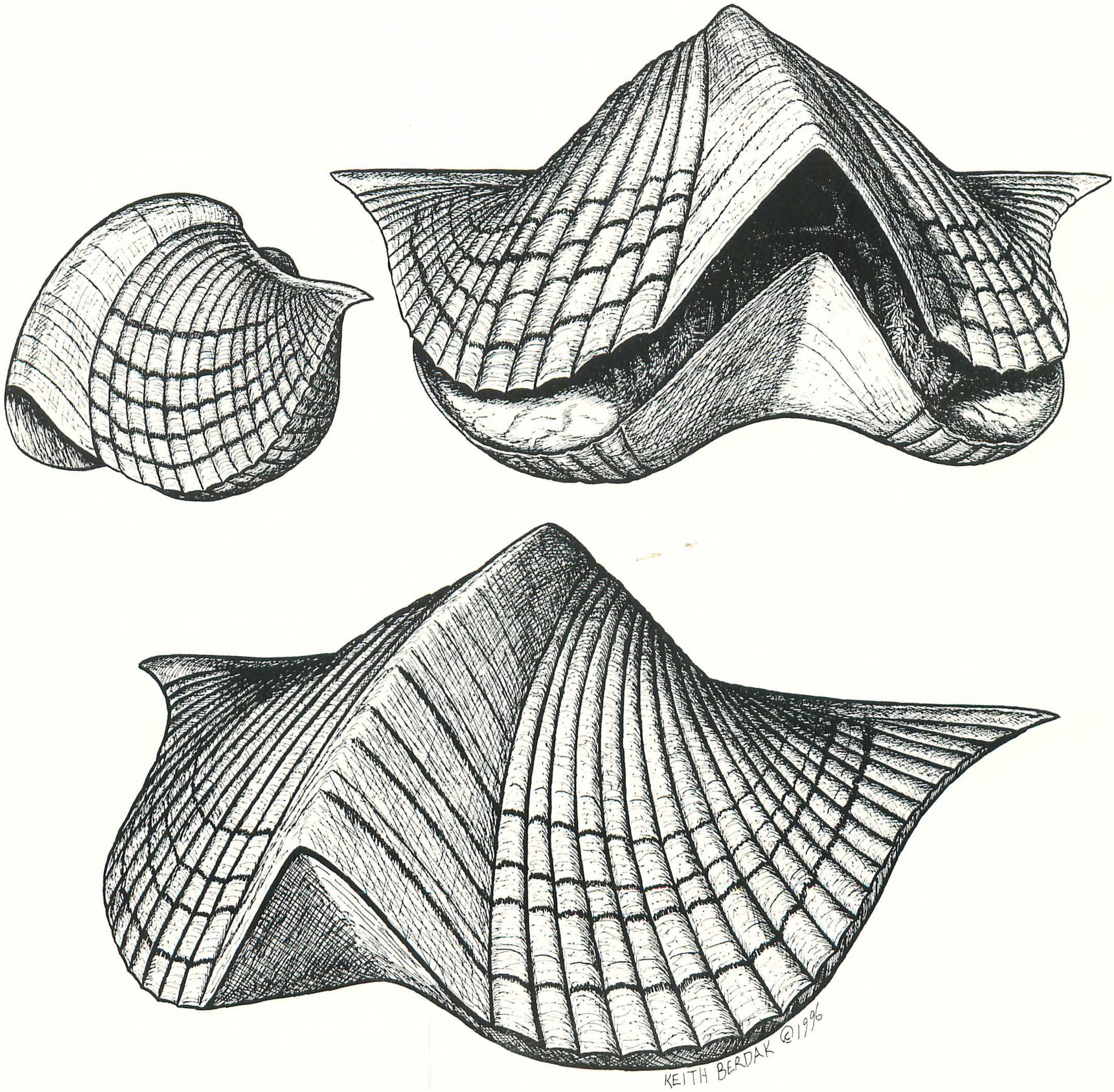

BRACHIOPODS

MAPS DIGEST

EXPO XVIII EDITION

MID-AMERICA PALENONTOLOGY SOCIETY

A LOVE OF FOSSILS BRINGS US TOGETHER

Western Illinois University
Union Ballroom
Macomb, Illinois 61465
April - 1996

ACKNOWLEDGEMENT

To the authors, artists and all those individuals who have contributed to this issue of EXPO DIGEST XVIII EDITION on **BRACHIOPODS** I express my most greatful appreciation and "thanks". Many people said they collected **Brachiopods** but did not know enough about them to write an article on the subject. I suspect most amateurs know more about them than they think. By writing an article, as we do research we educate ourselves, then as others read the article, they too gain knowledge which helps when getting started collecting fossils.

All fossil collectors, amateurs and professionals have collected **Brachiopods** at one time or another. **Brachiopods** are the most abundant paleozoic fossil found from Pre- Cambrian to the present; the Lingula from Ordovician to the present is one of the living fossils. There is hardly a fossilferous area which does not contain **Brachiopods**, they stand out conspiciously as a persistant class of animals from Pre-Cambrian to the present, and have become the most valuable fossils as geologic time markers, and for the purpose of correlation. To recognize this Phylum and their importance to the geological time table is long overdue.

Dr. G. Arthur Cooper, Paleobiologist Emeritus, National Museum of Natural History, Smithsonian Institution, Washington, D. C. The foremost authority on **Brachiopods** in this generation of collectors; and we are most fortunate to have an article from him in this issue of **Brachiopods.**

I deem it a privilege and a pleasure to dedicate this EXPO XVIII EDITION of the MAPS Digest to **Dr. Cooper**.

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

The **Front Cover** for this issue of the **EXPO XVIII EDITION OF THE DIGEST** entitled *"SPIRIFERS"* was drawn by: Keith Berdak, 621 Twillman Drive, St. Charles, Missouri. Ph. 314-946-3526 The *Paraspirifer bownockeri,* (Stewart UMMP 61129); specimen was found in a quarry at Sylvania, Ohio, Silica Formation, Devonian age.

The **Back Cover** is *Dicellomus politus,* 8x Late Cambrian, Eau Claire Formation, Strum Wisconsin. Photo: Gerald Gunderson, 6413 Elmwood Avenue, Middleton, Wisconsin. **Story** page 118 in this issue of the Digest (marked Figure 2)

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G. ARTHUR COOPER
THE SAGE OF THE BRACHIOPODS

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INTRODUCTION

Few paleontologists studying a particular phylum stand notably above the other past or present specialists on that group. A spectacular exception to this generality is Gustav Arthur Cooper. His publications always cite him as G. Arthur Cooper. He often signs his correspondence "Coop". I have, however, occasionally heard some other scientists sometimes refer to him as "Gus Cooper".

I probably first heard of G. Arthur Cooper in Fall, 1960, as a student in Bill Berry's Invertebrate Paleontology class at the University of California at Berkeley. In that class, we were given the names of significant workers for each of the major groups of invertebrate fossils. This sometimes presented problems because for some groups there is no noteworthy worker--in others there are so many significant workers that it is difficult to single out one or few workers to discuss. If you did not know much about brachiopod scientists, you might think there would be unusual difficulties in naming key workers for this group because there are so many significant workers. This is emphatically untrue for brachiopods because one man, G. Arthur Cooper, greatly outshines all the other outstanding brachiopod workers.

What is so unique about this one man? I will try to give some of the probable reasons in this paper. A few significant reasons are given below. G. A. Cooper has worked on brachiopods from every period from the Cambrian to the Recent and every order from the Lingulida to the Terebratulida. He has been publishing his research for over sixty-six years (1930-1996). Few scientists produce for this long of a period. To date, he has published alone or with other workers over 132 different works. The quality of his works has remained constant over this time. Dr. Cooper has named and described by himself or with others at least 506 genera of brachiopods. This is over 12% of all the brachiopod genera that have ever been established. He has established almost three times as many brachiopod genera as his leading competitor, the Czech paleontologist Vladimir Havlíĉek. G. A. Cooper can probably identify more brachiopod genera on sight than anyone else in history.

His particular contributions are numerous and noteworthy. I will mention three periods where his works are brachiopod classics and where his work has made his study areas classic reference sections. These are the Devonian, particularly of New York; the Ordovician, particularly of the Appalachians; and the Permian of West Texas and adjoining parts of New Mexico.

His first significant paleontological project was on the stratigraphy and biostratigraphy of the Devonian Hamilton Group in central New York. He commenced this work in the late 1920's and returned intermittently to the Devonian throughout his career. He, along with G. H. Chadwick, played a major role in developing our modern view of the stratigraphy of the Devonian Catskill Clastic Wedge (also called the Catskill "Delta") in New York and Pennsylvania. Through their efforts, it is now one of the most carefully studied examples of facies changes in North America. They showed, with the help of brachiopods, that planes of time equivalence, instead of roughly paralleling the boundaries between rock types, as assumed by most earlier workers such as James Hall, can cut diagonally across them. The Devonian here is now a classic reference section for North America. His major works on this subject include "Stratigraphy of the Hamilton Group of New York" (1930), "Stratigraphy of the Hamilton Group of Eastern New York" (1934), and with other workers, "Correlation of the Devonian Sedimentary Formations of North America" (1942). Even today, he still feels a particular fondness for Devonian Brachiopods. In a letter to me (12/27/95), he says "...I think the Devonian still stays with me as my first love and a critical time in geological history, also the most brachiopiferous time of geological time."

His next project (I should point out that none of his projects totally ended, but continued on at a usually reduced level) was the Cambrian and Ordovician brachiopods and their biostratigraphy. He gave particular attention to the Early and Middle Ordovician, especially in the Appalachians. This work started in the 1930's with E. O. Ulrich, and tapered off by the mid-1950's. The works he produced are still the standard references, particularly for the Middle Ordovician and its brachiopods. His major works are "Ozarkian and Canadian Brachiopoda" with E. O. Ulrich (1938), and his impressive two-part monograph "Chazyan and Related Brachiopods" (1956), which had 1245 pages and 269 plates.

His final classic project, that I will mention here, is his study of the Permian brachiopods of West Texas and adjoining parts of New Mexico. He started collecting brachiopods in West Texas in 1939, and was still collecting them in 1968. He, alone or with his colleagues, collected an estimated 144,314 pounds of fossil-bearing rock for etching. No other paleontologist has ever etched out so many fossils. His work has helped make West Texas the classic reference area for the North American Permian and probably the Permian of the world. His classic publications on the West Texas Permian with Richard Grant are probably the greatest single work on a brachiopod fauna ever completed. This work is entitled "Permian Brachiopod of West Texas". It came out between 1972 and 1977 and consists of eight volumes including plates: 3,370 pages; 780 plates; 42 figures; and 2 tables.

BACKGROUND

G. Arthur Cooper was born February 9, 1902, in the College Point District of New York City. I find it hard to believe he was born in New York City. He always seemed to me like a cultured Englishman who had lost his accent. This is probably due to my false stereotypes of New Yorkers and/or the uniqueness of Cooper.

The history of his interests relevant to geology are rather parallel to mine. He got interested in minerals in high school and went to Colgate University in Hamilton, New York, to train as a Mineralogist with a major in Chemistry and a minor in Geology. Following graduation from Colgate, he decided to work on a Master's degree in Mineralogy at the same school. Unfortunately for mineralogy, but fortunately for paleontology, Colgate lacked the appropriate optical equipment. Cooper went into geology instead. Colgate has its campus and surrounding hills underlain by fossiliferous rocks of the Devonian Hamilton Group. According to Cooper "my heart was in geology" so the campus and its environs made it easy "to wean myself away from minerals" (personal communication, 1995). He did his Master's thesis on the stratigraphy of the Hamilton region. However, he never totally lost his fondness for minerals. He has helped enlarge and improve the Mineral and Gem collections at the U.S.N.M. during his tenure there.

Cooper did his Ph.D. on the Hamilton Group for all of New York State at Yale University. He graduated from there in 1929 as a Stratigrapher. His favored group of fossils during his thesis studies was the bivalve molluscs. The famous Charles Schuchert at Yale helped divert Cooper's primary fossil focus to brachiopods. He got Cooper to assist him with a project that Schuchert financed to revise the brachiopod genera. The bad economic conditions at the time forced termination of the project after two years. They were still able to publish in 1932 part of their work as the classic "Brachiopod Genera of the Suborders Orthoidea and Pentameroidea".

Cooper was appointed Assistant Curator of Stratigraphic Paleontology at the United States National Museum (now the National Museum of Natural History) of the Smithsonian Institution in 1930. He commmenced work there in autumn of that year. He was to remain there 57 years, rising to head curator of geology and finally Chairman of the Department of Paleobiology. He would probably have stayed even longer at the museum, I suspect, but for the reduction of support for paleontology at the U.S.N.M. (now NMNH) and deterioration of the social conditions in Washington's neighborhoods.

Cooper as a Field Scientist.--G. Arthur Cooper has been a stand-out in many areas of his professional career. This includes field work, fossil preparation, curation, photography, research proper, and education. Field studies have always figured prominently in Cooper's work. This stands in striking contrast to too many of the young paleontologists today who rarely or never work with fossils in the field. He has always loved field work and did as much of it as he could. One of the great regrets of his last years is the inability to endure the rigors of the field because of physical limitations. There are few brachiopod-rich parts of North America that he has not visited. There are also few geological formations yielding noteworthy brachiopods in North America that he has not sampled.

Cooper as a Preparator.--As an invertebrate fossil preparator G. A. Cooper has few equals. He is one of the significant pioneers in the use of acid to extract fossil from limestone. He and his colleagues at the U.S. National Museum developed more techniques and extracted more fossils from limestone than anyone before or since. A good place to see some of these techniques is in the first volume of "Permian Brachiopods of West Texas". It isn't surprising that he is the lead author in a chapter on this subject in Kummel and Raup's "Handbook of Paleontological Techniques". As most paleontologists know, it is difficult to observe the internal structures such as the loop in most fossil brachiopods because you can't separate the valves, and the interior is filled with solid matrix. As a result, most brachiopod paleontologists prepare and illustrate serial sections which are seldom used to recreate the parts involved. This makes it difficult for all workers, and almost impossible for workers not thoroughly conversant with serial sections, to use these in comparing various individuals or taxa with each other. I always disliked serial section illustrations and was surprised to discover that Cooper felt the same way. Where possible, he would dissect away the shell and matrix using tools such as needles to reveal the internal structures in three dimensions. He was meticulous and patient and was probably the world's leading artisian in this area. You can see his art particularly well-revealed in his 1983 work, "The Terebratulacea (Brachiopoda) Triassic to Recent: A Study of the Brachidia (loops)".

Cooper as a Curator.--He was a master curator. He alone is responsible for the U.S. National Museum having the world's best brachiopod collection and an invertebrate fossil collection that ranks with the top collections in the world. He was one of the curators I have always admired, who despite their lofty positions, delighted in pulling out a drawer of choice "goodies" to show any interested party.

Cooper as an Educator.--G. Arthur Cooper has never been a formal teacher, but has done as much or more than most regular teachers in passing on brachiopod lore through his publications, seminars, lectures, field trips, and informal discussions.

Cooper as a Photographer.--Cooper's photographic skills are legendary. Few are aware that he took the vast majority of the innumerable photographs in his many publications. He has probably taken and published more brachiopod photographs than any other scientist in history.

Cooper's Associates.--His associates, many of whom were not brachiopod workers, over the years reads like a Who's Who of nineteenth and twentieth century paleontology. There are almost no significant brachiopod workers in the twentieth century with whom he hasn't interacted. To name a few, his colleagues over the years have ranged from Charles Schuchert and E. O. Ulrich in the early years, to Norman Newell, R. C. Moore, Carl Dunbar, J. B. Knight, P. B. King, Harry Whittington, Helen Muir-Wood, Alwyn Williams, Howard Brunton, Ellis Yochelson, Richard Grant, and many more in later years.

Cooper's Personal Life.--Like many great scientists, Cooper has had the support of a great woman, his wife Josephine Cooper. She was also a geologist. She did not just lend him moral support for his activities, but took an active part in his research and curation. On the Permian project, she picked and sorted specimens, translated Russian publications, solved bibliographic problems, and numbered plates. She helped him keep a file of all brachiopod generic names and descriptions up to at least 1980. She did many other translations of Russian paleontological works beyond the Permian. I was a beneficiary of her translations of Russian works on living brachiopods. I suspect she did far more than these few tasks, including being a gracious hostess for the countless visiting paleontologists the Coopers entertained in Washington.

The Coopers have two children: a son and a daughter. The son is now a Professor of Forestry at North Carolina State University and a major figure in the Ecological Society. The daughter lives on the West Coast.

G. A. Cooper has been elected to many important posts and has received many honors over the years. Some include Honorary Doctor of Science at Colgate University, Fellow of the Geological Society of America, President of the Paleontological Society (1957), President of the Paleontological Society of Washington, President of the Geological Society of Washington, the Mary Clark Thompson Medal (1958), and the Paleontological Society Medal (1964).

Cooper has not confined his interests to just brachiopods. He has delighted in finding, extracting, and examining other kinds of fossils. To my knowledge, he has also published on bivalve molluscs, echinoids, starfish, and trilobites. He is an avid student of history with particular interests in Early American History, the opening of the West, the United States Civil War, and exploration of the world. He is enthralled with all types of Natural History. He and his wife were devoted habituees of the animals in the National Zoological Park in Washington, D.C. During his jaunts to west Texas, he took up wildflower study and photography. He had a particular love of the flowers of cacti. I can still recall a framed print of a beautiful desert wildflower photograph that he took on the wall of his house in Washington. Even today, in his 90's, he is photographing wildflowers around his apartment in Raleigh, North Carolina. On January 2, 1992, he already had taken approximately 2,000 wildflower slides there. He is also reported to be a baseball buff.

MY ACQUAINTANCE WITH G. A. COOPER

I first met Dr. Cooper in the early 1960's. I was a graduate student doing my Master's thesis research on invertebrate fossils from the Middle Ordovician Antelope Valley Limestone in the Grapevine Mountains on the east side of Death

Valley. I was giving particular focus to receptaculitids, brachiopods, and trilobites. I went to the U.S. National Museum in Washington, D.C., primarily to look at their Great Basin receptaculids. The first staff member I encountered was a fossil bryozoan worker who treated me and my request as if they were something disagreeable he had stepped in on a kennel floor. I was then directed or ran into G. Arthur Cooper. His manner was at the opposite pole from that of the first man. He treated me like an esteemed colleague, even though I was just a young fledgling paleontologist, and did everything in his power to help me.

I next saw Dr. Cooper in the late 1960's while I was working on the Recent Antarctic and Subantartic brachiopods. He made it possible for me to do this project by offering and letting me study brachiopods at the U.S.N.M. that had been alloted to him for study. He provided me with advice, facilities to work in, and even put me up at his house during one of my visits to Washington. I can still remember with great pleasure dining and conversing with Cooper and his gracious and equally intelligent wife at their house in Washington, D.C.

I have continued contact with Dr. Cooper since the 1960's. I occasionally visited him while he was still in Washington, but most of my dealings with him have been through the mail. Correspondence with Dr. Cooper has always amazed me, considering his prominence. During our relationship much of his correspondence to me has consisted of informal, personally typed letters or letters written in long hand. These letters stand in striking contrast to correspondence I have had with some other prominent zoologists or paleontologists. Some of them wouldn't even answer my letters--others would just send back my letters with a rude scrawl across them!

Even though we take opposing positions on the "splitting" versus "lumping" controversy, and my position in the brachiopod world is not a prominent one, he has never taken offense at my views, but has been as cordial, generous, and kind to me as anyone could be. His praise of others, including me, has been unstinting.

When I hear the phrase "gentleman and a scholar", I think instantly of G. Arthur Cooper because he is the epitome of this kind of person. This slow-speaking humble and reserved man has always reminded me of the fictional treasured English don of an elite private school portrayed in the cinema, except he is real. Dutro (1971) said that "No geologist who has been closely associated with him doubts for one moment that here indeed is a great and good man." I heartily concur.

CONCLUSION

Cooper left the National Museum of Natural History in 1987. Now in his 90's, he lives in a retirement complex in Raleigh, North Carolina. I use the term retirement loosely because men such as Cooper never retire, but just slow down a bit because of things beyond their control. He has published at least three papers since his retirement, helped the North Carolina Museum with their brachiopod collection, taken thousands of wildflower photographs, and probably done much more.

There will probably never be another paleontologist like G. A. Cooper who combines such interest, ability, dedication, perseverance, and integrity with such gentleness and kindness to his peers and to those far below him professionally. He is truly a prince among paleontologists.

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BRACHIOPODS - YESTERYEAR AND TODAY

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Living brachiopods are only a remnant of the vast numbers which existed in the past. Brachiopods began life in the Early Cambrian and are among the first shelled animals to appear in the fossil record. They increased in numbers and kinds, climaxing in the Devonian at 900+ * genera, after which there was a slight decline until the Permian when some stocks expanded and attained their greatest diversity and complexity. Brachiopods experienced a serious decline in the great Permian extinction. Survivors of that debacle increased during the Mesozoic (about 740 genera) only to suffer another drastic reduction in the extinction at the end of the Cretaceous. The survivors of that catastrophe number 60 genera in the Tertiary. The Recent genera include some persistent Tertiary forms, reminders of the vast numbers of the past. Does this mean that the modern fauna is the dying remnant of a great race, or is it the source for rebirth and expansion of the phylum in eras to come?

Modern brachiopods occupy all of our seas, most kinds ranging from the shore margin to 500 meters. Some have invaded the abyss. Pelagodiscus, an inarticulate, is known from the deeps of all the oceans, occurring as far down as 6160 meters. Abyssothyris, an articulate, has been taken at 6179 meters (20,867 feet, nearly four miles). Areas from which many modern brachiopods have been recorded are: the Caribbean, eastern Atlantic, Mediterranean, Antarctic and Subantarctic island regions, Japan, southern Australia and New Zealand.

Our brachiopod lore was brought into focus by the Treatise on Invertebrate Paleontology in 1965 (1.). In these volumes 1729 genera are classified in major and minor groups. A new edition of the Treatise now in preparation will reclassify, and bring into still better focus the evolution of the phylum and its problems, adding about 2800 genera which have been proposed since 1965. About 600 brachiopod workers world wide have been listed by R. Doescher (2). His large count indicates that the phylum will receive attention in spite of hard times to come which may result from decreased appropriations for our museums and some of our universities. It is unlikely that there will be many expeditions to search the sea bottom such as were made in the Geophysical Year of 1957 and its aftermath, when vessels of several nations discovered many new genera and species.

Brachiopods are relatively simply constructed and functioning animals and consequently much of their evolution is a constant repetition in different stocks of the same feature, both internal and external. Examples of this are the repetition of the spondylium in orthids, strophomenids, and rhynchonellids, the elongation of the ventral beak in the triplesids, terebratellids, and terebratulinids. However, the spination of the productids was never repeated after the Permian.

Many problems remain to engage the future paleontologist: the unravelling of homeomorphy, both internal and external, ecology of modern

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*Numbers given represent the descriptive work of various paleontologists rather than the true number of genera, which will never be known.

brachiopods; the origin of the calcareous shell in the Early Cambrian; were the orthids the source whence sprang the pseudopunctate stocks? Did the orthids give rise to the conservative rhynchonellids and the progressive terebratulids? What stimulated some pseudopunctate brachiopod stocks to produce the productids with attaching, supportive and protective spines? Were punctate shells derived from impunctate orthids or from other stocks? There are many other questions which make brachiopods an ideal group of animals for study as well as for the joy they give in field discovery. Go to it and enjoy them!

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IN PURSUIT OF THE ICY BRACHIOPOD AND BEYOND

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In 1983, I wrote an article entitled "In Pursuit of the Icy Brachiopod". It was serialized in the MAPS Digest in issues from that year into 1984. It was later also published in the Fossiletter in installments spread over various issues in 1984. Most of the information in this article was based on my studies for my brachiopod book (Foster, 1974).

This publication of a Brachiopod volume for the EXPO Edition of the MAPS Digest presents me with an opportunity to reissue this work as one piece--a more satisfactory way to present this particular article than installments. In the process, I have modified it very slightly and added a few of my new observations and ideas concerning brachiopods. The new materials are based largely on specimens loaned me by the U.S. government since my book (see Foster, 1989, for a formal write-up) and specimens from the Atlantic Ocean loaned to me by the French government (unpublished manuscript in progress). The French material was dredged by their expeditions from the vicinity of the Azores and Cape Verde Islands and by SCUBA collecting of Jacques Cousteau's "Calypso" teams off South America.

INTRODUCTION

It never ceases to amaze me how so many Midwestern fossil enthusiasts can have such narrow fossil interests. It is the rare collector who won't turn up his or her nose at a fossil that isn't a skeleton from an echinoderm, cephalopod, complete arthropod, or complete vertebrate. This means that the majority of fossils, including most of the geologically useful fossils, are largely written off and ignored. If these ignored fossils were all common and ugly, this attitude would be understandable. But this is not the case! These neglected fossils include numerous taxa with aesthetically beautiful skeletons. Rare species and rarely preserved skeletal structures abound in these fossil groups. A particularly noteworthy member of this rather unpopular portion of the fossil world is the phylum Brachiopoda. The brachiopods rank near the top with regard to beauty, long geological range, and importance to the science of geology. I believe many Midwesterners are prone to undervalue brachiopods because these fossil hunters live in what is probably the richest fossil brachiopod area in the world. In addition, they usually don't know which brachiopods and which brachiopod structures are rare.

I was fortunate enough to be raised in California where fossil brachiopods are rare and, when found, difficult to extract from the rock. As a result, I have always had a fondness for brachiopods. I vividly remember as a young man in California drooling over such Midwestern brachiopod goodies as the Ordovician orthides, strophomenides, and rhynchonellides from the Cincinnati area or the Devonian spiriferides from Rockford, Iowa and Silica, Ohio. I like all fossil groups to some degree. However, I do like some fossils much more than others. My favorites have included the traditional Midwestern favorites. Nevertheless, brachiopods and a number of other less popular groups have also always stood near the top of my favorites list.

I started my serious fossil research focusing on trilobites, brachiopods, and receptaculitids. In the 1960's, I realized as various other paleontologists have, that biologists were only making a limited number of the kinds of observations on Recent invertebrates that we needed in order to more fully understand ancient invertebrates. In fact, every year it seems that biologists pursue fewer and fewer of the kind of studies we paleontologists need as an ever increasing number of their ranks devote more and more time to biochemistry and medicine. For example, at the university where I teach, geology majors know more basic biology and how to recognize the major kinds of animals and plants better than biology majors. If paleontologists want adequate information about living organisms to use in their fossil studies, we will usually have to go get it ourselves. Since brachiopods are the only group of the three fossil groups I started studying to still live, I have devoted particular attention to them in the ensuing years. I have studied and am studying Recent brachiopods from the northeast Pacific, New Zealand, South America, Africa, Antarctica, and the Central Atlantic. My most comprehensive work to date has dealt with cold water brachiopods living south of 40° south latitude. This is the research I intend to discuss in this account. Time and space limitations prevent me from covering many of my adventures, observations and conclusions here, but I will try to relate the ones that still linger uppermost in my memory.

INTRODUCTION TO ANTARCTIC RESEARCH

I undertook my study of the brachiopods of the far south with the unwritten understanding that the U.S. National Museum had extensive unstudied collections from all over the area that I could work with. To my horror, after I had fully committed myself to the project, I found out that all they had were a few tiny collections from a limited number of localities. I was therefore forced to go into the frozen waters at the south end of the world and get and study my own brachiopods. This adventure turned out to be one of the most exciting parts of my research, but was also the most dangerous, time-consuming, and nerve-wracking. It provided an opportunity to visit some of the most beautiful locations in the ocean and to see and collect live brachiopods in their environmental settings.

Research Cruises.--My research vessel was the U.S.N.S. "Eltanin". The "Eltanin" was a small tanker that had been refitted for scientific research in the ice-filled polar seas. In refitting this boat, they had strengthened the hull, put in machinery for raising and lowering devices into the ocean, and added various sophisticated electronic gear for satellite navigation and bottom determinations. For some reason the government also built a large platform for helicopters on it at one end at great expense. This platform was never used because helicopter operations proved too expensive and unimportant. So this monstrosity just took up space that could have been much better used for some other purpose. On the bright side, the deck did serve as a nice platform for viewing and photographing sea birds such as the albatross on otherwise boring sunny days in the open sea. The "Eltanin", to my knowledge, is the only U.S. research boat to ever make relatively comprehensive oceanographic studies of one region over an extended period of time. The Russians did this regularly! Unfortunately this boat's activities were influenced over much by what types of scientific parties were on board. They were also unusually restrictive in who could go on the boat. As a result, on some cruises, many important studies such as those on bottom animals were neglected. Finally, before it had even finished three-quarters of its studies circumscribing Antarctica, the U.S. government loaned the boat to Argentina. We now have the "Eltanin" back, but it seems doubtful that it will ever go back into service again. It grieves me that the government made so little of what was a golden opportunity to advance all sorts of scientific areas of research.

The "Eltanin" was staffed by the U.S. Military Transport Service. They rotated the captain regularly which greatly hampered operations on some cruises if the new captain lacked polar experience. For example, on my second cruise we had a captain whose prior experience consisted of cruises in warm water areas such as the U.S. to Saigon run. He had apparently never seen ice before. As a result, he would undergo nervous shock whenever we got in or around ice and would avoid going into and operating in ice-filled areas. Since these areas make up most of the sea around Antarctica, his behaviour really hampered our dredging operations. I must admit that I did have a bit of sympathy for his attitude. On my first Antarctic cruise, the sound of ice scraping against the ship's hull a few inches from my bunk made me a bit uneasy as I realized that if the boat sunk due to ice, I wouldn't live more than a few minutes in the subzero water.

I made two different cruises on the "Eltanin" to the seas between New Zealand and Australia, and Antarctica. Off Antarctica, most of my direct study was in the Ross Sea. Each of the cruises took place in the Antarctic Summer (December to March) and lasted approximately three and one half months.

Problems on Research Cruises.--Going on an "Eltanin" cruise was a real eye-opener with regards to government inefficiency and waste. Long before I went on each cruise, the government requested that I send them a list of the supplies I would need. I did this promptly before each cruise. My request always included large numbers of specimen containers and large quantities of ethyl alcohol. Both times I went on the "Eltanin" my supplies never arrived. So I had to make due scrounging up old chemical containers and preparing buffered formalin from the supplies of other scientists. On the cruises I accompanied, there were only one or two scientists along to collect and preserve the biological specimens that were collected. I was told that on many cruises there was no one. I usually ended up helping to collect and preserve a representative sample for the Smithsonian besides doing my own work. There was never enough manpower, time, preservative, or containers to collect more than a small fraction of the biological material that was dredged. As a result, tons of valuable dead or dying invertebrates were shoveled back over the side of the boat. This material also often included hundreds of tiny brachiopods I wasn't given time to pick out. This was a terrible waste of animal life, scientifically valuable material, and thousands of dollars of tax money. I am still bitter about having to shovel back over the side, because of insufficient time, thousands of large and small brachiopods at one station off the Antipodes Islands. Yet on that same cruise, the NSF representative and a New Zealand bird watcher wasted a large amount of money and time running the boat back and forth off another island while they argued as to where to land to look at penguins. I shudder to think about what happened on cruises where students of the invertebrates were not present.

I discovered that the "Eltanin" tried to avoid dredging on rocky bottoms. Yet these are the very bottoms most brachiopods seem to prefer. If other boats have had this same bias our modern brachiopod samples may be more limited and unrepresentative than we realized.

Nearshore work off Antarctica was always hellish for the conscientious bottom invertebrate investigator. The sun never set - it just went down to the horizon. Therefore the boat operated around the clock. Many scientific parties would cease operations in shallow water thus causing the remaining operations to operate much more frequently. Finally, the water was so shallow that it wouldn't take long for dredges and grabs to go down to and return from the bottom. As a result, I would have little time between dredges to separate, study, photograph, and preserve specimens. In addition, the amount of material collected in each operation was far greater than in deeper water operations. For days on end, I would get little sleep and few formal meals during the nearshore operations. These times were made particularly frustrating by the fact that this was also when the best scenery was visible and the most fascinating live creatures were available.

In striking contrast to the nearshore operations, the deep water time was usually pure boredom. Many different scientific parties operated, it would take many hours for each of them to lower and retrieve their gear from the deep ocean bottom, and our dredging and grab operations would yield few, if any, animals. I might go as long as 18-20 hours between operations. There was now virtually no geological scenery although there were nice sunsets, striking cloud formations, and an occasional intriguing solitary wandering albatross.

On one cruise, a Russian whaling boat came close to ramming us. We would have collided if the "Eltanin" hadn't made a very quick 180° turn. We still only missed contact by inches. I don't know whether this was rank stupidity on the Russians' part, just part of normal Russian intimidation of U.S. government vessels, or whether it was intimidation because they thought we were a spy boat monitoring them for naval information or because they were engaged in illegal whaling practices. This incident was never reported to the United States public. I mentioned it once in a public talk in Peoria some years ago and one member of the audience virtually called me a liar and didn't believe the Russians were capable of such things.

The primary United States base in Antarctic, McMurdo, and its personnel was rather revolting. The first sight you saw when you come into the base was a disgusting mountain of garbage that dominates the harbor edge. Above it were numerous noisy skuas (a seagull-like bird) looking for tidbits. The U.S. servicemen seemed bitter at being located there and appeared to spend most of their time drinking, complaining, or watching movies. The nearby New Zealand base and its personnel were a striking contrast to the U.S. Their station was small, spartan, and neat -- their volunteer personnel spent much of their free time hiking or skiing while enjoying the glorious scenery and listening to classical music. On one of our visits to McMurdo we encountered the first tourist boat to ever visit Antarctica. It had gone onto the rocks while entering the harbor, but was pulled off without much damage several hours later by a U.S. icebreaker. It seemed strange that the people on this boat were paying $8,000 - $10,000 apiece to see what the U.S. servicemen couldn't wait to escape!

<u>Delights on Research Cruises</u>.--Despite the many problems and unpleasant situations, my cruises were very worthwhile with many enjoyable treats. My brachiopod collections were fantastic compared to those made any other previous expedition. For example, on just a single cruise, I collected more brachiopod specimens than the famous "Challenger" expedition did in three and one half years. The scenery in many parts of Antarctica is breathtaking. In places, I saw giant fields of icebergs or pack-ice or both stretching across the sea as far as the eye could see. Few sights can compare to Victoria Land with its enormous jagged peaks rising right out of the sea and cut by enormous glacial rivers of ice.

The benthic animal life is beautiful, varied, and bizarre. Contrary to popular legend, the Antarctic animals are not drab compared to their colorful tropical kinfolk. In fact, they often equal or exceed their warm-water relatives in delightful color and pattern. The variety and dominance of echinoderms is particularly noteworthy. Dredge hauls include and are often dominated by large numbers of asteroids, ophiuroids, holothuroids, and crinoids. I can still remember the thrill of seeing virtually the entire deck covered by writhing stalk-less crinoids. If only I had had the time and a motion picture camera! The Antarctic glass sponges surpass those anywhere else in the world in diversity, size, and abundance. Three to six foot tall glass sponges can excite even the most blase palate. Virtually every trawl sample was loaded with glass sponges and their silica spicules. Their presence made picking through trawls a tiny bit painful. It took me almost a year or so to get all of the spicule fragments out of my hands.

For those used to the tiny obscure pycnogonids ("sea spiders") of temperate waters, the Antarctica shelf hold a wonderous surprise. Here most of the pycnogonids are very conspicuous and some get to be fifty times as large as typical temperate forms from the Northern Hemisphere. Some of the isopods here get to be as large as small lobsters.

The birds and mammals can give much pleasure to the Antarctic traveler. I never tired of seeing small pieces of ice floating by bearing small groups of erect attentive penguins in their evening suit-like garb. Often when we anchored off large islands, in a short time, a score of small penguin heads would pop out of the water near the boat to look us over. Seals seem nearly as numerous as penguins in the parts of Antarctica we visited. However, they seem much lazier than the penguins. Whenever I saw them they were sleeping on the ice. Near McMurdo Station, there were hundreds sprawled across the ice. Man has made a very big dent in the whale populations that used to swarm around Antarctica. We were still able to see whales on at least two different occasions. Once along the channel leading to McMurdo Station, I saw a couple of killer whales prowling the ice edge in hopes that a penguin would get close enough on the ice that a whale could knock it off. My favorite encounter took place in the open ocean when the "Eltanin" stopped to lower equipment. A group (pod) of about a dozen small whales came in and surrounded the boat. Every so often, two or three would hold themselves erect with their heads out of the water. It seem rather touching and reminded me of a pack of rather strange, but friendly, curious dogs.

After we had been at sea several weeks we had virtually no problems with ailments such as colds and flu. Apparently once viruses or bacteria had run their course, there were no new human carriers to infect us.

The food on the boat ranged from good to excellent. My mouth still waters from thinking about having all the Australian lobster tails I could eat. There were also many good movies available on board.

RESULTS

Are Brachiopods Near Extinction Today?

Recent brachiopods are often regarded as a very insignificant or rare portion of the modern benthos (bottom-living organisms) and to represent a low point on a brachiopod decline that has been going ever downward since the end of the Permian. Barnes (1968) in an earlier edition of a popular textbook on invertebrate zoology stated that brachiopods are "...apparently on the road to extinction." My own work suggests that these popular ideas are incorrect. Brachiopods today are at a lower level with regards to fundamental variety and numbers, particularly in warm shallow water, compared to where they were in the Paleozoic. Nevertheless, they are still doing quite well and were not declining through the Mesozoic and Cenozoic. In fact, there is no convincing evidence that they are not doing as well or better today than they did in say the Jurassic. On my two cruises to Antarctica I collected over 12,000 live brachiopods and over 10,000 empty brachiopod shells. These were taken from only 89 small successful bottom trawls and 23 tiny camera grabs. Eighty-eight percent of the bottom trawls and sixty-five percent of the camera grabs contained brachiopods. A single small trawl made for a short time off Macquarie Island yielded over 6400 live brachiopods. It should be noted that in these operations, hard bottoms, the brachiopods favorite substrate were avoided. At nine different localities, brachiopods were the dominant or one of several dominant members of the macroinvertebrates. In the Ross Sea, they seem to be almost as diverse and numerous as bivalved molluscs.

Taxonomy and Its Problems

Introduction.--Some professional paleontologists and possibly even more people who are not professional paleontologists but who have to deal with fossils have become very concerned about the rapidly increasing number of narrowly and often ill-defined species and genera. To make matters worse, paleontological works seldom include keys, particularly pictorial ones, to aid in distinguishing their genera and species. Immoderate numbers of genera and species present problems in identification, memorization and retention, and general treatment utilizing the taxa.

This problem exists to a varying degree in all major groups of fossils I have investigated, but it seems particularly noteworthy in brachiopods. Most brachiopod workers seem to follow procedures first spelled out in the 1930's by paleontologists with little or no biological background. In these schemes, families were based largely on major differences in the cardinalia (major features in the posterior of the brachial or dorsal valve such as the cardinal process and brachiophores), genera on minor differences in the cardinalia, and species on minor details in the ornamentation and external shell form. There was no provision for characters that show variation within individual species. These workers also seldom reported on studies of large samples of individual species. I first had a serious encounter with some of these problems when I was studying Ordovician fossils from the Death Valley area of California. I etched the fossils out of one small limestone block. It contained over one thousand brachiopods that had been assigned to the same genus. Among these specimens, I could recognize typical specimens of each of the three different species assigned to this genus. However, there were also even more specimens that were unlike any of the recognized species but which formed a continuous morphological series between them. This strongly suggested to me that only one variable species exists and that the other presumed species are just phenotypic variants of that species. This also suggests the genus itself may not be viable since it contains only one species and all its related genera also contain only one species each. This analysis suggests the possible danger in rigid assignment of categorical value to certain characters, to narrow definition of taxa (plural of taxon - def. a particular group of organisms - i.e. we belong to the genus taxon Homo and the species taxon sapiens), and to little or no appreciation of variation within large population samples.

The two categories that I have directed the majority of my concern to have been the species and the genus. Many fossil brachiopod species differ by what seem to be the most trivial differences. They are also often based on a single specimen or only very small numbers of specimens. The genera differ by small, but usually distinct, differences. They often contain only one species

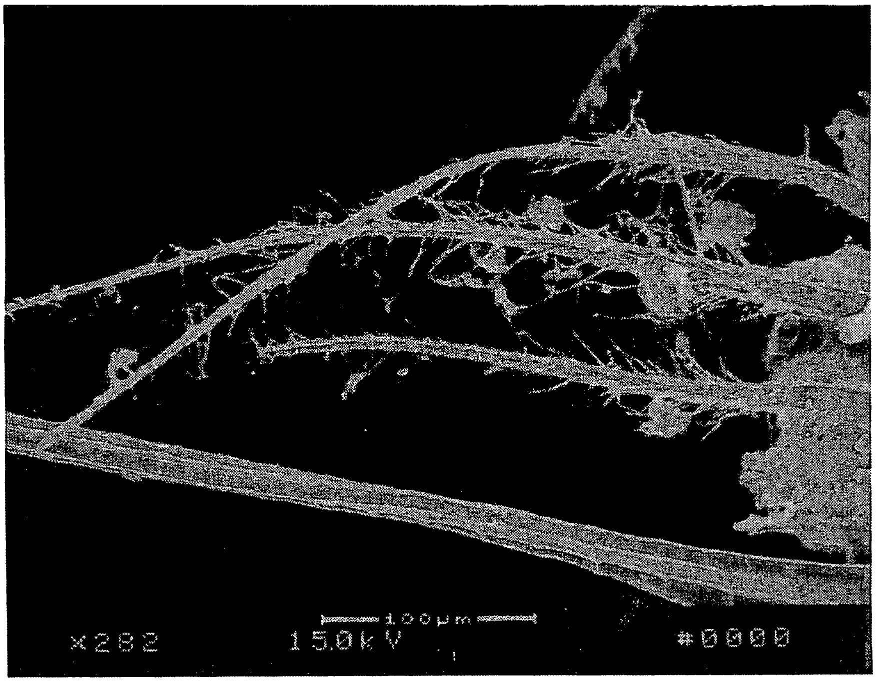

Figure 4 - Pelagodiscus atlanticus. Southwest of Sao Miguel, Azores Islands, 2,900 m. View of mantle edge showing a long type seta and short type setae.

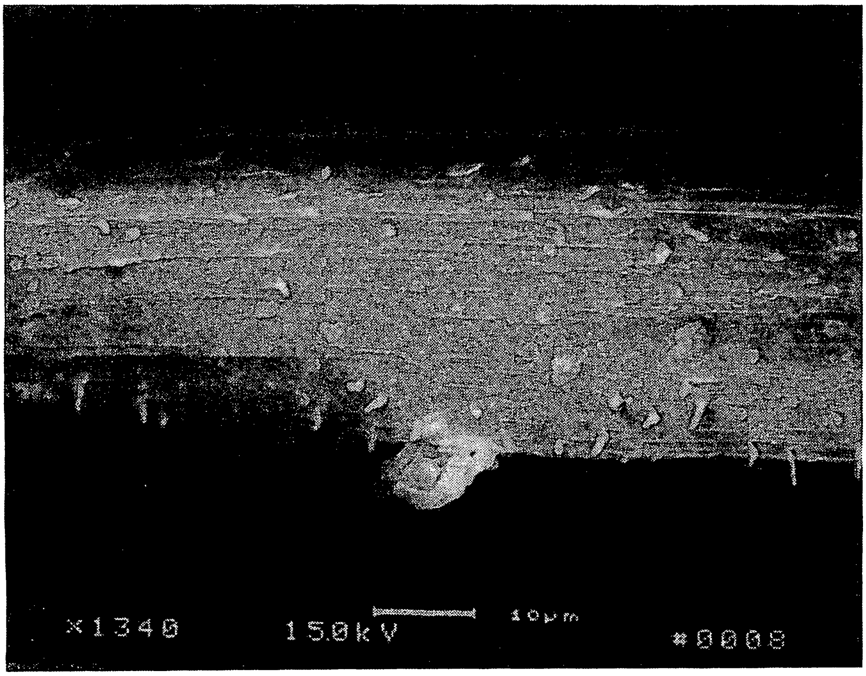

Figure 5 - Same as fig.4 - Close-up of large seta showing the short thorn-like bristles on its surface.

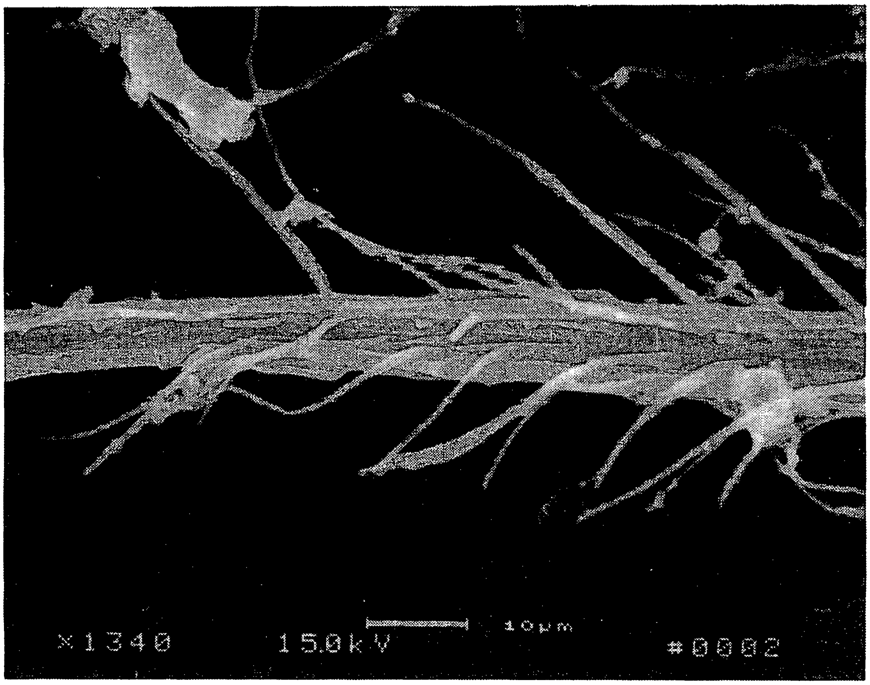

Figure 6 - Same as figs. 4 and 5 - Close-up of a short seta showing long hair-like bristles.

or a few species who often appear to just be variants of a single species. Genera and species are key categories in the long-ranging controversy in systematic biology and paleobiology between the "lumpers" and "splitters". "Splitters" are individuals who are strongly analytical in their approach to organisms. They look very carefully for differences, even minute ones, among different specimens or different groups of specimens. They then use these differences to set up new separate taxa. "Splitters" work hard to prevent inclusion of unrelated or less related individuals or taxa in the same higher taxon. They are usually specialists on one particular taxon that they know extremely well. They usually classify characters rather than groups of organisms. The "splitting" approach normally results in large numbers of taxa and innumerable publications for the splitting scientist. Most paleontologists who specialize in taxonomy and some biologists tend toward this approach. "Lumpers" take almost the opposite tack from "splitters". They adopt a more synthetic approach to the classification of organisms. They may also look very carefully for minute features that may differentiate individuals or taxa, but they don't stress using them to establish new taxa. Instead, they focus on grouping organisms based on their similarities. They tend to believe that too fine a division of taxa leads to an intolerable burden on the memory. They are not quite so worried as is the "splitter" about getting unrelated individuals or taxa included in the same taxon, if the taxon is useful. "Lumpers" tend to be generalists and work on more than one taxon of organisms. They focus on the groups of organisms rather than just the characters. "Lumpers" tend to establish fewer taxa and publish relatively fewer papers than "splitters". Most theoretically-oriented paleontologists and most biologists, particularly those who work on well-studied groups such as birds and mammals, are "lumpers". I personally lean toward this camp. Obviously there are scientists who take intermediate positions between these two views and try to get the most meaningful parts of both views.

The Species.--A large quantity of ink has been devoted to the definition and recognition of the species. There now seems to be a fairly general agreement that it is a group of individuals or populations that can freely interbreed in nature with each other but not with members of other such groups. They usually can be recognized by morphological, behavioural or ecological characteristics that differ from those of members of other such groups. Among well-known modern organisms, careful study can usually establish fairly objectively the validity of species in all but a few situations. Thus, in the present day, the species are, relatively speaking, our most objective taxa. Recognition of fossil species is much more difficult. There are fewer characters to use, often fewer specimens to study, and one can never test breeding behaviour. In addition, few comprehensive taxonomically-oriented studies have been made of modern taxa with significant fossil records.

The Genus.--The genus because of its frequent use, more distinct characteristics, broader geographic and chronologic ranges is probably the most important category in paleontology. It is also one of the greatest taxonomic problems because its recognition always involves some subjectivity. Because of the subjectivity in its recognition it is a key category in the "splitting" vs. "lumping" controversy. In principal, a genus is commonly regarded as a group of species who all evolved from a single ancestral species. A genus like this is said to be monophyletic. One that is not this way is said to be polyphyletic. This definition causes problems because even if we know the total ancestry of some related species, the size of the genera erected and the number of genera established can be quite variable. The further back in time you consider the ancestral species the broader and fewer in number your genera will be. For example, in the following evolution (fig. 1), you can recognize one genus (sp. 1-5), two genera (sp. 1-4 and sp. 5), three genera (sp. 1, sp. 2-4, and sp. 5) or four genera (sp. 1, sp. 2-3, sp. 4, and sp. 5) depending on how far back in time you establish the ancestral species.

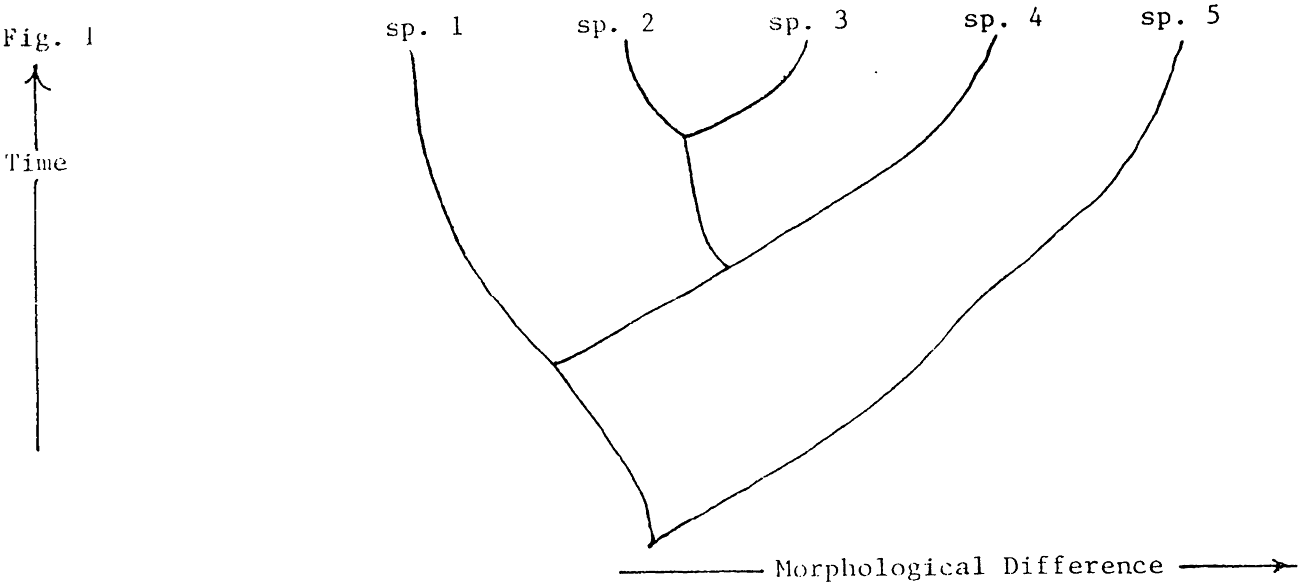

Fig. 1

Where we don't know the ancestry, which is the usual case, the recognition of genera become even more subjective.

The genus problem is particularly noteworthy in the phylum Brachiopoda. The expression of the "splitting" approach is conspicuous here. Most amateurs and many geologists who don't specialize in brachiopods and even a few brachiopod specialists are concerned about what has happened to well known brachiopod genera such as *Dictyoclostus* (now *Dictyoclostus*, *Antiquatonia*, *Peniculauris*, *Pugilis*, *Reticulatia*, and probably a few others) and *Marginifera* (now *Marginifera*, *Eomarginifera*, *Hystriculina*, *Kozlowskia*, *Desmoinesia*, and probably a few others). There has even been a song written by Mankin (1973) expressing one geologist's probable annoyance at the proliferation of brachiopod genera. It is sung to the tune of the "Battle Hymn of the Republic". "Mine eyes have seen the splitting of the genus I adore --It's been slyly subdividing into families galore - and with every publication comes another genus more! The names go rolling on --Look what happened to *Productus* --Oh what happened to *Productus*-- Gad, what happened to *Productus* -- There's

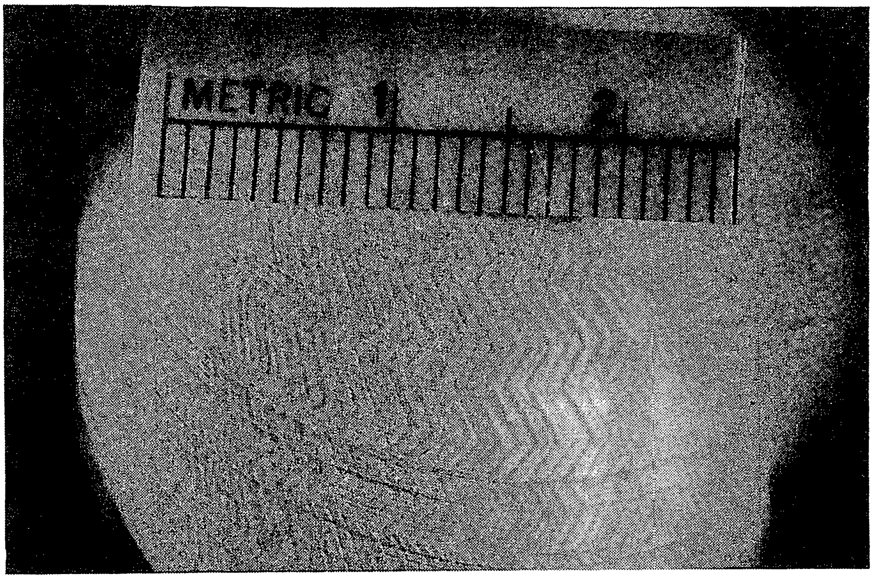

Figure 7 - Dyscolia wyvillei, West European Basin, (550-600 m). anterior surface of the anterior surface of the ventral (pedicle) valve showing zig-zag surface ornament.

hundreds out of one. You play it by the numbers counting every little spine -- And you carefully determine if the ribbings coarse or fine -- But without the cardinal process its an utter waste of time --You can't tell what goes on! -- Is it really true Productus? -- No it cannot be Productus -- Once it would have been Productus -- But now all hope is gone!" Every paleontologist would agree that Productus was too broad a genus and needed to be split up, but to some, including me, it seems to have now gone too far the other way, in this and many other brachiopod genera. Richard Grant (1980) estimated that a new brachiopod genus was being published every four days. He also stated that since the "Treatise" on brachiopods was published in 1965, 1300 additional new genera had been established. This figure is half the total number of described brachiopod genera. He posed the question as to whether this was progress or proliferation. Since he is author or co-author of over 124 different brachiopod genera, I suspect he favors the former answer to his question.

Antarctic Brachiopod Taxonomy.--A major aspect of my Antarctic research was to see what information a thorough study of Recent brachiopod populations might yield concerning the use of a hierarchy of characters in establishing various categories of brachiopod taxa, the recognition of genera and species, and the variations of characters in large populations over a wide geographic area. I was particularly interested in seeing how the "splitting" approach common in brachiopod taxonomy or the less common "lumping" approach would stand up when applied to large populations of living brachiopods in a limited area.

Intraspecific variation.--There is much more variation within modern brachiopod species than is reported for most fossil species. Almost every character varies noticeably within a species. This variation can occur in the same individual at different ages or in different individuals at the same age. Some variants are obviously due to environmental factors. For example, the shell outline of the inarticulate Crania lecointei depends on the size and shape of the attachment surface. One scientist established a new species of Crania for an individual of Crania lecointei with a different outline. Some characters that are believed to be of value in generic determination can vary within a single population. For example, Allan (1939) use disjunct deltidial plates as one of the major characters of his new genus Aerothyris based on Magellania macquariensis from Macquarie Island. However, some specimens from this same species off the Antipodes Islands have conjunct deltidial plates. Some characters change in a regular linear fashion in populations along geographic gradients. This can be seen in Liothyrella uva that ranges in the Pacific Ocean from Panama down the west coast of South America through the islands between Cape Horn and the Antarctic Peninsula to Antarctica (see fig. 2). As one moves southward into colder water the brachiopods in this species tend to have progressively fewer punctae (perforations in the shell wall), thinner shells, weaker spiculation, and a more regular mosaic of the shell wall fibers.

Species Taxonomy.--There is no easy formula for species recognition in Recent brachiopods. Each case must be evaluated on its own merits by using large population samples and taking account of character variation, ecology, and distribution.

Many modern brachiopod species have considerable geographic ranges. These broad ranges contrast sharply with the very limited geographic ranges of most fossil species. I believe that this difference reflects the very narrow morphological definition of many fossil species. The Recent wide-ranging species Liothyrella uva has populations in various parts of its range that differ considerably from each other in morphology (see fig. 2). These differences are due to the separation of the populations and the different environments the populations inhabit which have affected their phenotypes and genotypes. If these populations had been preserved in the fossil record, they almost certainly would have been called different species and instead of one species, there would be at least six. Naming variants as different species can obscure important environmental and geographic information.

On the other hand, some valid species differ from each other by seemingly small differences. For example, Magellania joubini in the Ross Sea is superficially more similar to Magellania fragilis than some of the geographic populations of Liothyrella uva are to each other. As a moderate "lumper" I started my studies with the view that the two species of Magellania off Antarctica just represented variants of one species. However, careful study of many samples over a wide area of the Ross Sea showed that they were different species: Magellania fragilis largely in deep water and M. joubini largely in shallow water. In fact, I discovered there was a similar third species probably assignable to Magellania, M. spinosa (now called Fosteria spinosa by the Russians) primarily along the seaward edge of the Ross Shelf. Thus either the morphological "splitter" or "lumper" may be correct, depending on the particular situation. To assign a priori specific value to certain characters without regard to individual circumstances is completely unwarranted.

Generic Taxonomy.--Because of the subjective nature of the genus, there can be no right or wrong in their establishment. Studies of the modern brachiopod fauna suggest that continued maintenance and establishment of the inordinate numbers of narrow or monotypic brachiopod genera in both the Recent seas and the fossil record is both unreasonable and impractical since these genera are too often the results of uncritical oversplitting or too narrow a definition of monophyly. They convey little information of value that is not already provided by good species and simply overburden the literature. For example, using the standard fossil brachiopod approach, the populations assigned to the living genera Terebratella and Magellania would be split into eleven different genera. Of these eleven genera only one genus would contain more than one species. The broad genera Terebratella and Magellania are not altogether satisfactory, but do play a much more practical role in taxonomy than numerous narrow genera.

Conclusions.--The study of the systematics of the modern Southern Hemisphere brachiopods does not reveal any radical departures from the basic relations seen in most well studied animal groups. They show that we must live with at least a certain amount of uncertainty in our classifications and with many taxa that are not sharply delimited. Tiny morphological differences should be noted and analyzed using as many large samples as practical, but name giving should be controlled in our search for a classification that as Mayr (1969) says "will combine maximal information content with maximal ease of retrieval of this information." The standard hierarchy of character values for brachiopods might do more good if it were shoved down one level so that specific characters became intraspecific characters, generic characters specific characters and so on. However, a priori assignment of categorical value to certain types of characters should not be done.

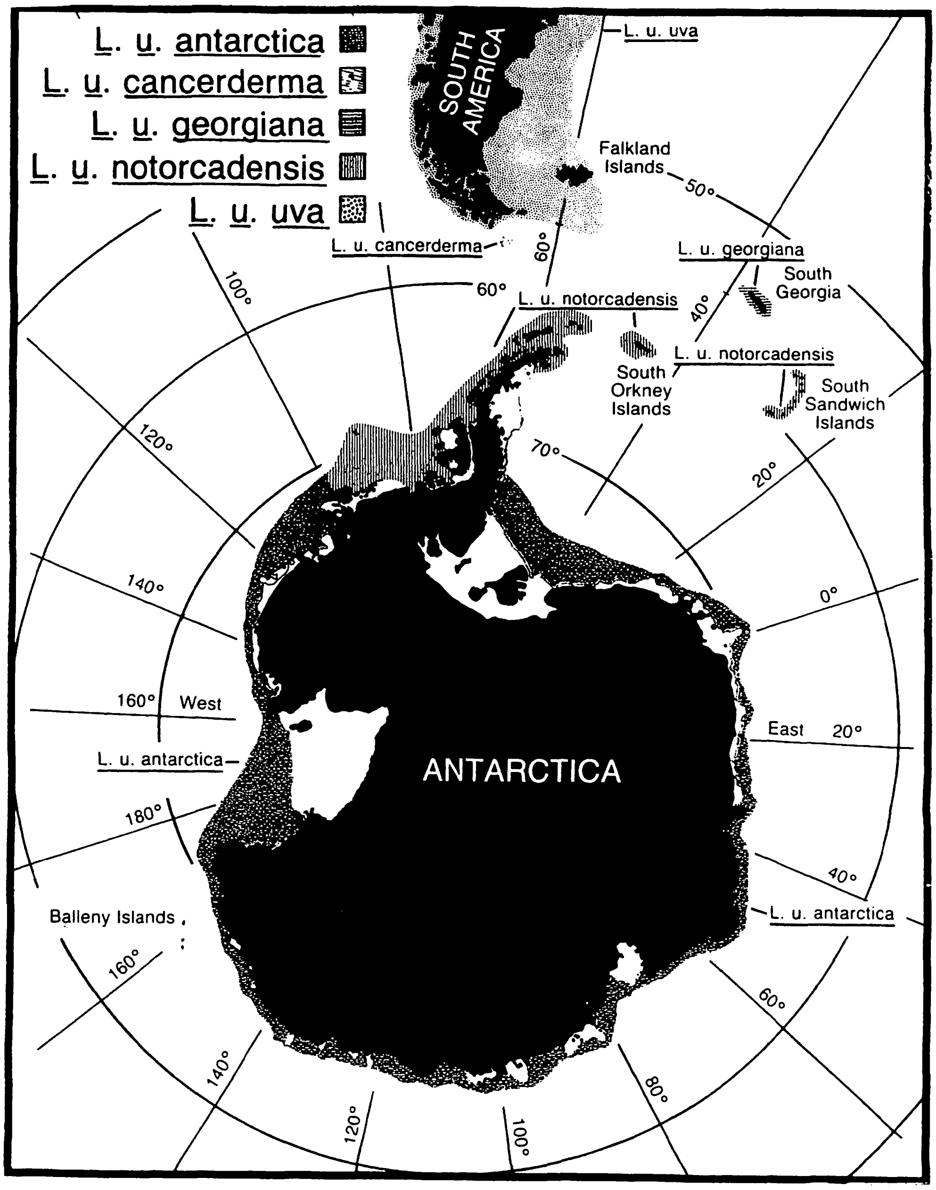

Figure 2 - Distribution of the subspecies of Liothyrella uva around southern South America and Antarctica.
(from Foster,1989)

"Soft part" anatomy at the specific and generic levels in modern brachiopods does little more in most cases than complement the more easily observable differences in the calcareous skeleton. Therefore in the study of fossil brachiopods the lack of "soft parts" does not seem to be the handicap that it is in some other organisms. However, at the family level and higher, "soft part" anatomy appears to have considerable value.

Paleontologists who publish taxonomic works would greatly help both other scientists and amateurs if they would include keys, particularly pictorial ones, in their publications to aid in the identification of taxa. Impractical, hard-to-use taxa benefit no one in the long run and have given a bad name to paleontologists.

Ecology

The southern hemisphere brachiopods have adapted themselves in a number of ways to cold water. The most obvious is reduction in the calcite in their shell and body spicules. Cold water dissolves calcite readily so that it requires an abnormally large energy expenditure to precipitate calcite under those conditions. By precipitating less of it in their bodies and shells cold-water brachiopods conserve needed energy. As an extreme example, the species of Crania in the southern hemisphere greatly reduce or eliminate all the calcite in their pedicle valve. Terebratulides all have fine extensions of the mantle (mantle caeca) extending into the shell material. The holes are called punctae. The function of these caeca are not known with certainty. Some reasonable possibilities are aids in constructing shell and/or repairing damage, inhibitors of shell-boring organisms like bryozoans, and means of secondary respiration when the shell is closed. Campbell (1965) suggested, based on fossil studies, that puncta density was directly proportional to water temperature -- cold water brachiopods having fewer punctae for a given shell area than warm water brachiopods. I made numerous counts of modern brachiopods punctae. They confirm Campbell's contention. However, they suggest a great variability in this feature as well as some species that strikingly differ from the normal condition and may even show the reverse correlation.

Some populations of M. macquariensis that may have evolved in colder water seem to be moving north now, but because of their cold water adaptation they are forced into deeper, and therefore colder water as they move further north into waters with higher surface temperatures.

My cruises off Antarctica enabled me to be the first brachiopod student to discover the calcite-penetrating ability of the brachiopod pedicle in some taxa. Many unexplained pits or perforations in brachiopod shells had their origin this way. We are now finding these rather commonly in both Recent and fossil brachiopods.

A rather mysterious situation was discovered off one of the Subantarctic Islands. Here all I found were empty brachiopod shells. I have seen no other place like this in my travels. This locality was apparently far from strong sources of human pollution so all I could deduce is that a disease or influx of new efficient predators or temperature change totally eliminated the population.

Off one Subantarctic Island, many of the live brachiopods occurred on live "Pecten" shells. Obviously this provides a way that the sessile adult brachiopod could extend their geographic range.

The diversity of brachiopods was greatest near the seaward edge of the Ross Sea Shelf where two different water masses are supposed to meet. This appears to be a good marine example of the ecotone effect that is commonly noted on land. The ecotone effect occurs where two different environments meet. Often this ecotone has a greater variety of species than either of the contiguous environments alone. For example, most bird watchers know that you can see more species where say a field meets the woods than out on the field or in the woods.

Niche.--Since most brachiopods are believed to feed in essentially the same way on minute organisms and/or dissolved organic matter, you would not expect to find more than one species in the same location. For competition would presumably drive out other less well adapted species. This is often called Gause's Principle or the Competitive Exclusion Principle which says essentially that only one species can live in the same niche (have the same way of life) in the same place. The brachiopods seem to follow this principle. Wherever a species reaches large size and numbers it is usually by itself -- and conversely a great diversity of species at one spot only occurs when they are all small in size and in small numbers (not flourishing). However, there are spots where two species seem to be flourishing together. Where that occurs, the two are normally very different in morphology. For example, Magellania fragilis occurs regularly with Macandrevia vanhoeffeni. They have distinctly different musculature and pedicle foramina (one round - the other slot-like). This suggests that some brachiopods may have different niches (that is they feed or move differently) and hence can flourish together. Thus, in fossil samples, where many different species of the same genus are reported together in large numbers at the same horizon, the species taxonomy may be suspect.

Progenesis

The Ross Sea brachiopods in many populations seem to illustrate progenesis. Progenesis is precocious (early) sexual maturation of an organism still in a morphologically juvenile stage. Much of the Ross Sea bottom contains only widely scattered hard objects amongst the mud. Most of the objects are not large enough to permit attachment of large brachiopods who would normally be the only ones sexually mature. As a result, to live and reproduce successfully in broad areas of Ross Sea, the brachiopods have had to change the timing in their development so that sexual maturity occurs at an early stage of overall morphological development when the animal is small. This change occurs in some population of species who may mature normally in other areas (i.e., Liothyrella uva, Magellania fragilis, Magellania joubini) or may occur in all populations of other species (i.e., Magellania spinosa, Amphithyris halletensis).

Surlyk (1974) has since observed a similar situation in some brachiopods in the Cretaceous chalk of Denmark. I have also observed a possibly similar divergence of various southern hemisphere brachiopod taxa.

Paleozoogeography

The fossil and modern brachiopod evidence suggests that most of the southern hemisphere continents have been separated from one another, at least since the Early Cenozoic. A few species may have spread more widely to some islands during the Cenozoic by chance dispersal in a current system called the Westwind drift. South America does appear to have and have had some connection during the Cenozoic with Antarctica so that some species or closely related genera occur off both continents. The Pliocene or Pleistocene chilling appears to have eliminated or forced north various taxa that formerly inhabited Antarctica, New Zealand, and South America. Those taxa that survived in more northerly areas have been unable to return because of deep water barriers or continued inhospitable water temperatures. The present fauna thus consists of cold-tolerant older elements and Recent cold-tolerant immigrants such as Macandrevia. A few cold-tolerant species that evolved in the subantarctic region seem to be spreading northward, but as they do so they are moving even deeper to maintain their optimal water temperature.

NEW THOUGHTS

Geographic Distribution

The traditional view of brachiopod distribution is one of species living on the shallower continental shelves or in very deep water of the abyssal floor. Their dispersal is usually envisaged as movements within these areas or shallow species crossing deep-water "barriers" by sweepstakes dispersals. These ideas are probably true for a majority of brachiopod species, but do not represent the situation for all brachiopod species. Some shallow water species may also be able to cross deep-water barriers by establishing a few very deep water populations in the intervening abyssal area which is generally unfavorable to them. Macandrevia americana may be an example of a species with such a strategy. It normally occurs on relatively shallow continental shelves, but a few populations have been found in much deeper water locations between shallow shelf locations. Some brachiopods are distributed on the tops of seamounts, oceanic ridges, and oceanic rises that are at only moderate depths compared to the very great abyssal depths around them. The Russians call these regions thalassobathyal. These areas may serve as stepping stones for dispersal of shallow-water brachiopods across generally unfavorable deep regions. They may also form barriers to the distribution of abyssal brachiopods.

Progenesis

Additional work has strengthened my supposition that progenesis is a common adaptive strategy among brachiopods living where hard objects for attachment are small and few in number or where space is limited between the branches of arborescent "stony corals" dominating an area. As one might expect, this strategy is particularly common on very deep bottoms where a soft substrate is usually the rule. The progenesis can happen rapidly without significant genetic change in different populations of a single species or slowly in a substantial and long term manner involving the evolution of totally new species or even new genera.

Anomalous Species

Some taxa of brachiopods have one or more anatomical features that seem to set them apart from the majority of brachiopods. These features suggest that these brachiopods may have behaviours and life styles that are rather unlike those of typical brachiopods. Two taxa, Pelagodiscus atlanticus and Dyscolia wyvillei, seem particularly unusual among the brachiopods I am currently studying.

Pelagodiscus atlanticus.--Pelagodiscus atlanticus (see fig. 3) is probably the most famous known deep water brachiopod known. It can exist at depths exceeding 7,460 m. It is also probably the most widespread geographically (cosmopolitan) of the living brachiopods being found in deep water areas of the three "oceans" all over the world. My current research has revealed some interesting morphological features (presumably adaptive) in this species.

Most brachiopods of all geological periods have edges of the dorsal and

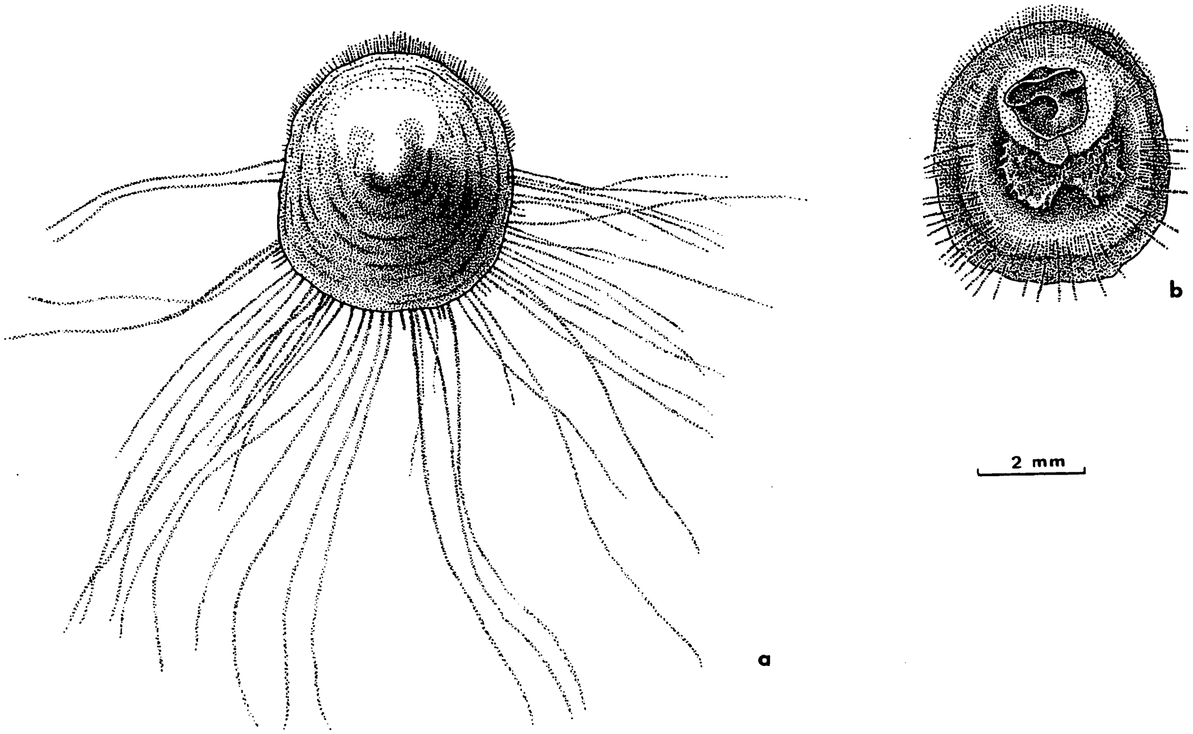

Figure 3 - Pelagodiscus atlanticus. Off Antarctica,(a)2,507- 2525m) Dorsal view of shell. (b) Ventral view of shell (long setae only partially shown). (from Foster, 1974)

ventral valves that meet when the shell is closed. The only well-known exception to this were the extinct oldhaminidine strophomenides who seem to have had their acme in the Permian Period. The living species Pelagodiscus atlanticus also shows this unusual feature. The dorsal valve has a larger circumference than the ventral valve leaving a gap between the valves when the shell is closed. This gap doesn't leave the animal completely vunerable. In preserved specimens the dorsal mantle edge is not at the anterior extremity but toward the interior and almost opposite the ventral mantle edge. A similar position in life would have largely protected the dorsal mantle. The rather dense small setae along both mantle edges form a grill over the gap that could very well be protective. Finally, since the ventral valve lies directly against the substrate, clamping down of the dorsal valve against the substrate would result in protection of the shell interior. Perhaps one or more of these devices have allowed the animal to be largely protected from the consequences of having a gap. The gap itself is possibly an adaptation to save some of the metabolic energy of shell formation in a resource - poor environment. The gap could also allow the animal to run currents through the mantle cavity without opening the shell.

Pelagodiscus atlanticus has the largest array of mantle edge setae of any living brachiopod with which I am familiar (see fig. 4). There are two main types: large setae (see fig. 5) and small setae (see fig. 6). The large setae are distinctly longer and wider than the small setae. They are more rigid than the small setae, have more distinct joints and are covered with rows of short thorn-like bristles. There are two sizes of large setae. The larger large setae can attain a length twice that of the shell. They are only on the dorsal mantle edge. The smaller large setae tend to have lengths approximating that of the shell and occur on both mantle edges. The small setae are more flexible, have indistinct joints, and have bristles that are longer, thinner, and more hair-like than those on the large setae. They all lack bristles at their proximal ends and a few have no bristles at all.

Pelagodiscus atlanticus possesses longer setae and lophophore filaments relative to shell size than in any other known living brachiopod. The long setae were previously mentioned. The lophophore filaments can extend beyond the shell a distance that exceeds or equals that of many of the small long setae. These projections extending beyond the shell circumference suggest that this species has a much broader sensory field and possibly broader feeding area than that in other known brachiopods. Long sensory projections are known in some vagile deep water animals, but have not been described for sessile deep water animals such as brachiopods. Perhaps predation is so intense in the very deep water favored by this species that an expanded early warning system to detect the approach of potentially harmful organisms is advantageous. The very long lophophore filaments could possibly also manipulate currents or extract dissolved organic chemicals and nutriment particles at some distance from the shell and simple lophophore and thus reflect feeding adaptations required for life in the deep nutriment-poor water.

The existence of right- and left-handedness is a rather common phenomenon in the biological world. Most of us know about it in humans and many of us know about it in biological entities such as gastropods, foraminifera, and amino acids. Pelagodiscus atlanticus exhibits a similar phenomenon. In some specimens, the left posterior oblique muscle passes dorsal to the right posterior oblique muscle--in others it passes ventral to the right posterior oblique muscle. These two opposing conditions were observed in approximately equal numbers of specimens. To my knowledge, this is the first example of handedness to be observed in brachiopods.

Dyscolia wyvillei.--Dyscolia wyvillei, which reaches a length of at least 60 mm, is probably the largest living brachiopod, known to occur at moderately great depths (known range: 550-600 - 1922m). Some specimens of the relatively enormous species Magellania venosa can occur at depths comparable to those inhabited by D. wyvillei, but they do not seem to reach their large size at those depths.

Papillae occur at the mantle margins in D. wyvillei, but have not been reported there in other brachiopods. Muir-Wood (1959) thought the papillae were hard denticles in the shell material, but my observations suggest they are just soft part features which may contain spicules. They tend to alternate in position between the two mantles so that, with their setae, they can form a grill when the shell is open slightly. Muir-Wood's (1959) suggestion that they serve for protection of the shell opening seems quite plausible based on their form and location.

Dyscolia wyvillei exhibits surface ornament with capillae that often show a strong zig-zag pattern (see fig. 7). A few bivalve mollusc taxa show a weaker zig-zag pattern that is somewhat similar. The function, if any, of this zig-zag pattern is unknown. The capillae are probably too low for this pattern to have any obvious effect on shell strength although this still may be a possibility.

This species is noteworthy in both its apparent nervous system and in its spiculation. The mantles each contain approximately 25 very distinct branching and partially anastamosing fibers (see fig. 8). My presumption is that they are nerves, but I have never seen them so distinct before in brachiopods. Dyscolia wyvillei has the most widespread spiculation I have ever seen in a brachiopod, particularly in one of this size. It has spicules in every structure that has ever been reported to contain spicules in brachiopods. It even has spicules in the stomach and esophagus which have not been previously known to bear spicules in brachiopods. The reason or reasons for the seemingly anomalous nervous system and spiculation are currently unknown.

The lophophore in this species is unusually small compared to the size of the mantle cavity (see fig. 8). I could not compute the volumes of these features because of a paucity of specimens to permit the destructive procedures that would allow these calculations. However, I could compare the relative areas of the lophophore as projected into the commissural plane and the brachial valve interior in the commisural plane. These measurements are still crude because of the contracted nature of the lophophore and its filaments caused by preservation without relaxation. This situation is normally the rule with modern preserved brachiopods. The ratio of lophophore area to brachial valve interior area in Dyscolia wyvillei at a length of 47.1 mm is approximately 1:20. The same ratio in Magellania venosa (length = 73.1 mm) from the northeast coast of Argentina is 1:1.5. In Terebratulina unguicula (length = 18.5 mm) from off Washington state the ratio is 1:2.4. Liothyrella neozelanica (length = 38.1 mm) from off New Zealand has a ratio of 1:5. This ratio would undoubtedly be higher if the volume of the lophophore and mantle cavity could be determined. In addition, the lophophore is essentially a schizolophe, an unusually simple lophophore which is essentially a ring of filaments indented anteromedially. This type of lophophore has not been reported in other adult brachiopods anywhere near the size of D. wyvillei The dimensions of the lophophore relative to shell size appear to decrease with increasing size. The disproportionate size and simplicity of the

Figure 8 - Dyscolia wyvillei. South of Terceira, Azores Islands, dorsal valve interior showing the tiny lophophore and possible nerves.

1 cm

lophophore suggest that at least in large adults of D. wyvillei it may not be a major organ of nutriment extraction and sorting. It may function largely as a current generating structure. Perhaps this species does not feed in the normal suspension feeding mode of brachiopods and instead extracts large animals from the incoming water. The strikingly large mouth with folds in this species may reflect this. Perhaps the unusually distinct nerves may also be related to this mode of feeding. Another possibility is that this species extracts dissolved organic matter through its mantle surface. It would thus feed in a manner proposed by McCammon (1969). A final possibility is that it feeds on or contains mutualistic chemosynthetic bacteria and thus has no need for a typical lophophore. Many specimens are found not far from oceanic ridges and others are in positions that could be near fracture zones. Both areas often have hydrothermal vents. Bivalve molluscs in the vicinity of vents are often unusually large. Campbell and Bottjer (1975) speculated that the largest known Mesozoic brachiopod, the Cretaceous rhynchonellide genus Peregrinella, might be a cold-seep restricted brachiopod. It could have fed on bacteria or other organic material, or had a mutualistic relationship with bacteria, or both at an "undersea oasis". They pointed out that brachiopods have not been considered typical of hydrothermal vent or cold-seep settings nor have they been known to harbor mutualistic chemosynthetic bacteria. I think Dyscolia wyvillei may be a likely modern candidate for this type of adaptation. We need, however, to make bacteriological studies of fresh or even live specimens of D. wyvillei and learn more about the exact locations of vents or seeps in relation to the occurrences of this brachiopod species. Knowledge of their living behaviour would also allow us to test my other conjectures regarding their feeding behaviour.

The Origin of the Azorian Brachiopod Fauna

The Azores Islands are located near the middle of the Atlantic Ocean close to the Mid-Atlantic Ridge. The present ocean circulation charts show the surface currents in this area coming from the west. Thus one would expect the brachiopod fauna to have the closest ties to brachiopods in the western Atlantic. This is emphatically not so! The Azorian brachiopods have similar and identical taxa to those in the eastern Atlantic and Mediterranean. This same anomalous situation is also seen in marine fish (Briggs, 1974). This evidence suggests our understanding of oceanic circulation is inaccurate or that currents have changed direction during the Cenozoic or that sea floor spreading has had a major affect on animal distribution in this area or some combination of these.

SUMMATION

I started studying living brachiopods with many questions regarding all aspects of their biology. As my studies have progressed, even more questions have come to mind. I have been able to completely answer a few questions, to get partial or tentative answers to a moderate number of questions, and, for the moment, no satisfactory answer to a large number of questions. Thus, there is much more to be learned about living brachiopods and even more to be learned about their myriad of ancestors as they evolved in a multiplicity of ways via enormous numbers through hundreds of millions of years of earth history.

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Platystrophia THE BRACHIOPOD GENUS FROM THE UPPER ORDOVICIAN OF NORTHERN KENTUCKY AND SOUTHEASTERN INDIANA

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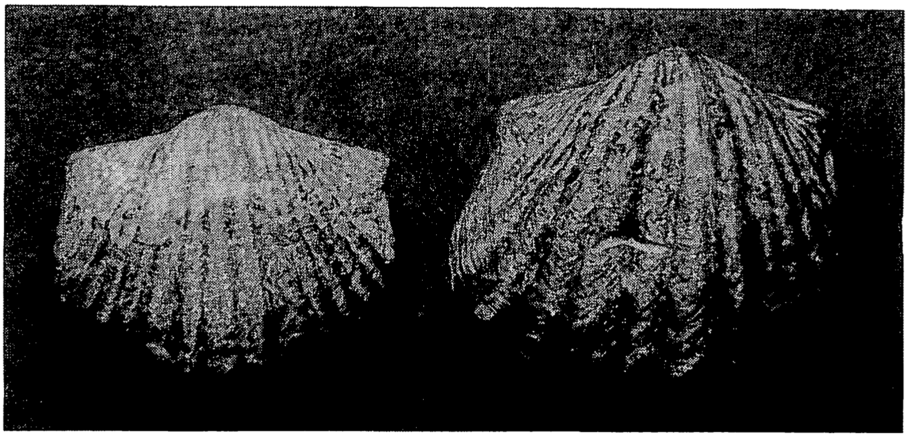
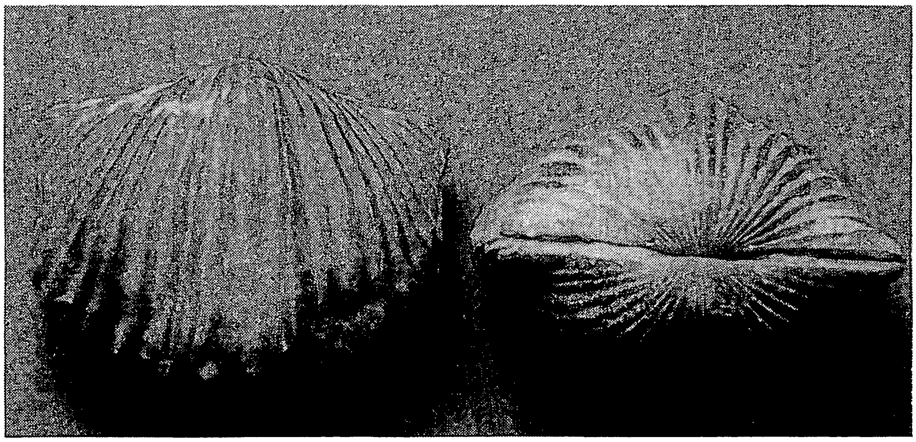


P. ponderosa, two specimens from the Majors Rock Shop in Sligo, Kentucky



P. ponderosa, two large specimens collected at Fort Mitchell, Kentucky. Length along hinge, left specimen 45 mm, right specimen 43 mm.

THE BRACHIOPOD GENUS PLATYSTROPHIA FROM THE UPPER ORDOVICIAN OF NORTHERN KENTUCKY AND SOUTHEASTERN INDIANA

INTRODUCTION

An avid fisherman for many years I was introduced to fossil collecting on April 15, 1958. My son, a student at Illinois State University called to say they needed some boxes, newspapers and hammers, they meaning some of his instructors and fellow student. I was to meet them on the morning of the 15th at Braidwood, Illinois to collect Mazon Creek plant fossils. I was hooked, from then on fishing was to be a shared time project with rock collecting for his geology studies. Shared time was collecting from the mine dumps in the northland iron mines of Minnesota and Michigan. Then a new course in Oceangraphy took him to the Bahamas and the Gulf Coast of Florida to study sea life, among them sea shells. Specimens he brought home started a new interest. In the meantime field trips to Madison in southeast Indiana brought to our attention many other fossils including brachiopods.

Paleontology offers a choice of many interesting creatures to study and I decided early on that brachiopods were very appealing to me. However, I have a broad collection of other invertebrates plus petrified wood and plant fossils. Among the brachiopods the genus Platystrophia is well represented in northern Kentucky and to a lesser degree near Madison, in southern Indiana. Its numbers and varieties make it an interesting species to collect and study.

HISTORY

In her introduction to her book, *A STUDY OF THE BRACHIOPOD GENUS PLATYSTROPHIA,* Eula Davis McEwan writes, " The brachiopod genus Platystrophia is of interest because of the abundance of its species and the great variation exhibited in their development. Early investigators differed considerably in the relationship of this group of brachiopods and referred its species to *Terebratulites, Terebratula, Porambonites, Atrypa, Spirifer* and *Delthyris.* The peculiar granular surface and general outline of the shell led most early writers to refer its species to *Spirifer* and *Delthyris* , but the intimate structure is clearly distinct from all these genera."

In 1848 Davidson showed the internal structure of this group of shells to be *Orthis* with several of his fellow investigators agreeing with his interpretation. In 1850 King proposed the name Platystrophia for this group of *Orthids* and used *Terebratulites biforatus,* Schlotheim, 1820 as his type species. King's name did not come into general use till after 1883. Thus a new genus was born.

DISCOVERY

While on a trip to Sanibel Island, Flordia to collect sea shells in 1960 , we found the Major Rock Shop in the small town of Sligo, Kentucky. We stopped to shop around and soon found a box of excellent specimens of Platystrophia ponderosa. After selecting two specimens and talking to the owner Raymond Prewitt he told us he would be glad to show us his collecting site. since we were traveling we suggested a later date. This brought us back to Sligo on September 4, 1960 and the source of his fossils.

The location is a short distance from Sligo. North on Hwy. 42 to county road 157, turn right to Sulphur, left to a double road cut, one for the road and one for the L& N Railroad, that runs parallel to the road. Fossils were abundant and included several species of Platystrophia with Hebertella, Rafinesquina, and several species of bryozoa. In the years that followed we returned here on 5/29/71, 5/28/73, 3/23/75, 5/31/75, 4/18/76 and 5/15/83. In the seven trips we made here we never encountered another collector.

On 3/25/75 while returning home from Sulphur we followed that road East to Hwy. 421, then North about 4 miles South of Bedford, Kentucky. We stopped at a road-cut and found more Platystrophia, Hebertella, Rafinesquina and a great many more bryozoa. We returned here 9/16/75 and 5/.15/83. This we call the Bedford site. Again no other collectors were encountered.

More collecting areas were found in and around Fort Mitchell, Kentucky. Credit for these locations go to Bill and Virginia Popp, well known members of the Earth Science Club of Northeastern Illinois. They led field trips to northern Kentucky many of which I could not attend. The first location was a housing development that is now built over. The area had been graded, the ground laid bare. We parked at the end of the street where the last house was completed. The yellow clay, with a pouring rain to help, exposed the typical Cincinnati area fossils, just waiting to be picked up. Two interchanges, Dudley Road & Madison Pike, and Dudley Road & Winding Trail Road both yielded many fossils.

Over the years many trips were made to southeast Indiana and northern Kentucky as well as many other places in the midwest and parts of Ontario, Canada. My construction related work often left me little time on weekends for field trips. In June of 1977 I retired and moved to Prescott, Arizona to a more favorable climate.

NEW INFORMATION

A new publication by the United States Geological Survey in 1979 titled CONTRIBUTIONS TO THE ORDOVICIAN PALEONTOLOGY OF KENTUCKY AND NEARBY STATES, PROFESSIONAL PAPER 1066, A - B adds more information to the study of this genus. Part A by John Pojeta, Jr., starts with an introductuion, then discusses the Lithostratigraphy, the Middle and Upper Ordovician boundary, methods of collecting, processing, results and finally the collecting localities. Part B by Leonard B. Alberstadt is a report of the brachiopod genus Platystrophia. An introduction followed by distribution, faunal migrations, in and outside the Ohio valley, systematic paleontology of Middle and Upper Ordovician species with seven plates of the described species and some illustrations of related species.

In the final work of identifying the different species of the Platystrophia several references were used. The work of McEwan of 1919 is still considered the standard reference. Alberstadt's work is also very helpful. Other references are in the literature cited.

In identifying the individual species some of the important features are, the length of the hinge line, the thickness of the articulated valves, the number of plications on the fold, in the sulcus, the size of mature specimens and the appearance of the cardinal extremities.

The study made by the United States Geological Survey with the cooperation of the Kentucky Geological Survey took place from 1961 until 1972. It covered 87 7.5 minute quadrangles in central and northern Kentucky, southeast Indiana and southwest Ohio. Fossils were collected from almost 1100 localities. Reports were made from 317 localities in 55 quadrangles.

COLLECTING

All my collecting was done before the U.S.G.S. report was published in 1979 with the exception of a trip to collect at Sulphur and Bedford on 5/15/83. The quadrangle map shows collecting was done in Smithfield (Sulphur) and Bedford quadrangles (Bedford) but no collections are listed in the locality register. The Covington quadrangle lists eight sites in the locality register near Erlanger, Kentucky, all for Platystrophia ponderosa. Fort Mitchell is between Erlanger and Covington quadrangle but no collecting sites are listed. The Fort Mitchell area yielded seven species of Platystrophia. Figure 2 is a chart of the species of Platystrophia collected by the writer from Kentucky and southern Indiana. The X's in the last column are species listed by Alberstadt, 1979.

Sulphur as noted was the most heavily collected and was the largest of the three areas collected. It had the most abundant fossils both in number of specimens and the number of varieties. Collecting trips were made to obtain the maximum number of species and varieties to be found. Bedford was a smaller area and lacked some of the species and varieties found at Sulphur. As we go north to Fort Mitchell and nearer the Ohio River, the number of Platystrophia decline and the other species of fossils increase.

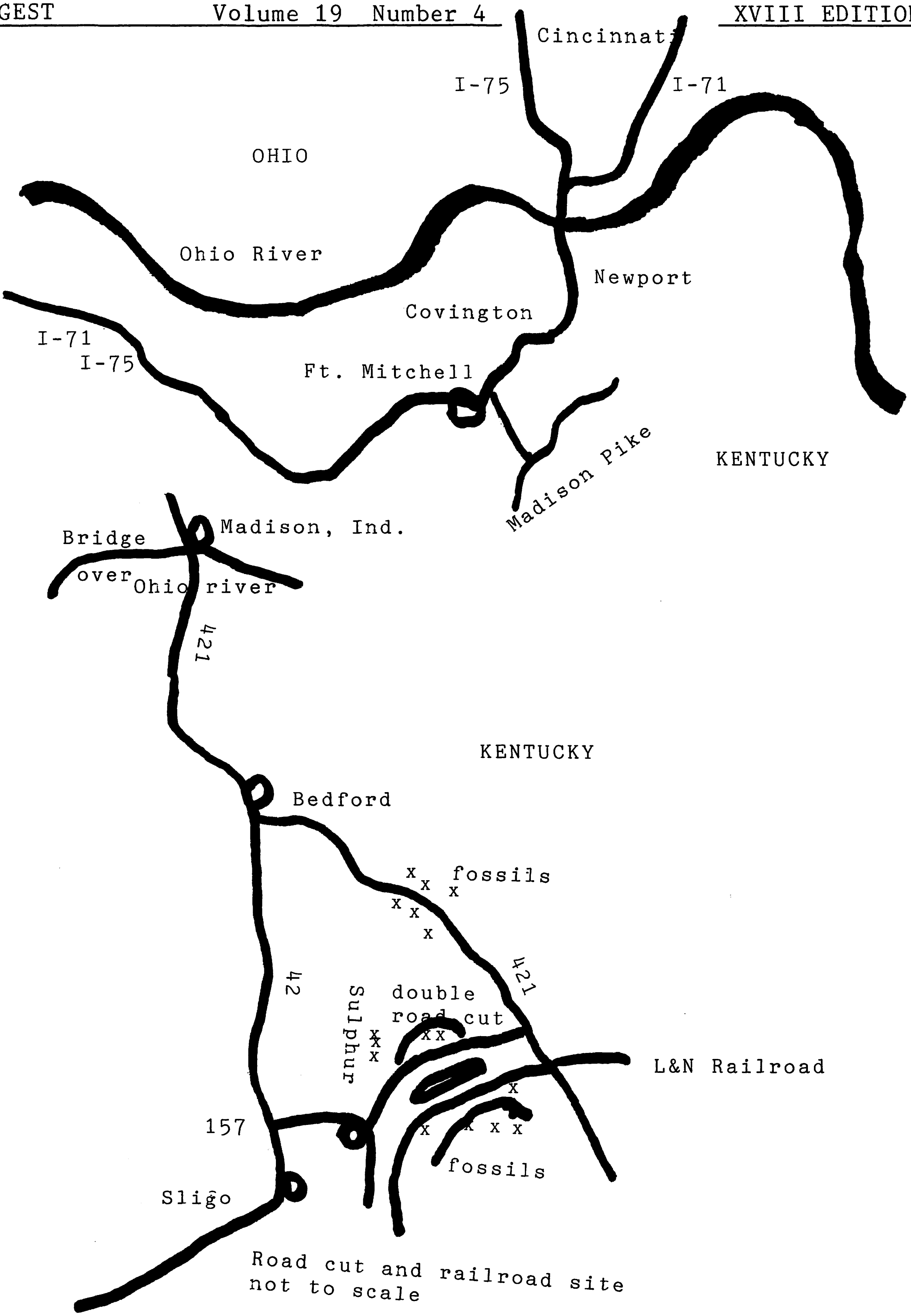


Fig.1 Maps of the collecting areas in northern Kentucky. The lower area is not drawn to scale. The upper Covington-Ft.Mitchell is from a Kentucky Highway map.

SYSTEMATIC PALEONTOLOGY

The following species are identified from the references cited. The comments are those of the author while some are from McEwan and Alberstadt with credit given. The species of Platystrophia have been placed in groups by McEwan and others.

The Low Fold Group

Platystrophia acutilirata (Conrad). The species is rare in Kentucky, Alberstadt list one reference from the Drake Formation. The writer has four specimens from the Maquoketa Group, Fort Atkinson Limestone, Larson Quarry, DeKalb, Illinois. This reference is from McEwan.

Platystrophia annieana (Foerste). The number of specimens in our collection indicates this is a fairly common species. They range in size from small to large measuring up to 35 mm along the hinge line. They are second to P. ponderosa in size. Richmond Group, Waynesville Formation to Whitewater Formation.

Platystrophia clarksvillensis (Foerste). No reference made by Alberstadt of this species in the Kentucky collections but specimens are shown on plate 7, figures 30-33 from specimens in the National Museum of Natural History collection. They are described and illustrated by McEwan. Richmond Group, Arnheim Formation.

The High Fold Group

Platystrophia crassa (James). This shell is much narrower than P. laticosta or P cypha and is also globose. The width at the hinge line of my specimens average 20 mm. Maysville Group, Fairmount Formation.

Platystrophia cypha (James). Moderate size, length at hinge line 27 mm. Occurs in only a scattering of locations in the Bull Fork Formation of Kentucky. Richmond Group. Arnheim Formation.

Platystrophia laticosta (Meek). Is about as abundant as P cypha in the Kentucky collections appearing in the Ashlock Formation, (Grant Lake Limestone) Maysville Group, McMillan Formation.

Platystrophia unicostata (Cummings). This species not discussed byAlberstadt but is illustrated on plate 7 , figures 9 -16 from specimens in the National Museum of Natural History, Smithsonian Institute. Figure 14 has only one plication in the sulcus, a distinguishing feature for this species. My collection has one specimen from Madison, Indiana with one plication in the sulcus. Other specimens have two major plications on the fold with two very weak plications and one major in the sulcus. Maysville Group, Bellvue member, McMillan Formation.

Platystrophia ponderosa subgroup

Platystrophia ponderosa (Foerste). The largest species in the genus. Has variable outline, cardinal extremities in most species at right angles but slightly acute or spiriferoid in some. It is the most numerous of all Kentucky species, and the easiest to identify.

P ponderosa auburnensis (Foerste). Identified by description and illustration by McEwan, page 424, pl. 49, figures 9 -12. Maysville Group, McMillan Formation, Mt. Auburn member.

Platystrophia ponderosa subquadrate mutation. Recognizable from their dimensions, they appear longer than wide. See photos.

	hinge line	length	width at mid center
Specimen 1	28 mm	25 mm	24 mm
Specimen 2	19 mm	25 mm	20 mm
Normal sp.	27 mm	28 mm	34 mm

Maysville Group, McMillan Formation.

Platystrophia foerste (McEwan). Found in the Richmond Group at Waynesville, Ohio, Versailles, Indiana and Orangeburg, Kentucky.

Platystrophia wallowayi (Foerste). Two specimens collected in a roadcut on Highway 56 about 1 mile west of the entrance to Clifty Falls State Park, Madison, Indiana. The number of plications, measurements and the rest of the description generally agree with McEwan. Richmond Group. Arnheim Formation.

CONCLUSION

In bringing this paper to a close let me say that this is only an introduction to this genus. It contains a brief early history of how it developed and how the writer became a fossil collector. To anyone interested in this genus, McEwan reports 27 species plus nine subspecies in this three state area. There are also three species in the Silurian rocks near Dayton, Ohio. This genus is widespread in the Middle and Upper Ordovician in the United States. It is found in Illinois, Iowa, Wisconsin, Michigan, Minnesota, Missouri, Oklahoma, New York, North Carolina, Wyoming, Idaho and Texas. Kentucky and Tennessee have many species from the Middle Ordovician I didn't have time to collect. Illinois added P. equiconvexa, P. acutilirata and a third specimen from the Maquoketa, found at the Larson Quarry in De Kalb identified as Platystrophia sp., but look very much like ponderosa. 37 years of collecting has brought me to age 81, too old to do any field collecting but I hope enough time to do some cataloguing and also update my collection.

PLATYSTROPHIA	Sulphur, Kentucky	Bedford, Kentucky	Ft. Mitchell, Kentucky	Madison, Indiana	Pearl Packing Co Madison, Indiana	Totals each species	Listed by Alberstatdt in USGS P. P. 1066 B
acutilirata							X
annieana	50	12	5	1		70	X
" mutants	14	5	2			19	
aff. P annieana	6					6	X
cf. P annieana ped. valve			1			1	X
clarksvillensis	5		2	10	2	19	
crassa	20	4	3		2	29	
cypha	14	8	5		1	28	X
laticosta	37	5	14		3	59	X
ponderosa	272	124	19			415	X
" mutants	18					18	
" subquadrata var.	3					3	
" auburnensis	1					1	
P. cf. foerste							X
wallowayi				2		2	
unicostata	10	4	10		1	25	X
juveniles & unidentified	12	14	8			34	
Totals each Location	462	176	69	13	9	729	

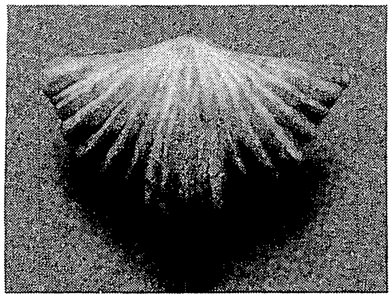
McEwan describes recurrent mutations specimens in the low fold group. In this area these include P. annieana and P. ponderosa. Normal specimens have four plications on the fold and three in the sulcus. Mutations have plications in the sulcus numbering four to six and on the fold from five to seven.

P. cf, P. annieana pedicle valve from Alberstadt, 1979, plate 4, fig. 17

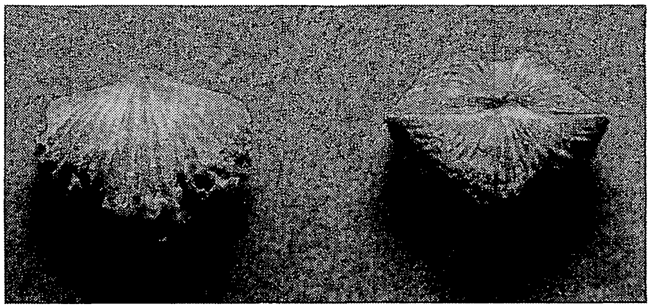
P. aff. P. annieana from Albestadt, 1979, plate 5, fig. 66, 67

P. ponderosa subquadrate variety from McEwam, 1919, page 447, plate 50, figs. 12-15

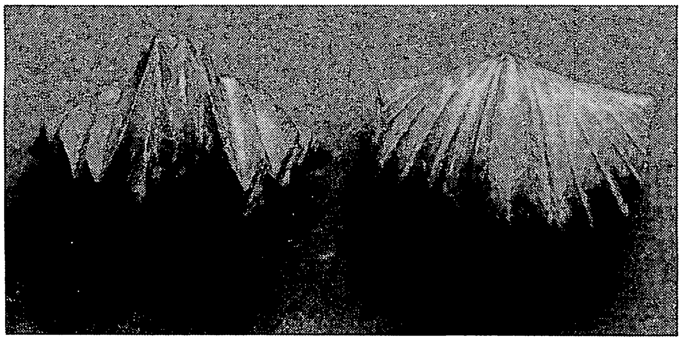
Figure 2. Species and numbers collected



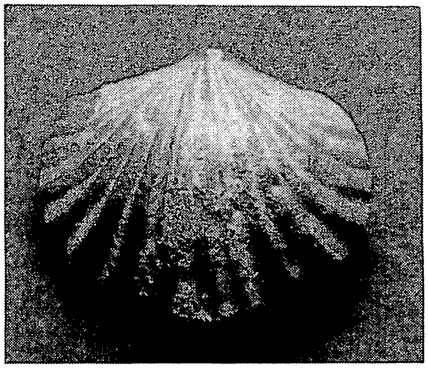
P. Cypha
Sulphur,Kentuck



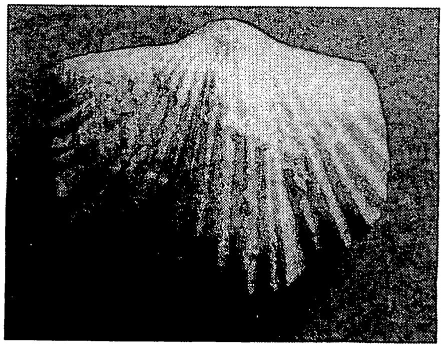
P. crassa, note narrow and globose shape. Sulphur, Kentucky



P. unicostata, note 1 major plication in sulcus, 2 major plications on fold.
Ft. Mitchell, Kentucky



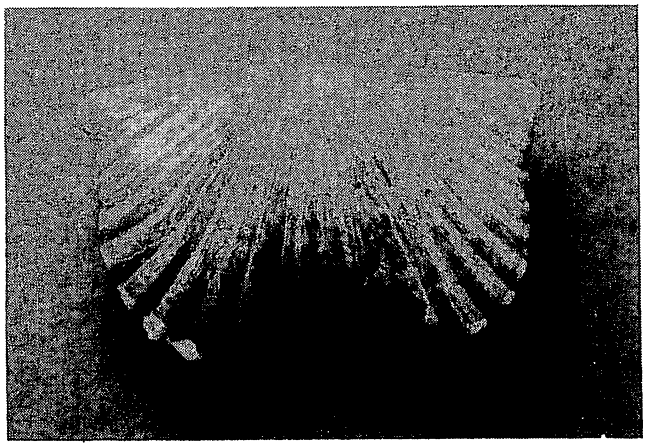
P. annieana, note large plications.
Ft. Mitchell, Kentucky



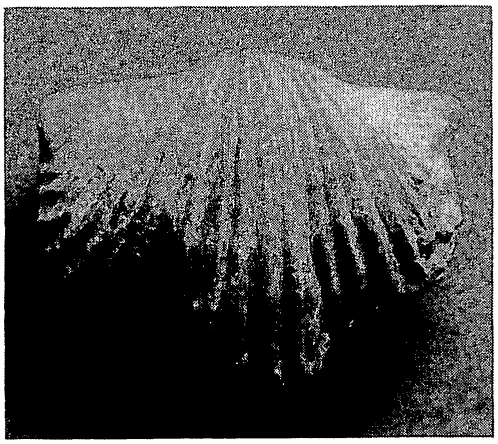
P. annieana mutant
6 plications on fold
Bedford, Kentucky

P. annieana, note variation in cardinal extremities of all specimens in photos
Sulphur, Kentucky

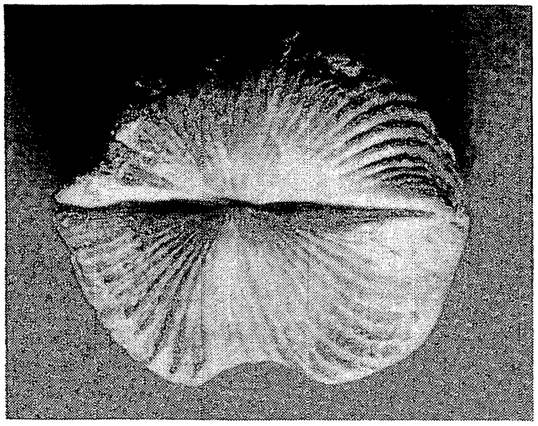
P.. ponderosa brachial valve and pedicle valve of two individuals
Bedford, Kentucky



P. ponderosa, pedicle valve, note the cardinal extremities of this individual. Also there are 5 plications in sulcus.
Ft. Mitchell, Kentucky



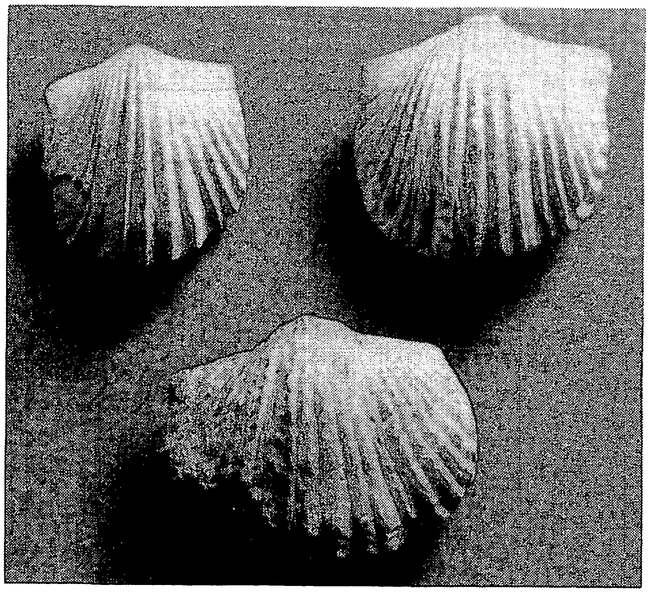
P. ponderosa, brachial valve, please note shapes of all these and all other P. ponderosa illustrations. Sulphur, Kentucky



More P. ponderosa

Posterior view of
a very globose
specimen.
Sulphur, Kentucky

Two mutant specimens, left specimen has 6 plications on fold with 5 in sulcus, right specimen has 7 on fold and 6 in sulcus.
Sulphur, Kentucky



Subquadrate mutations
are the two specimens on
the top row, compare
with normal specimen
on the bottom.

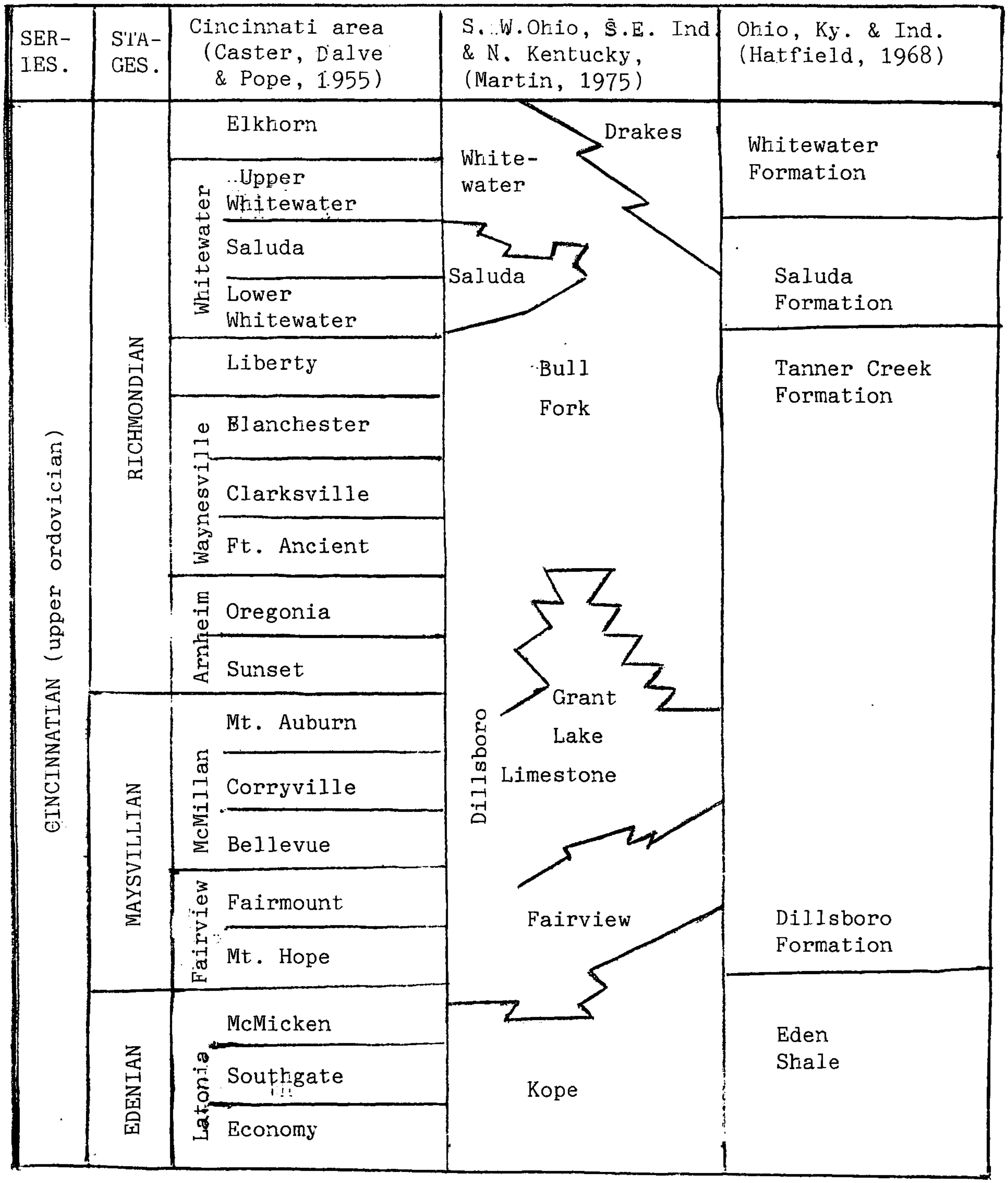


Figure 3. Different interpretation of the rock found in the Ohio, Indiana and Kentucky area. From Cincinnati Fossils, edited by R. A. Davis 1985, Cincinnati Museum of Natural History Used by permission.

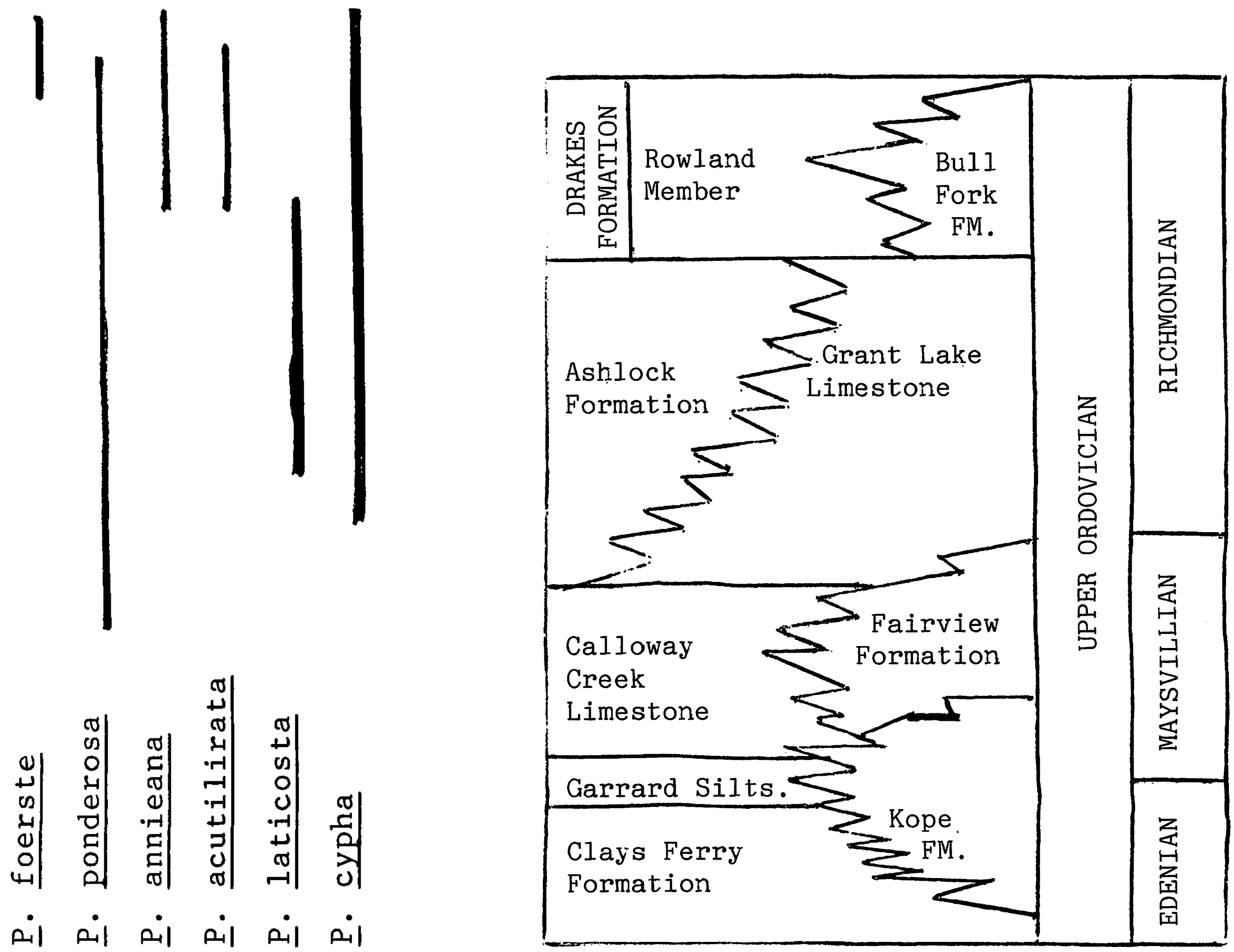


Figure 4
Upper Ordovician Stratigraphic distribution of <u>Platystrophia</u> species in Kentucky as determined by the United States Geological Survey and the Kentucky Geological Survey, collections made between 1961 and 1972.
The verticle bar diagram shows <u>P.</u> <u>ponderosa</u> beginning at the base of the Calloway Creek Limestone, above the Garrard Siltstone. <u>P.</u> <u>annieana</u> is in the uppermost part of the Upper Ordovician Drake/Bull Fork Formation.
<u>P.</u> <u>acutilirata</u> is found in the same range. The <u>P.</u> <u>laticosta</u> - <u>cypha</u> group begin in the lower part of the Richmond/Ashlock Formation, Grant Lake Limestone.
This diagram, from Sweet & Bergstrom (1971) U.S.G.S. report 1979

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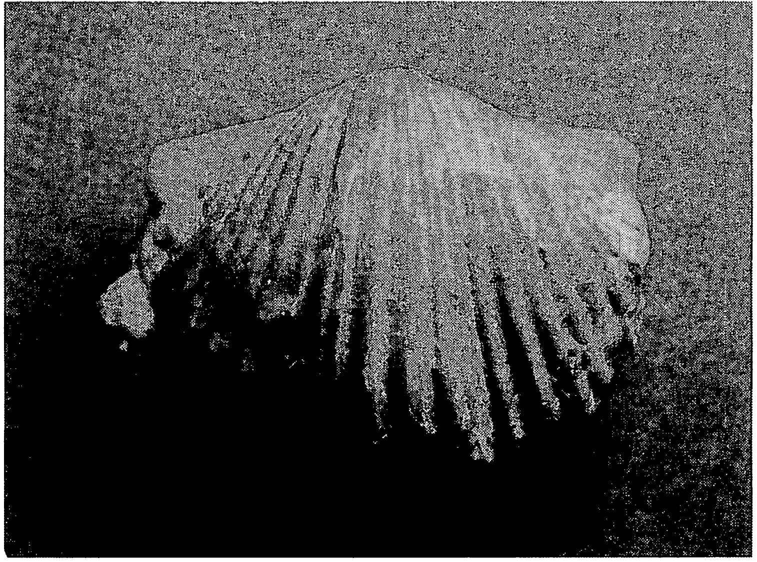

P ponderosa with bryozoa growth. This is the largest specimen I have collected, hinge line 47 mm, height 40 mm, thickness 33 mm. Sulphur, Kentucky

BRACHIOPODA

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Temple, Texas 76501-1709

The phylum BRACHIOPODA, commonly called BRACHIOPODS are BRACHS is one of the oldest and largest invertebrate groups. There are living brachiopods with the same form as their (Cambrian) ancestors.

The vast size of the phylum and the great variety of the characteristics of the members makes recognition difficult. However, their common form makes them BRACHIOPODS. Brachiopods are bivalves which are symetrical from left to right but not top to bottom nor front to back. Over 1,600 genera have been described. The current Volume H of the *Treatise On Invertebrate Paleontology* is in two volumes. It is in the process of being revised and there may be MANY times as many genera described and the number of volumes increased.

Brachiopods are solitary marine animals which are anchored by a fleshy stalk or pedicle. The fleshy parts of the animal are inclosed in a pair of valves. The two valves of the early brachiopods were not connected but held together by musculature. These form the class Inarticulata with 50 orders and 129 genera. They are found in Cambrian to Recent periods.

The second and much larger class is the Articulata. In these the two valves are held together (articulated) by complementary teeth and sockets. There are nine (9) articulate orders with 1,534 genera. These are based on my counting and well may be wrong.

The external shape of the many orders varies greatly. Their shape is a great help in putting specimens in the proper order. Internal structure is not here considered. Briefly the orders are as follows:

PHYLUM BRACHIOPODA

CLASS - Inarticulata - 129
Valves held together only by muscles and body walls.

ORDER: LINGULIDA - 51 genera.
Generally these are oval in shape and the exterior of the valve is smooth. There are some exceptions.

ORDER: ACROTHREDIDA - 63 genera.
Usually circular or subcircular and the exterior of the valves are smooth.

ORDER: OBELLIDA - 5 genera.

Shell is biconvex (both valves convex), subcircular to elongate oval in outline. Shell exterior is usually smooth but some species have external semicircular or parallel grooves.

ORDER: PATERIMIDA - 7 genera.

Shell is rounded or elliptical in outline, growth is Holoperiphal (growth occurs around the entire valve, though not equally).

CLASS - Uncertain - 3 genera.

Both valves biconvex.

ORDER: KOTORGINACEA - 3 genera.

CLASS - ARTICULATA - 1,584 genera, 44 subgenera.

Valves are held together by hinged teeth and dental sockets. These are well developed, or, rarely, lost or replaced.

ORDER: ORTHIDA - 189 genera, 9 subgenera.

The shells are generally unequally biconvex (the shell has a true hinge line parallel to the hinge axis). Generally they are semicircular behind this hinge line. Some have "wings". Most genera are costellate and have radial ridges on the external surface of the shell.

ORDER: UNCERTAIN - 4 genera.

Umbro (beak) of the pedical valve combines with a smooth triangular umbonal plate.

ORDER: STROPHOMEIDA - 375 genera, 26 subgenera.

This is the largest order, including the largest (6 1/2" or more) and thickest genera known. Shells are commonly biconvex, respinate (pedicle and brachial valves reverse concavity during successive adult stages of growth), or gentivulated (abrupt and more or less persistent changes in direction of valve growth producing angular bands in lateral profile). The wide differences in this order came from an attached mode of life by cementation or spinous anchorage followed by the loss of a functional adult pedicle early in the evolutionary history of the order.

ORDER: PENTAMERIDA -84 genera, 3 subgenera.

The shells are usually biconvex. The delthyrium commonly serves as the pedicle opening.

ORDER: RHYNCHONELLIDA - 210 genera, 2 subgenera.

This shall is usually rostrate (prominent beak of pedicle [bottom] valve is partially closed by two deltodial plates).

ORDER: SPIRIFERIDA - 305 genera.
The spirifers vary greatly in external appearance and internal structure. They cover some 95 pages in the Treatise.

ORDER: TEREBRATULIDA - 290 genera, 4 subgenera.
The Terebratulida have a functional pedicle with the delthyrium (a median triangular aperature) partly closed by deltidal plates - plates in the delthyiodal chamber [cavity beneath the umbo]. Like the spiriferida, the Terebratulida vary greatly in external appearance and internal structure. They cover 1,326 pages in the Treatise.

ORDER: UNCERTAIN - 12 genera

ORDER: SUBORDER, AND FAMILY: 53 genera.

Most of this is based on information from Part H - BRACHIOPODA of the TREATISE ON INVERTEBRATE PALEONTOLOGY. Directed and edited by Raymond C. Moore, published in 1965 by the University of Kansas Press under the sponsorship of the Geological Society of America .

Now-- for all of you brachiopodal experts, this is not intended for you, but for the thousands of people who know little more than that brachiopods have two valves.

BRACHIOPODS INTERNATIONALLY

Brachiopods	ENGLISH
Brachiopoden	GERMAN
Brachiopodi	ITALIAN
БРАХИОПОДЫ	RUSSIAN-with German root
Braquiopodos	SPANISH
Brachiopoderne	DANISH - SWEDISH
Брахчоподц	BULGARIAN
Braquiopódes	PORTUGESE
Armfüßler	GERMAN
Brahiopodj	YUGOSLOVIC
Brachiopodes	FRENCH
Плеченогие	RUSSIAN-with Russian root
Armfødder	RUSSIAN-with Danish root
腕足动物	CHINESE (Wang Zu Dong Wu)
Ramenonocži	CZECHOSLOVIC
Ramenonogi	POLISH

BRACHIOPOD

Articles Written in the past by Franklin Hadley

ALISPIRIFER sp.

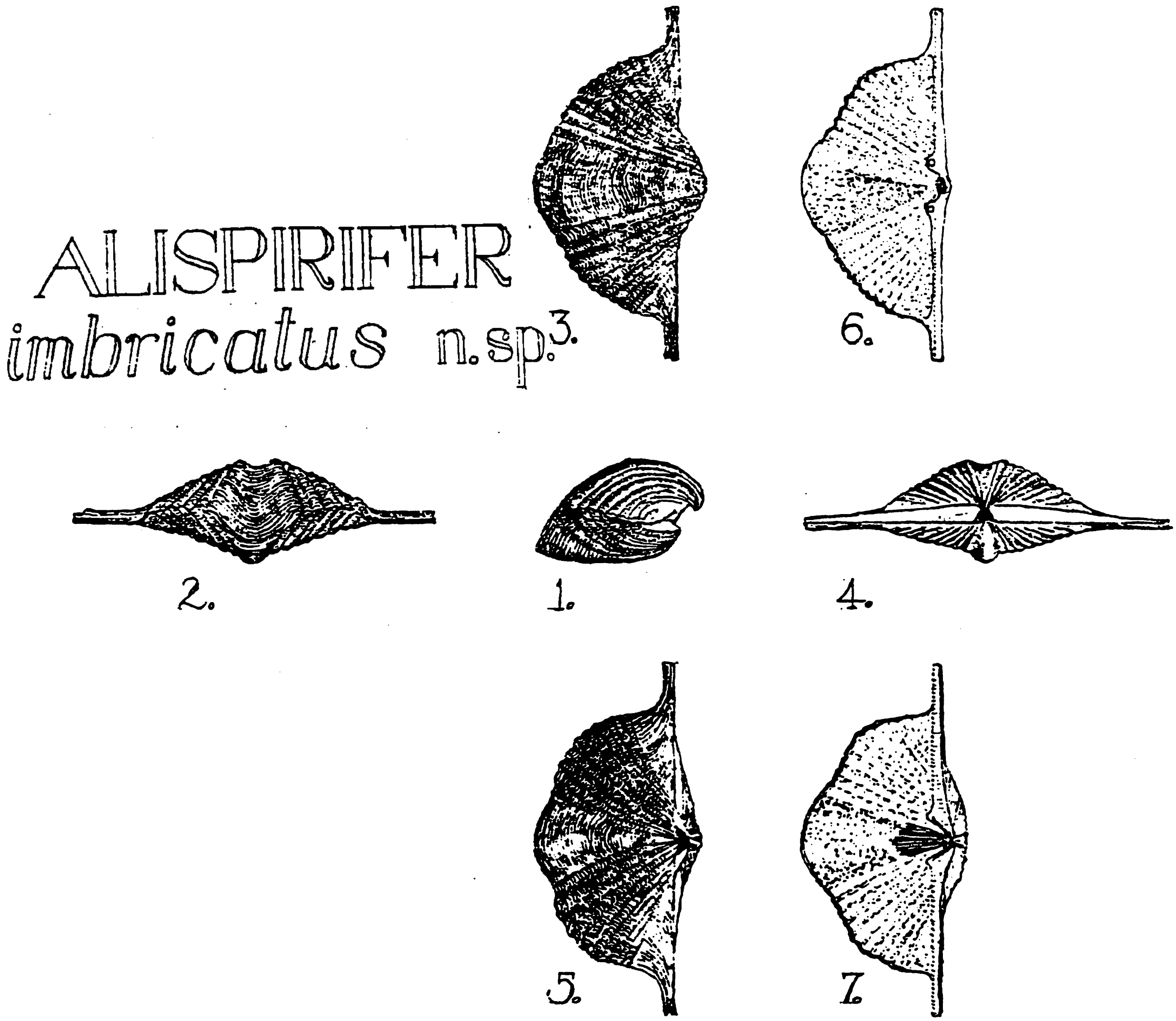
A new species of brachiopod from the Lower Mississippian rocks of Indiana.

DIAGNOSIS Spiriferoid; alate, hingeline maxium width of shell; mucronate in specimens not broken in life or burial; ventral interarea moderately high, concave; denticulated hingeline; lateral slopes with eight simple rounded costae, intercostal grooves simularly rounded; costae lacking on fold and in sulcus; prominate evenly spaced imbricating growth lines; micro-ornamentation of fine radial striae, 18-20 per mm, in line on adjacent lamellae; delthyrium open with apex obstructed by rounded callosity, sometimes protuding spherically.

REMARKS Brachiopods of this genus were first described by K.S.W. Campbell ,1961 from the Lower Carboniferous rocks of New South Wales, Australia. Campbell also suggested their occurrence in Argentina. A new species of this genus has been discovered by the author in the Lower Mississippian, Carwood Formation, of the Borden Series near Brooklyn, Indiana. It will be named *Alispirifer imbricatus* in a paper in progress, co-authored by Alan Horowitz, Indiana University. This will be the first of this genus reportedly found in North America.

Many specimens have been collected from two sites approximately 1/4 mile apart. At one site the specimens were found uncrushed but lacking both mucronation and micro-ornamentation. An irregular pattern of growth lines at the cardinal extremities is evidence for shell regeneration after breakage. At the second site, the great majority of the specimens were crushed, the brachial valves collapsing into the pedicle valves. Mucronation was preserved in many of these valves, and so was the micro-ornamentation. A thin layer of pyrite had preserved the shell surface. This author suspects them to be more widely spread in the Borden Series, but their poor preservation has prevented previous recognition. The illustration by the author depicts an individual with mucronation found in a crushed specimen.

The seven (7) views are: 1. lateral, 2. anterior, 3. ventral, 4. posterior, 5. dorsal 6. interior of a dorsal valve showing the cardinal process made of longitudinal plates, 7. interior of a valve showing the denticulated hinge and the longitudinally striated muscle scar.



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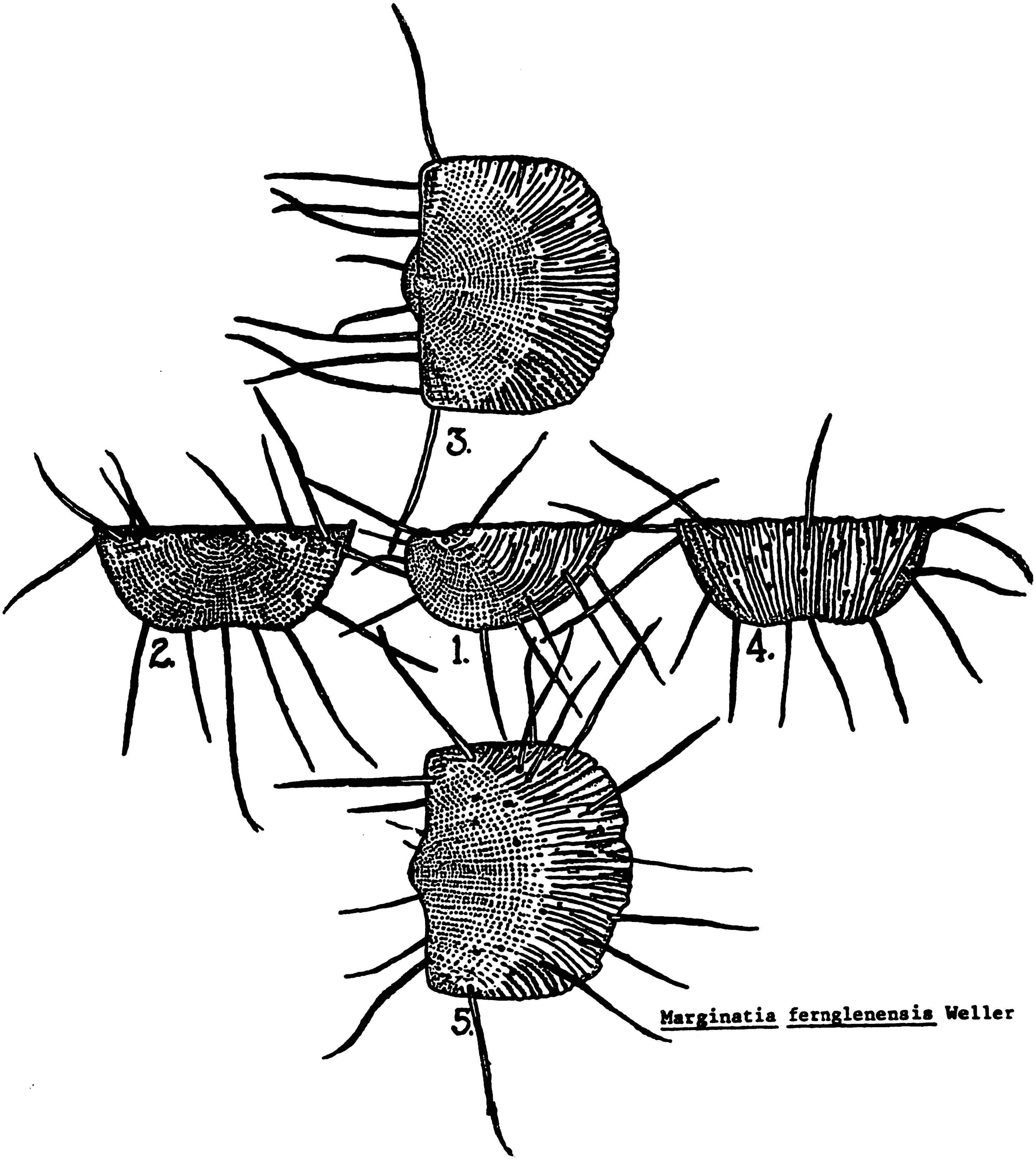
Reprinted from the ISP Newsletter June 1986

The five views of the *Marginatia fernglenensis* Weller are: 1) lateral, 2) posterior, 3) dorsal, 4) anterior, 5) ventral.



Marginatia fernglenensis Weller

MARGINATIA fernglenensis

Marginatia fernglenensis Weller, 1909

Productus fernglenensis was described by S. Weller, 1909, and again in 1914. In 1960 Muir-Wood and Cooper named *P. fernglenensis* as type species for their new genus *Marginatia.*

It occures in the Lower Mississippian period: Illinois and Missouri (Fern Glen Formation), Indiana (Carwood Formation), Missouri (Pierson Formation), Kentucky (New Providence Shale), Alabama (Fort Payne Chert), Ohio (Wooster Shale), Alberta (Banff Formation)

A specimen collected by me from the Carwood Fm. of the Borden Series, near Brooklyn, Indiana was identified by Dr. G. A. Cooper, Paleontologist Emeritus National Museum of Natural History, Smithsonian Institution, Washington, D.C. The specimen is 50% wider and 18% longer than the largest observed by Weller. Where Weller, 1914, stated spine bases were usually inconspicuous or absent, this specimen has abundant spine bases scattered all over the ventral valve. Muir-Wood and Cooper,1960, in Comparing *Marginatia* to *Antiquatonia* states that it lacks a row of spines near the hinge. This specimen of *Marginatia* has spine bases near the hinge line.

While Muir-Wood and Cooper, 1960, does not use the term "fasciculate" in describing costae arrangement on the anterior slope of the ventral valve, Weller, 1914, does. It is this outstanding external characteristic that makes *Marginatia* immediately recognizable.

In spite of the difference in size and presence of spine bases absent in Weller's 1914 specimens, I have placed the specimen from the Carwood Formation of Brooklyn, Indiana, in the species *Marginatia fernglenensis.* This is the same as named by Weller from the Fern Glen formation of Missouri which was then interpreted as being Kinderhookian in age. Muir-Wood and Cooper, 1960, stated the Fern Glen Formation to be Osagian in age, the same time period as the deposits at Brooklyn, Indiana.

Specimens of other brachiopod species collected at the Brooklyn, Indiana site are remarkably well preserved displaying characters not previously reported. One example is the presence of microscopic prostrate anteriorly pointed spines of the *Punctospirifer Sp.*

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SYRINGOTHYRIS texta

A large brachiopod from the Lower Mississippian rocks of Indiana.

DIAGNOSIS: Spiriferoid; physical proportions highly variable from short and acutely pyramidal ventral valve. Hinge line straight; cardinal or even convex. Interarea differentiated into three regions: The central including the delthyrium and two lateral regions separated by a diagonal line originating at the apex and intersecting the hinge line 1/2 distance between the delthyrium and cardinal extremities; central regions marked by verticle striations while the lateral regions marked by horizontal growth lines. The delthyrium higher than wide with apical angle of approximately 40 degrees. Delthyrium completely covered by a convex pseudodeltidum and bordered by shallow but well defined dental grooves. Lateral slopes of both valves with approximately 20 low rounded costae, intercostal grooves sharp, costae originating at beaks, sulcas and fold without costae. Growth lines evident but fine except very coarse near front and lateral margins. Shell punctate except absent in central part of differentiated interarea. Lateral slopes of both valves ornamented by characters resembling "twilled cloth."

Internally the adminicula (dental plates) of the ventral valve are short and thick, the syrinx bearing plate between them only slightly depressed at the delthyrial apex, and deepening as it extends toward the hinge line; the tubular syrinx extends from beneath it toward the hinge line. The muscle scar lies between the adminicula with an arching median ridge which has a central depression. The scar is diamond shaped, determined by the bounding adminicula, from whose anterior edges it converges medially approximately 1/2 distance to the anterior margin. The scar is marked by small ridges radiating from center of the median ridge central depression.

REMARKS: This species was described and named by Hall, 1857, as Spirifer texus. In 1863 A, Winchel described a shell which came from the yellow sandstone lying beneath the Burlington Limestone at Burlington, Iowa, and which possesses the syrinx bearing plate and made it the basis for a new genus *Syringothyris*. In 1909 in the North American Index Fossils, Grabaw & Shimer, editors, the species, with a corrected Latin ending *Syringothryis texta.*

Reports have it as being found in the Lower Mississippian rocks throughout the

North American midwest, Alberta, Canada, China, Siberia and U.S.S.R.

In Indiana it is found in the Spickert Knob Formation of the Borden Series. The collecting site is among the Knobs of southern Indiana, in a roadcut of a narrow county road. The strata are horizonal while the roadcut slopes radically. Many specimens are uncovered each spring after freezing and thawing cause exfoliation of the rock face. Some specimens may be found in the roadside ditch; others are partially exposed, awaiting the patient collector with a hammer and chisel to extract them. sometimes a specimen with complete shell is extracted; more often the shell pops off in pieces. The pieces must be rescued and wrapped with the specimen to be cemented in place later.

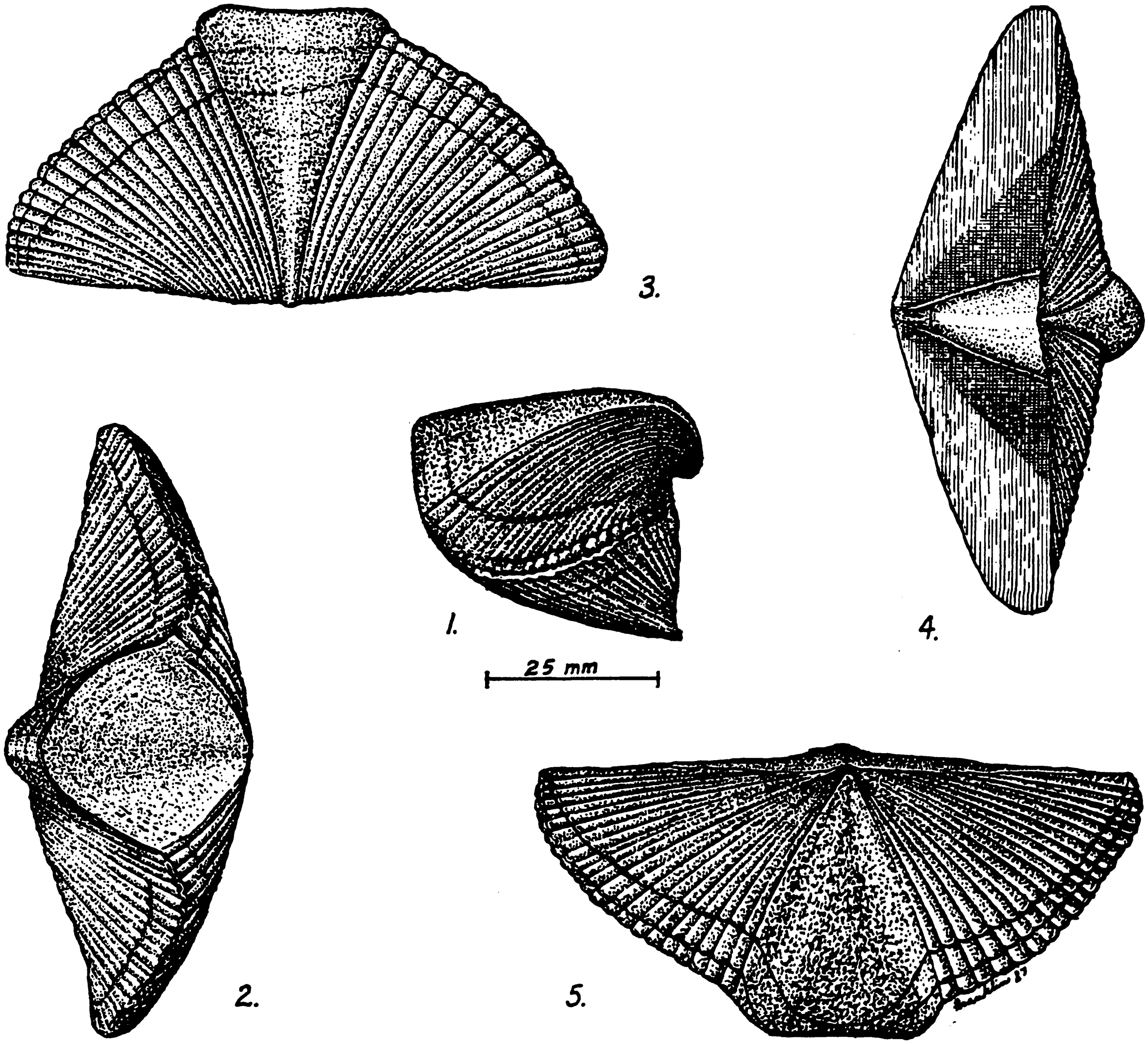
In April, 1984, on the Wednesday prior to the MAPS EXPO, MAPS member Gary Eichorn from Montana accompanied me to the collection site. We took along a stepladder to aid in reaching the specimens, since the road downslopes. The stepladder was supported on exfoliation debris and Gary mounted the ladder while I held it in place. As Gary was hammering away, the ladder base gave way and Gary rode it all the way down. I could only jump aside, letting the ladder base slide, laughing myself silly, relieved that Gary remained vertical.

The "twilled cloth" ornamentation which must have prompted Hall to name his species *S. texus* is not restricted to his named species. Nor is it restricted to shells of the genus *Syringothyris*. Another large brachiopod with a pyramidal ventral shell found in the Lower Mississippian rocks and without the syrinx, *Pseudosyrinx sp.*, also has the "twilled cloth" pattern. Its shell is also punctate. It is rare in Indiana; less than 1/2 dozen have been found.

The variable physical proportions of the specimens collected at the site noted above prompted me to send a particularly spherical specimen (belonging to Margaret Kahrs) to Dr. G. A. Cooper, Paleobiologist, Emeritus N. M. N. H. Smithsoniam Institution, asking him for any remarks. Dr. Cooper's explanation for its plumpness is that many larva settled on the same desirable spot and competed for space as they increased in size. Those that couldn't grow laterally had to grow in whatever direction was available that they could still open their valves for feeding.

The pseudodeltidium which covers the delthyrium is rarely perfectly preserved in Indiana. Specimens of *S. texta*. Many specimens , however, show traces sufficient to prove its existence.

Even rarer, to the point of nonexistent, is a perfect specimen with shell attached that dosen't require removal of matrix. I use a Burgess Electric Vibro-Graver for massive matrix removal and modified dental tools for the finishing work. An Opti-Visor provides the necessary magnification. Good lighting is an absolute must.



SYRINGOTHYRIS texta

The five views are: 1) lateral, 2) anterior, 3) ventral, 4) posterior, and 5) dorsal

ECHINOCONCHUS

The brachiopod of the genus *Echinoconchus* has been a very successful one. It arrived upon the early Mississippian scene fully developed and became extinct during the Permian. It is reported from the New Providence (Early Mississippian) Shale of Kentucky to the root shale (Early Permian) of Kansas.

In Indiana the *Echinoconchus alternatus* is found in the Spickert Knob Formation, the mid-slope of the Borden Delta, and in the Edwardsville formation, the top-set of the Borden Delta. The Edwardsville is the formation from which the original Crawfordsville crinoids were mined 125 years ago. In areas adjacent to Crawfordsville, The Ramp Creek Limestone Member is found above the Edwardsville. It, too is the source of many beautiful crinoid specimens in its alternating carbonate and noncarbonate rocks.

A suggestion by personal of the Indiana State Museum that the brachiopods from Ramp Creek could be salvaged, resulted in the contribution of several good specimens by Robert Howell, collector and preparator.

Two laterally crushed specimens of *Echinoconchus alternatus,* both from the Ramp Creek, had 1/2 inch long spines protruding from their anterior margins. These slender spines are illustrated in views 1 and 4 of the reconstruction.

Since collected specimens are sometimes void of all spines, and short spines are preserved on some specimens, perhaps the typical *Ecninoconchus sp.,* while living, was covered with a mat of recombent spines 3/8 to 1/2 inch long.

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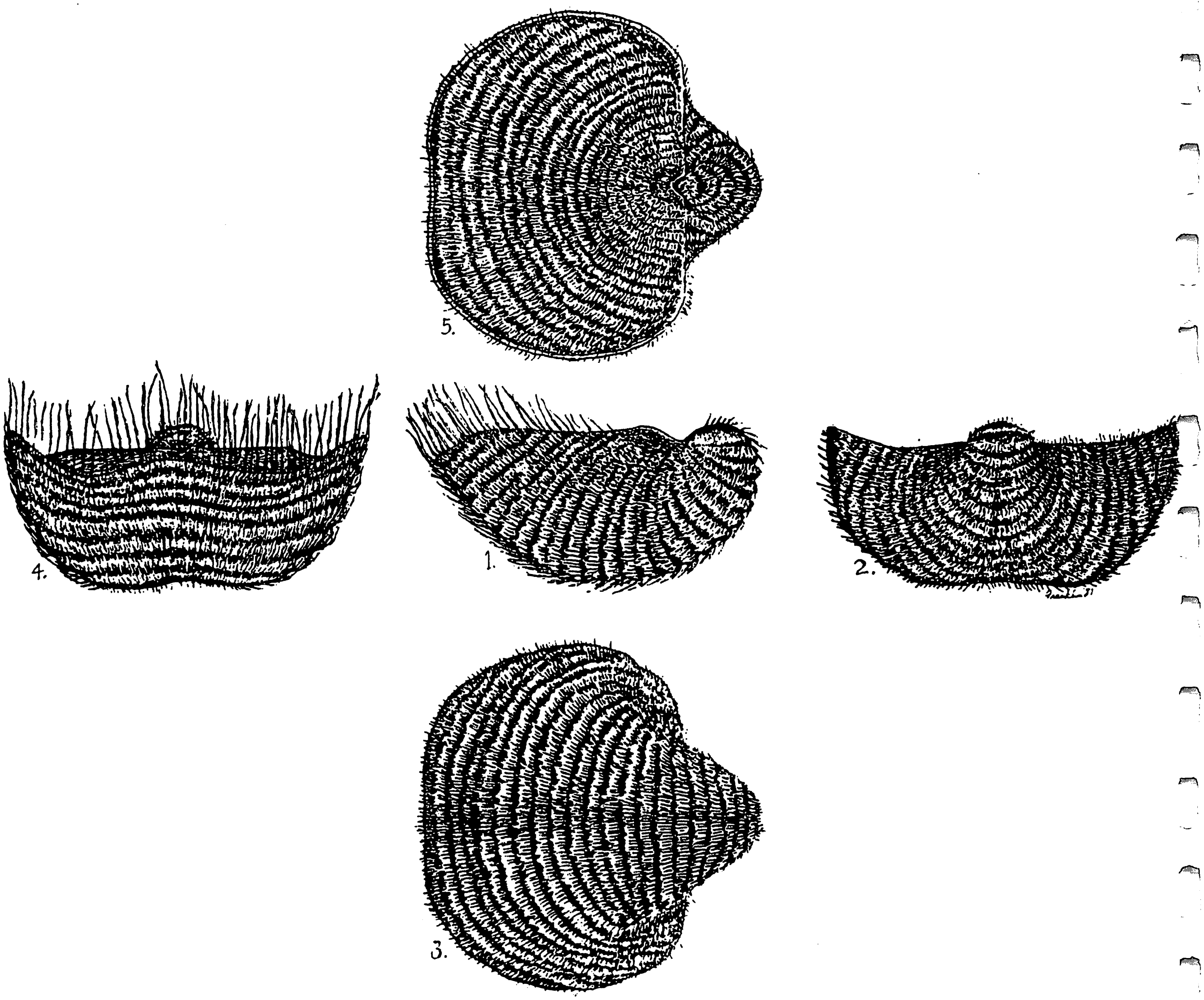
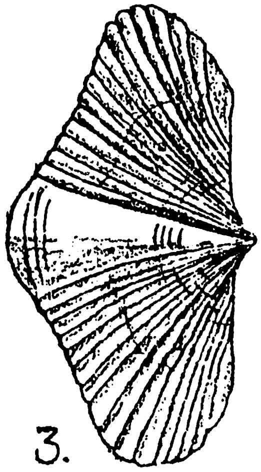


ECHINOCONCHUS *alternatus* NORWOOD & PRATTEN

Views of reconstructed specimen:
1) lateral 2) posterior, 3) ventral, 4) anterior, 5) brachial

Editor's note:
The Brachiopods articles on the preceding pages, were written By Franklin Hadley and here reprinted by permission from Mrs. Rhoda Hadley. Franklin passed away in Nov. 1991, he specialized in Brachiopods. He also did the art work for his articles.

PLATE



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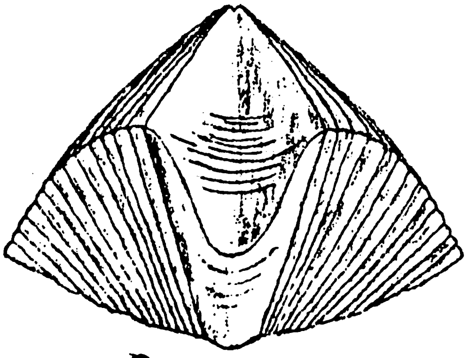

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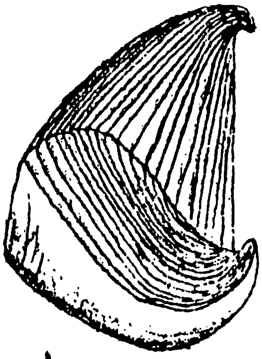

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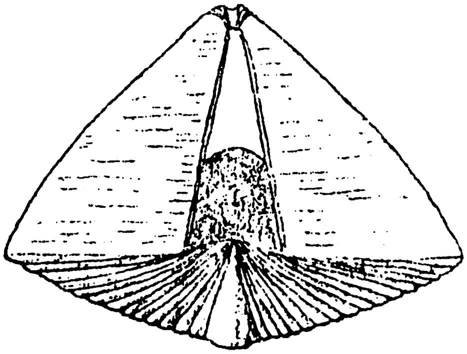

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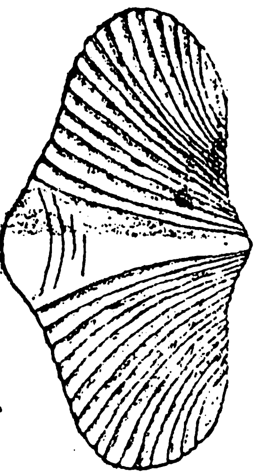

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Art by: Franklin Hadley

PSEUDOSYRINX *indianensis* n.sp.

PLATE

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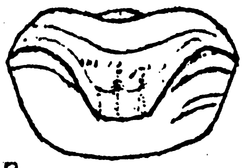

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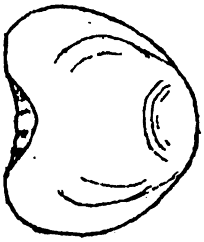

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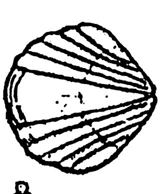
DIVACHONELLA *kahrsi* n.sp.



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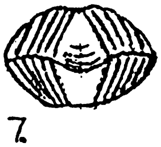

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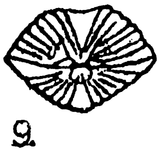

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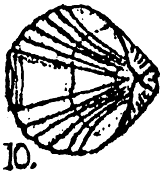
Art by: Franklin Hadley



10.

BRACHYTHYRIS *brooklynensis* n.sp.

Brachiopods from Selected Formations of the Lower Paleozoic Section of Oklahoma

Author: Mark G. Mckinzie
Date: December 1995

INTRODUCTION

Brachiopods were a common and important component of most shelly faunas through out the Paleozoic marine environment in what is now the state of Oklahoma. First appearing in the Cambrian, the inarticulates with their chintinous/phosphatic shells, and then the articulates with their calcareous valves became dominant elements on the sea floor. Their habitats ranged from intertidal pools and mud flats to reef flanks to deep-water shelf settings. They are especially abundant from the middle Ordovician onward through the lower Permian in Oklahoma. In this paper I have tabulated known occurences of brachiopods from selected intervals of the lower Paleozoic (Cambrian through Devonian) in Oklahoma.

I did not attempt to collect data on the Carboniferous and Permian systems for Oklahoma as the Mississippian and Pennsylvanian systems are extensive, especially in the north-east quadrant of the state. Brachiopod listings for this time interval would be long indeed. A good source for a fairly complete and accurate listing of contemporaneous brachiopods can be found in "Texas Pennsylvanian Brachiopods"(1990). Please refer to the references at the back of this article. Permian brachiopods are pretty much confined to the Wolfcampian series as the younger Permian deposits are primarily fluvial/terrestrial in orgin and brachiopods are very rare to non-existent.

REGIONAL GEOLOGY

Oklahoma is blessed in having an extensive and nearly complete lower Paleozoic section exposed in numerous outcrop areas (see Figure 1). These exposures include the Slick Hills area bordering the north-east end of the Wichita Mountains, the Arbuckle Mountains (including the Hunton Uplift near Ada) in the south-central part of the state, and outcrops bordering the Ozark Plateau in the north-east corner of the state. These deposits are primarily shelfal carbonates with minor amounts of shales and sandstones. There are also deep-water facies represented by outcrops in the core of the Quachita Mountains of south-east Oklahoma.

Paleozoic depostion of sedimentary rocks in Oklahoma began in the late Cambrian with the erosion and weathering of Pre-Cambrian and Cambrian igneous basement by the encroaching sea (see Figure 1). This basal unit is called the Reagan Sandstone and consists of arkosic sands and silts derived from direct weathering with little or no transportation. This lithic unit soon gave way to the overlying platform carbonates of the Arbuckle Group as the seas continued to advance, and conditions became optimal for lime precipitation.

Carbonate deposits dominated from the upper Cambrian through the lower Devonian as a fairly stable shelf existed in Oklahoma during this period of time. Of course, there were exceptions to the rule when major marine retreats(regressions) or advances(transgressions) occured due to a combination of tectonic or climatic events (or both!). This period of quiescence ended with a major, continent-wide marine regression and ensuing depostion of the black, anaerobic, organic-rich Woodford Shale.

BRACHIOPOD TABLES

The seven tables listed below represent selected formations from the late Cambrian through the early Devonian in Oklahoma. It is by no means a complete and comprehensive listing of all the brachiopods that can be found in Oklahoma. However, it will give the fossil collector a good jumping off point in identifying some of the more common brachiopods encountered in the lower Paleozoic of Oklahoma. Many readers will no doubt recognize alot of these brachiopods at the generic level with ones they have collected from their home state. This is to be expected as some of these brachiopods were cosmopolitan by nature, and are found in similar deposits across the United States.

The tabulations of brachiopods is based on work done by J.H. Stitt (Reagan Sandstone and Signal Mountain Formation), J.R.Derby (West Spring Creek Formation), G.A. Cooper (Mountain Lake and Pooleville Members of the Bromide Formation), and T.W. Amsden (Henryhouse and Haragan Formations).

CONCLUSION

Brachiopods are not the most sought after and prized of fossils, and they can be easily overlooked if the potential for a complete trilobite or echinoderm is high. However, they have a certain appeal all their own which is based in part on how successfull they were as a phylum during the Paleozoic. They also make good index fossils when used in conjunction with other groups.

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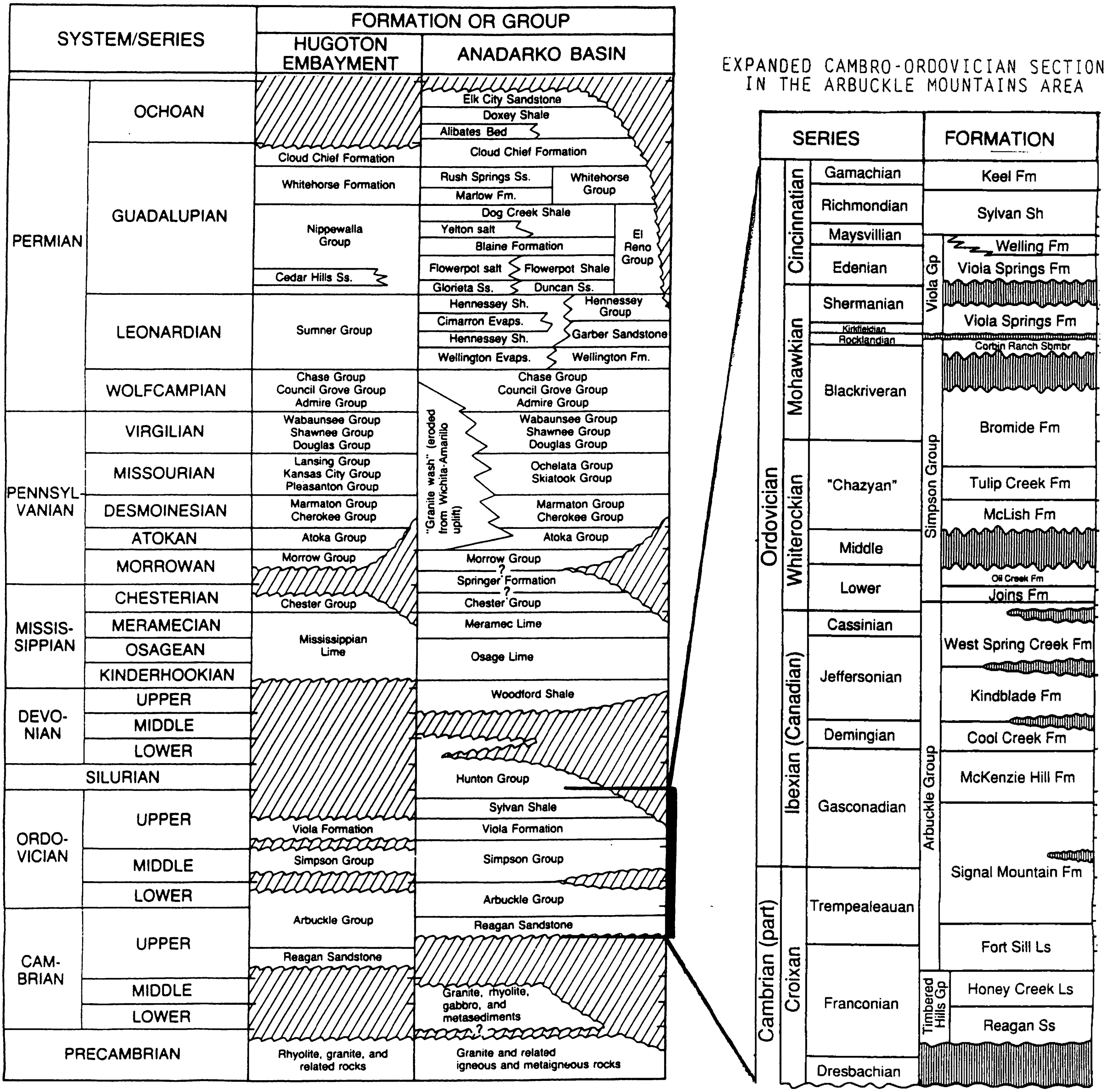
Figure 1. - GENERALIZED STRATIGRAPHIC COLUMN FOR THE LOWER PALEOZOIC SECTION OF OKLAHOMA



modified after Johnson(1988)

modified after Derby(1991)

TABLE 1.- FORMATION/GROUP: Reagan SS./Timbered Hills Gr.
SYSTEM/SERIES/STAGE: Late Cambrian/Croixian sr./Franconian st.
OUTCROP AREAS: Slick Hills, Arbuckle Mountains

ORTHIDS
Billingsella sp.
Eoorthis remnicha, E.indianola

TABLE 2.- FORMATION/GROUP: Signal Mountain Fm./lwr. Arbuckle Gr.
SYSTEM/SERIES/STAGE: Late Camb-early Ord./Croixian - Ibexian sr./
Trempealeauan - Gasconadian st.
OUTCROP AREAS: Slick Hills, Arbuckle Mountains

ORTHIDS
Apheorthis ornata
Finkelburgia sp.
Nanorthis hamburgensis

TABLE 3.- FORMATION/GROUP: West Spring Creek Fm./Arbuckle Gr.
SYSTEM/SERIES/STAGE: Early Ordovician/Ibexian sr./Cassinian st.
OUTCROP AREAS: Slick Hills, Arbuckle Mountains

ORTHIDS
Anomalorthis sp.
Desmorthis nevadensis
Diparelasma typicum, D. sp.
Oligorthis arbucklensis

TABLE 4.- FORMATION/GROUP: Bromide Fm./Simpson Gr.
SYSTEM/SERIES/STAGE: Middle Ord./Mohawkian sr./Blackriverian st.
OUTCROP AREAS: Arbuckle Mountains, Criner Hills, Slick Hills

ORTHIDS
Atelelasma oklahomense
Chaulistomella crassa,C. magna
Chaulistomella mira,C. mundula
Chaulistomella nitens,C. obesa
Fascifera dalmanelloidea
Glyptorthis costellata,G. crenulata
Glyptorthis obesa,G. uncinata
Herperorthis crinerensis,H. sulcata
Mimella extensa,M. subquadrata
Multicostella convexa,M. sulcata
Oepikina expatiata,O. extensa
Oepikina formosa,O. gregaria
Oxplecia filosa,O. gouldi
Pauorthis macrodeltoidea
Plectorthis symmetrica
Skenidoides oklahomaensis
Skenidoides perfectus

SPIRIFIDS
Cyclospira parva
Glosella liumbona
Protozyga costata,P. elongata
Protozyga loeblichi,P. magnicostata

STROPHOMENIDS
Bellimurina compressa
Bellimurina subquadrata
Dactylogonia sculpturata
Dactylogonia subaequicostella
Microcoelia bella
Murinella partita
Neostrophia gregaria
Platymena bellulata
Plectambonites sericeus
Sowerbyella indistincta
Sowerbyella plicatifera
Sowerbyella variabilis,S.vulgata
Sowerbyites hami,S. lamellosus
Strophomena costellata,
S. crinerensis,S. oklahomaensis
Strophomena trentonensis
Valcourea transversa

RHYNCHONELLIDS
Ancistrorhyncha costata
Ancistrorhyncha globularis
Rostricellula cuneata,R.sp.1

TABLE 4. (CON'T)

INARTICULATES

Acanthocrania erecta,A. oklahomaensis
Acanthocrania subquadrata
Craniops tenuis
Ectenoglossa sculpta
Lingula elegantula,L. eva
Lingulasma oklahomaense
Lingulella galba,L. glypta
Orbiculoidea eximia
Pachyglossa biconvexa
Petrocrania inflata,P. sp. 3
Philhedra sp. 1
Plectoglossa oklahomaensis
Psuedolingula imperfecta
Schizambon perspinosum

PENTAMERIDS

Camerella anteroplicata
Camerella oklahomensis

TABLE 5.- FORMATION/GROUP: Viola Springs Fm. & Fernvale Fm./Viola Gr.

SYSTEM/SERIES/STAGE: Late Ord./Late Mohawkian - Cincinnatian sr./
Kirkfieldian - Maysvillian stages
OUTCROP AREAS:(Viola Springs FM) Arbuckle Mountains, Criner Hills
(Fernvale Fm) Ozark Plateau of N.E. Oklahoma

ORTHIDS

Austinella kankakensis,A. whitfieldi
Dinorthis pectinella,D. transversa
Glyptorthis pulchra
Herbertella occidentalis
Herbertella frankfortensis
Hesperorthis tricenaria
Oepikina sp.
Onniella quadrata
Plaesiomys bellistriatus,P. subquadratus
Platystrophia prima

STROPHOMENIDS

Leptellina sp.
Paucicrura rugata
Plectambonites clarksvillensis
Plectambonites rugosus
Sowerbyella sp.
Strophomena incurvata
Tetraphalerella planodorsata

INARTICULATES

Lingula iowensis

RYNCHONELLIDS

Hiscobeccus capax
Lepidocyclus capax,L. cooperi
Lepidocyclus laddi

TABLE 6.- FORMATION/GROUP: Henryhouse Fm./Hunton Gr.

SYSTEM/SERIES/STAGE: Middle-Late Sil./Ludlovian -Pridolian stages
OUTCROP AREAS: Arbuckle Mountains/Hunton Uplift

ORTHIDS

Dalejina henryhousensis,D.subtriangulis
Dicoelosia oklahomensis
Dolerorthis hami
Isorthis arcuaria
Psuedodicoelosia oklahomensis
Ptychopleurella rugiplicata
Resserella brownsportensis
Skenidioides henryhousensis
Strixella acutisulcata

SPIRIFIDS

Atrypa tennesseensis
Delthyris kozlowskii

STROPHOMENIDS

Amphistrophiella prolongata
Amphistrophiella alterniradiata
Amphistrophia loeblichi
Amsdenina roemeri
Anastrophia delicata
Coolinia reedsi
Dictyonella gibbosa
Leptaena oklahomensis
Leptaenisca irregularis
Leptodonta attenuata
Linterella oklahomensis
Lissostrophia cooperi
Lutterella carmelensis

TABLE 6. (CON'T)

SPIRIFIDS

Homoeospira subgibbosa,H. foerstei
Howerella henryhousensis
Merista oklahomensis
Meristina roemeri
Nanospira concentrica,N. parvula
Navispira saffordi
Nucleospira raritas

STROPHOMENIDS

Lutterella altisulcata
Strophonella laxiplicata

RYNCHONELLIDS

Morinorhynchus attentuatus
Undulorhyncha filistriata

TABLE 7.- FORMATION/GROUP: Haragan-Bois'd Arc Formations/Hunton Group

SYSTEM/SERIES/STAGE: Early Devonian/Lockhovian stage
OUTCROP AREAS: Arbuckle Mountains/Hunton Uplift

ORTHIDS

Dalejina oblatus
Dicoelosia varica
Isorthis pygmaea
Pacificocoelia sp.
Platyorthis angusta
Skenidium insigne

SPIRIFIDS

Atrypa oklahomensis
Atrypina hami
Crytina dalmani nana
Howellella cycloptera
Kozlowskiellina velata
Meristella atoka
Navispira virginia
Rensselaerina haragana
Spinoplasia gaspensis
Trematospira sp.
Nucleospira ventricosa

PENTAMERIDS

Gypidula sp.

INARTICULATES

Lingula cuneata
Orbiculoidea media

STROPHOMENIDS

Anastrophia grossa
Anopliopsis pygmaea
Chonetes sp.
Chonostrophiella helderbergia
Leptaena acuticuspidata
Leptaena rhomboidalis
Leptaenisca concava
Levenea subcarinata pumilis
Linterella acutirostella
Orthostrophia strophomenoides
Plectodonta petila
Schellwienella marcidula

RHYNCHONELLIDS

Anchillotoechia haraganensis
Costellirostra singularis
Cupularostrum lindenensis
Cupularostrum glomerosa
Eatonia exserta,E. medialis
Morinorynchus haraganensis
Oburamentella wadei
Rhynchospira maxwelli

BRACHIOPODS

THE WHO WHERE WHY & WHEN OF COLLECTING

Marc Behrendt
421 S. Columbus St.
Somerset, OH 43783

I collect Brachiopods. Is that so bad?
Imagine this scenario:
I run into some collectors at a quarry.

Them "Hi , how's your day been?"

Me "Fantastic, how about you?"

Them "Oh we found a couple. What did you find?" (watching with eager eyes.)

I open my case and display a mass of beautifully complete brachiopods of many species.

Them - (mouths open agape, hands rise in front of faces as they try to look away) " Oh - - that's ......er.... very nice." They walk away, whispering and shaking their heads, looking around to make sure nobody saw them talking to a brachiopod collector.

This story is fictional and a bit silly, yet sometimes I get this impression when I meet up with other collectors in the field. Brachiopod collecting tends not to get the notoriety found among trilobite, crinoid, or other "glamour" fossil circles.

Brachiopod collecting is very enjoyable, offers many surprising challenges, and can can be as addictive as collecting pennies.

The first step is to collect the traditional easy to find specimens. Like pennies, one accumulates many specimens, then sorts through them to find new species to add to the collection. The second step is to find complete 3 - dimensional specimens. For example, Mucrospirifers are abundant in Devonian areas, but how many collectors have a specimen fully complete with the long wing spines intact? The third step is to look for the rare and hard to find varieties. This is when things really get challenging.

Often, just identifying the specimens is the challenge. While separating brachiopods from St. Paul, Indiana, some friends had a pile of several hundred small, very similar looking specimens. When studied closely, they discovered the number of sulcal ridges varied from 3 to 6, even though the brachiopods looked virtually identical.

Another aspect of brachiopod collecting concerns the epifauna - organisms connected to an animal in life or shortly after death. Epifauna alone could constitute a specific collection theme. I've discovered most epifauna after the brachiopods were cleaned. The most common epifauna encountered are typically bryozoa, cornulites, spirorbis, worm tubes, and crinoid holdfasts.

Occasionally a brachiopod is found with an injury, either scarred over, or "fresh". Some gastropods were carnivorous and literally drilled through the valve leaving a hole from which the brachiopod was eaten. Old healed wounds are occasionally apparent, showing an odd pattern or variation to the ornamentation on the valves.

Brachiopods can be collected anywhere fossis can be found. Roadcuts, old quarries, landslide debris - any shale or limestone exposures make great places to collect. Brachiopods can often be found lying on top of the ground, just waiting to be picked up! Surface collecting can be done along rivers, in emergency spillways to dams, or any place the top layer of rock has weathered away.

Brachiopods can be collected any time of the year. Spring is great because the freeze-thaw cycles have opened up new exposures and fresh fossils can be collected. Summer is nice because heavy storms wash all the mud and dust from hidden fossils, making them visible. Fall offers communion with nature as you collect; the scenery is rich with colors and sounds as life prepares for winter. Last, what better way to beat cabin fever than a winter collecting trip along a waterway, or any locale where snow doesn't hide the fossils?

Personally, I enjoy collecting whatever is available at a location. My true loves are trilobites and gastropods, but I like to get a good faunal representation from any site. Collecting brachiopods is a refreshing change after a morning of pounding, splitting, and scouring shale for my favorite species. Very often, as I crawl on my hands and knees to surface collect for brachiopods, I find enrolled trilobites, blastoids, and other interesting fossils.

The biggest two challenges associated with brachiopod collecting are cleaning and displaying the specimens. A separate article is devoted to cleaning and preparing brachiopods.

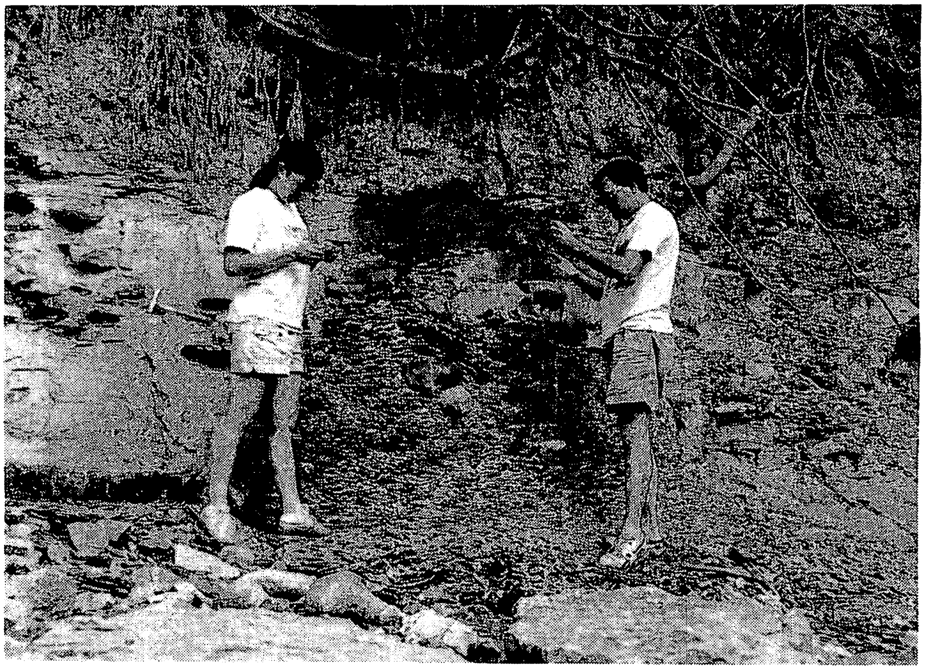
To display all my brachiopod specimens, I would need a small auditorium, so I decided to get organized and determine what specimens I really wanted in my collection. The first thing I did was single out the two best specimens of each species. The duplicates became available for trading or test cleaning. The next step was to store the specimens so they may be protected, yet displayed with ease. This was accomplished by placing them in small open-faced boxes. An identification label fitting neatly in each box, the boxes all fit neatly together in a large storage carton in multiple layers.

My display case is not large. I exhibit my favorite specimens and those of a certain local, which I change periodically.

Collecting brachiopods is a fun and relaxing hobby with its own special charm. A collector can be casual or serious, searching for whatever is around or something specific. The next time you see a BRACHIOPOD, pick it up and look at it closely. You may be surprised by its beauty.

A good brachiopod collector gets close to her collecting area at Caesar Creek State Park in Ohio

Any shale exposure can offer an opportunity to find a brachiopod. Here Margaret Kahrs exposes a fresh layer of shale, soon to yield numerous fossil specimens.



During summer, river banks make great locations to search for fossils of any kind. Here the author and his wife closely check a crumbly shale bank for brachiopods.

Roadcuts offer easy access and easy collecting, such as this Kentucky highway offers

BRACHIOPOD
HOME PREPARATION

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Brachiopod cleaning and preparation is similar to any other invertebrate fossil preparation, yet there are techniques that seem to work especially well on the delicate brachiopod shells.

As with any fossil, good preparation begins in the field. The specimen must be stabilized. Flakey shell areas or fractures must be secured to the specimen. A single drop of thin super glue will penetrate the fractures and run their course. then, just don't toss the brachiopod specimen in a box. If you make the effort to take the specimen home, care should be taken to insure its safety, as any valuable fossil should be protected.

Wrap the specimen in newspaper if it is on matrix or is large enough to not get lost in the paper. Small specimens can be wrapped in squares of toilet paper, then placed into a small container which will protect them.

When I began collecting fossils, I filled several business envelope boxes with many specimens. When I was ready to clean and prepare them, I was dismayed at the terrible condition my specimens were in, and some of them were dandys, too. Careful packing would have preserved those brachiopods, and I would have many more unique specimens.

Once the specimen is home, there are two choices to make - clean it right away or store it. Generally, it is stored. Again, these specimens were hauled all the way home, so continue to make an effort to protect them from crushing, falling, or wetness. A piece of shale that dries after collecting, then gets wet again, may dissolve, as will the fossil it contains.

There are several ways to clean a brachiopod. Methods range from simple to technical. Techniques may require tools as simple as a sewing needle, or complex as with acid bathes. I will deal only with the methods a typical collector may use in the home.

1. Brushing - Often, big, robust surface collected brachiopods come already free of matrix. A toothbrush and a bucket of water may be all that is needed to make the brachiopod shine. Soft shale comes right off the specimen, harder shale may need aggressive brushing or be allowed to soak a bit to be loosened off. Limestone typically will not come off. This is the first step I use after collecting roadcuts. Not only does it remove all the mud and dust, but I can display many specimens directly from the field. Caution : Do not use this method on any matrix or brachiopod that may be the slightest bit fragil or flacky.

2. Chemicals - Dissolving the matrix chemically is a popular method that allows many brachiopods to be cleaned at one time. The most popular chemical used is Quaternary O, which is no longer manufactured, but perhaps you may be able to locate somebody willing to part with some of their stockpile. Resembling black petroleum jelly, it is reusable, and can be used indefinitely. Place about 3 Tablespoons of Quaternary O in a pint of water, then boil the mixture. The jelly - like material dissolves into the water and, then dissolves most shale. Hard, dense shale may take longer, but 15 minutes is usually sufficient. Cool specimens gradually, then rinse them off. The transformation is amazing! All the matrix is gone, and the fossils are intact.

I have been told other strong industrial detergents work similar to Quaternary O , but I have never tried them.

Caution: This will dissolve all matrix. If the brachiopod needs matrix to remain intact, do not use this method. I boil only single valves, or intact, solid brachiopods. A damaged brachiopod may disintegrate if the internal mold is shale. Super glue does not bond for long in the boiling solution. Any repaired specimen should be omitted from the pot.

3. Hand tools - Hand cleaning a specimen is a skill that requires practice and a steady hand. Tools range from tiny chisles and dental tools, to a simple pin vise. When dealing with brachiopods, the pin vise fitted with a typical sewing needle is often the tool of choice. The needle's shape and sharpness is determined and maintained with a sharpening stone. Under a magnifying lens, remove matrix slowly and completely. Dental tools work extremely well on brachiopods, the only difference being the cost of the tools. don't let this procedure's simplicity fool you. Before the advent of chemicals

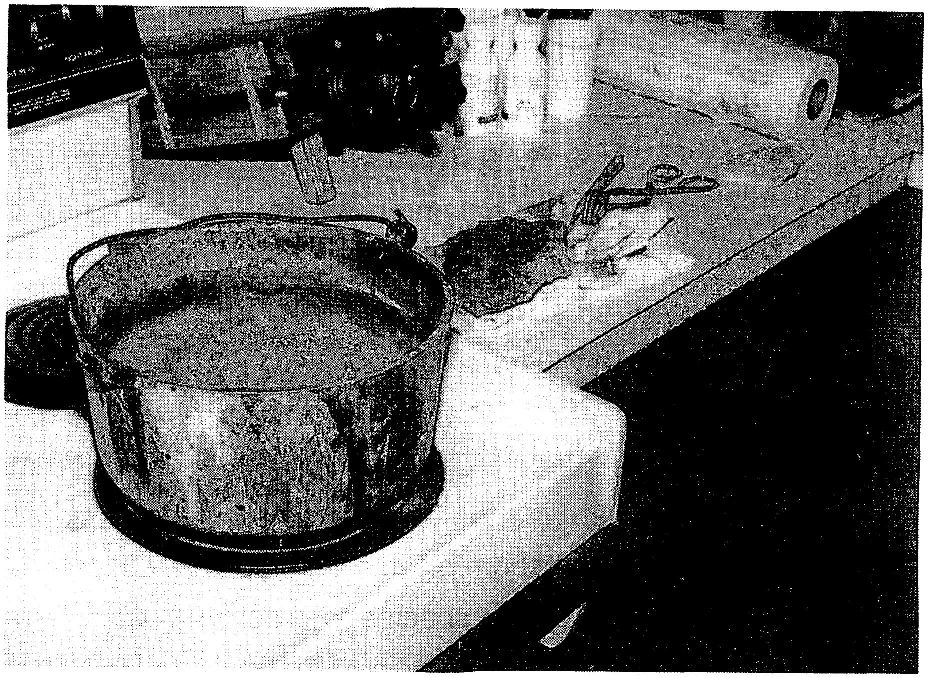
and power tools, most fossils were cleaned by hand tools. The end results of experienced hand tool preparers are absolutely fantastic!

4. The Air Abrasive Machine - Microsandblasting is a popular fossil preparation method . It works very well with brachiopods, however there are drawbacks. Delicate shell articulation may erode with even minimal powder, pressure and flow settings. The most difficult articulation to clean, in my opinion, are lateral growth lines found on many specimens. I have resorted to Quaternary O as the choice method for these kind of brachiopods, if possible. The air abrasive method is a good choice for specimens on matrix, smooth shelled specimens, and for thick shelled, sturdy specimens. The delicate thin shelled brachiopods, which are also the most beautiful when cleaned, require a deft touch and the art of knowing when to stop cleaning; and should not be attempted until one is comfortable dealing with delicate specimens. I always try to collect a few "seconds" of a species to practice clean. This way, I know the specimen's vulnerability and what may or may not work on it. Remember, it is always better to underclean than overclean a specimen.

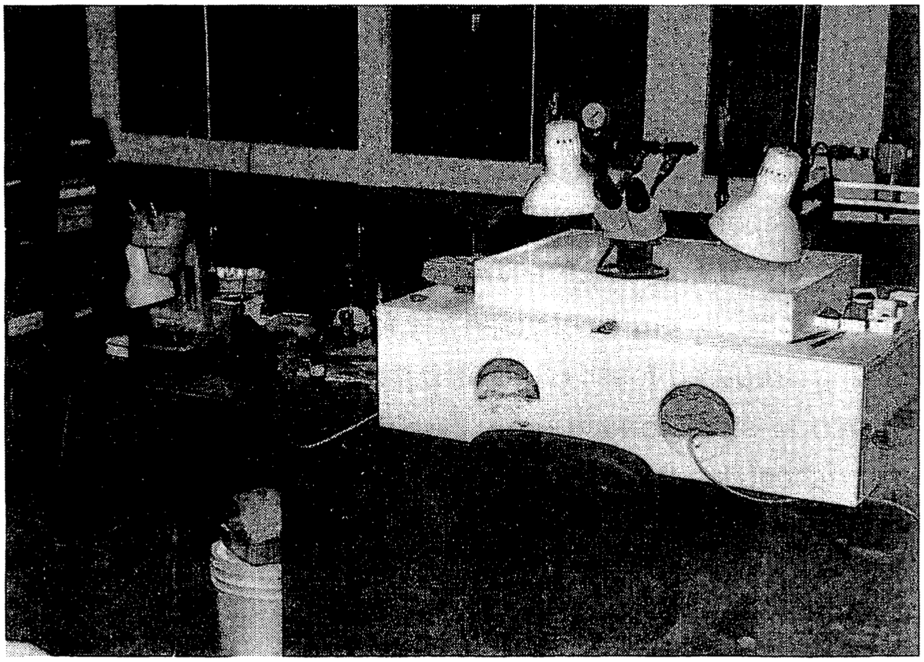
Use low pressure, and stick with the soft powders. I prefer #2 dolomite, but sodium bicarb is also appropriate with deligate specimens. Direct the powder at a very low angle and work on the shell as little as possible. Direct the flow from the beak or pedicle end of the shell, flowing outward to the edges. If you shoot from the edges inward, you may burn away a great deal of the shell. Always direct the flow toward the edge from the pedicle area.

Epifauna is very important to preserve. It offers a window to the relationship of the organisms in their ecosystem. Typically, Epifauna are small and burn off easily. Use great care to maintain the intergrity of these tiny fossils.

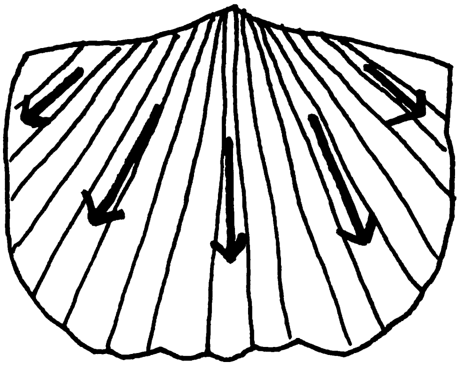
A great looking prepared fossil requires patience, the use of the right procedures and knowing when to stop working on it. Whatever methods are used, practice on seconds until an acceptable level of skill is achieved. Then when it is time to show off your collection, You will shine as brightly as your specimens.



Quaternary O in action. All that is needed is the chemical, water, a pot, a heat source and a brush to remove the mud after the bath is complete



An air abrasive machine requires an enclosed workbox, as well as direct lighting and a good microscope. Note on top right of box, pin vise and needle tip forceps still have a place with air abrasive work.



When cleaning brachiopods, always direct the energy toward the outer edge, or with the grain of the ridges.

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CUYAHOGA FORMATIONS

Mississippian BRACHIOPODS OF OHIO

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The Waverly group of the Mississippian Formations, stretches from the Ohio River in the south, to Lake Erie in the north, where outcrops continue eastward to the Pennsylvania border. Rocks deposited in the latter half of the Mississippian Period are not found in Ohio, and therefore, we can only assume that the state was dry land in the late Mississippian age.

The siltstones, sandstones, limestones and shales of the Waverly Group of Formations all contain fossils, but trying to find top grade fossil specimens is strictly a hit or miss proposition. The preservation varies from faint impressions in shale or siltstone, or hollow molds in sandstone, to well preserved fossils of many varieties in the Cuyahoga Formations. The problem is how to remove the fragile fossil specimens from the hard ironstone concretions, that have imprisoned them and preserved them so well for many millions of years. Over 95 % of the fossils are preserved in the very hard concretions, with about 5 % in fairly good condition being preserved in either layers of shale or siltstone.

My collection has been concentrated in the Cuyahoga Formation in the north central part of Ohio, in which I have drawn sketches of the many sizes and varieties of the brachiopod species that can be found in these formations, and these are only from three small locations in southern Medina County, middle Ashland County, and southern Ashland County.

The brachiopod specimens are all sketched normal sizes from fossils that I have collected, except for the inarticulate brachiopods, which are marked as to magnification to show details of these small fossils.

PLATE - 1

Figures - 1a, & 1b, - show Syringothyris typus, which is one of the largest of the Mississippian brachiopods. Figure 1b shows the very high cardinal area of this particular species. It is 95 mm in width and 55 mm in height.

Figure - 2, Lingula cuyahoga, a very small inarticulate brachiopod on matrix.

Figure - 3, Orbiculoidea newberryi, another small fragile inarticulate brachiopod on matrix.

Figure - 4, Chonetes glenparkensis, one of the smallest of the Mississippian articulate brachiopods, less than one half an inch wide, with spines of the cardinal margin distinctive, but not always preserved.

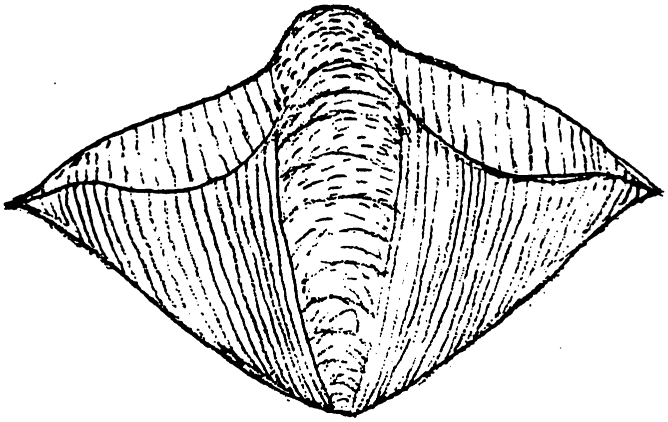
Figures - 5a, and 5b, Camarotoechia and Rhynchopora are here lumped together as they cannot be distinguished by the outside of the shell. They have very characteristic internal structures which are seldom preserved in our Mississippian specimens.

Figure - 6, Chonetes pulchellus, another of the smaller Mississippian brachiopods.

Figure - 7, Athyris sp. which is from the Meadville Member of the Cuyahoga Formation, and shows a little variation by being of a more circular shape, than the normal Athyris lamellosa specimens that are found in the shales of the Cuyahoga Formations near Haysville, Ohio.

Figure - 8, Buxtonia scabricula, is another of the spiney shell productids that has one very convex, and one almost flat valve. Both the concentric and radiating ridges are strong in Buxtonia, but the radiating ridges are interrupted before reaching the edge of the shell, there are also numerous large spine bases showing on the external surface of these shells.

Plate - 1



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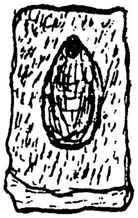

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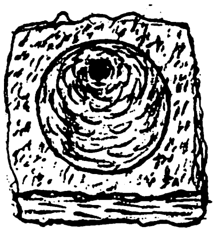

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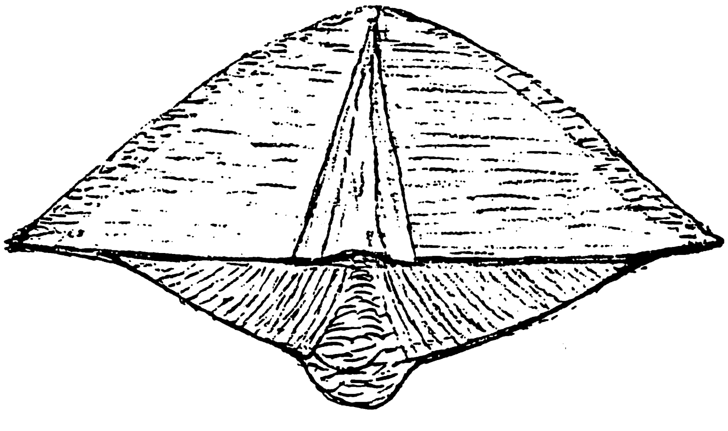

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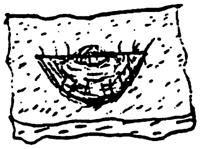

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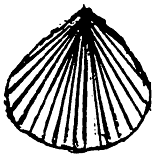

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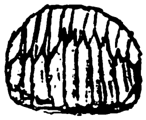

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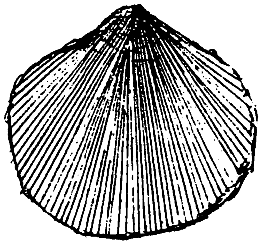

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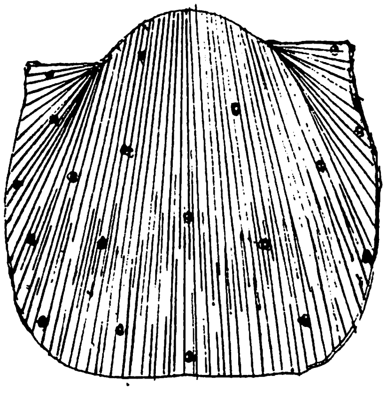

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PLATE -2

Figures - 1a, and 1b, are Spirifer striatiformis, which has a strong sinus and fold, as in Syringothyris, but a lower cardinal area which is characteristic of this species. Being an internal cast without a shell, it shows part of the internal structures.

Figures - 2a, and 2b, shows the side and bottom views of the small Girtyella flora, brachiopod.

Figure -3, is a Schuchertella sp., brachiopod, and the only one that I have. It has a perfectly flat valve on the interior surface of a concretion from the Meadville Member of the Cuyahoga Formation in Medina County.

Figure - 4, two Ptychospira magna, shells found on inside surfaces of split concretions.

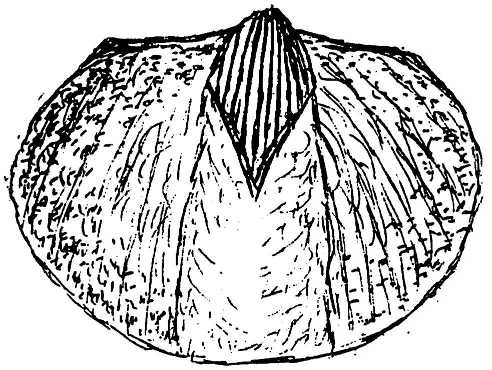
Figures - 5a, and 5b, are top and side views of Productus spinulicosta, semielliptical in outline with surface marked by strong concentric lines, with several rows of interrupted spine bases. Note two spines extending from shell base onto the matrix in Fig. 5a.

Figures - 6, and 8, are of Productus sp., from the Meadville Member of the Cuyahoga Formation of Medina County.

Figure - 7, Torynifer pseudolineata, a brachiopod that is imbeded in the base of a large Platyceras snail.

Figure - 9, Schellwienella sp., which is represented in the Cuyahoga by one species.

Plate - 2



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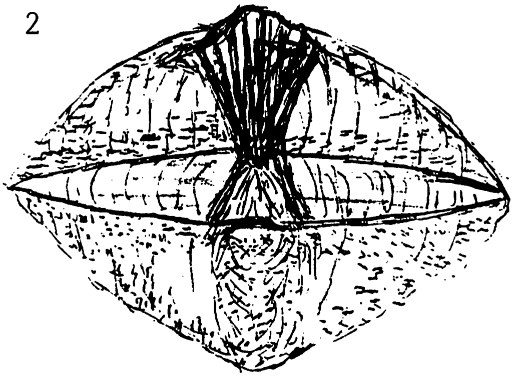

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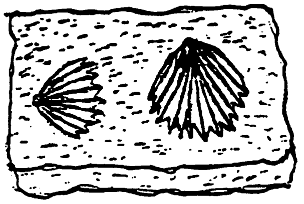

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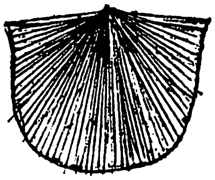

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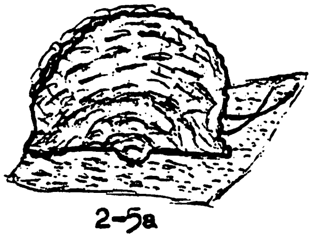

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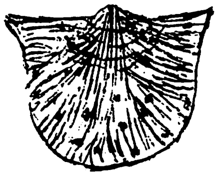

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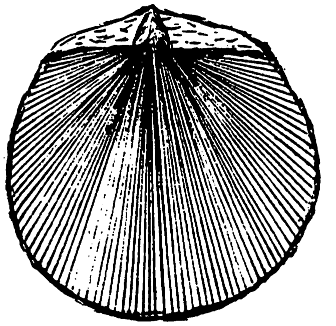

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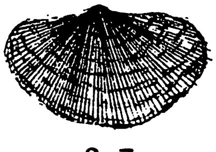

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PLATE - 3

Figures - 1a, and 1b, are views of the top and hinge line view showing the cardinal area of Spirifer centronatus, along with the coarse ridges, radiating outward from the hinge line.

Figures - 2a, and 2b, are of a large Girtyella sp., brachiopod from the shale location in Ashland County.

Figure - 3, Athyris lamellosa, usually wider than high, and is found in the Cuyahoga and Logan Formations.

Figures - 4a, and 4b, is a variety of Productus, found in the concretions from the southern Ashland county formations of the Cuyahoga Formation.

Figure - 5, Avonia concentrica, a medium wrinkled shell with scattered spine bases.

Figure - 6, is a medium thin shell with one slightly convex and one almost flat valve. The radiating ornamentation is distinct but fine and thread-like, with a very short hinge line, the Ripidomella oweni is almost circular in shape.

Figure -7, Dictyoclostus bovis, is another large Productid, having one convex and one nearly flat valve. It is separated externally from Buxtonia by its continuous radiating ridges and the lack of spine bases on the external shell.

Figure - 8, Strophalosia beecheri, a small brachiopod with concentric wrinkles and scattered spines. The spines are seldom preserved, but their position is indicated by the broken bases. The surface also has low wart-like bumps.

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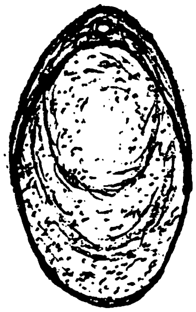
Bulletin 54, Ohio Fossils, by Aurele La Rocque and Mildred Fisher Marble, Division of Geological Survey, Fourth Printing, 1961

Plate - 3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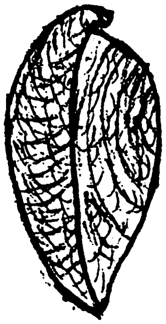
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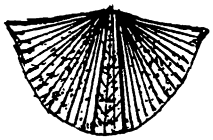
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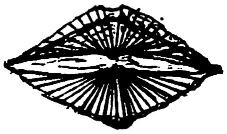
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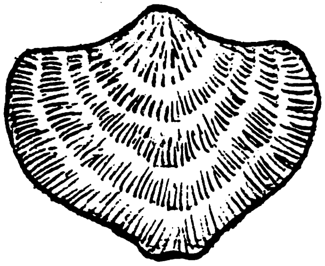
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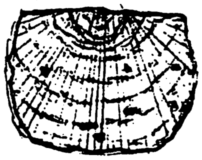
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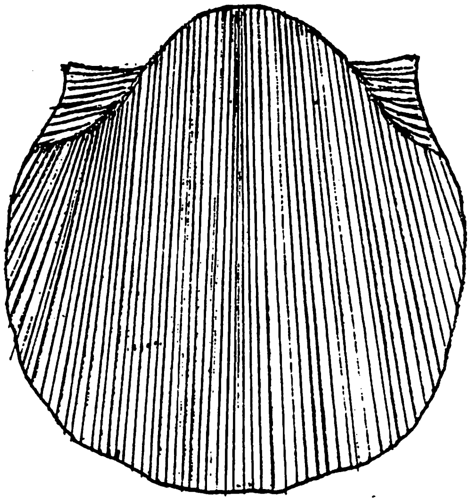
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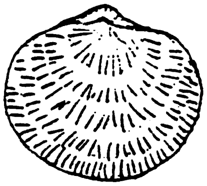
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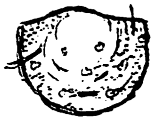
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TEXAS PENNSYLVANIAN CHONETIDS

by
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Paleontology Section, Houston Gem and Mineral Society

Abstract

Seas of the Texas Pennsylvanian Period were home to a wide variety of vertebrate and invertebrate animals. Phylum Brachiopoda was well represented with sixty-seven genera and one hundred and sixty-five species reported in the professional literature. Chonetids are a special part of brachiopods due to their excellent preservation, which makes them prized by professional and amateur collector alike. Six chonetid genera found in the Texas Pennsylvanian are *Eolissochonetes* Hoare, 1960; *Lissochonetes* Dunbar and Condra, 1932; *Mesolobus* Dunbar and Condra, 1932; *Quadrochonetes* Stehli, 1954; *Chonetinella* Ramsbottom, 1952 and *Neochonetes* Muir-Wood, 1962. These six genera are represented by twenty-nine species. Differences between genera and species are detailed for identification.

Introduction

Pennsylvanian Period oceans were rich in all marine vertebrate and invertebrate life including brachiopods and their numbers only declined toward the poles. Major Texas Pennsylvanian outcrops occur in central and north-central Texas along the drainage systems of the Colorado and Brazos Rivers with minor exposures in West Texas in the Marathon and Solitario. Locations of Texas Pennsylvanian Rock Outcrops are shown in Figure 1. Road cuts in the central/north central hill country provide a wealth of invertebrate specimens including the chonetids, some of the smaller but most fascinating brachiopods. Chonetids are valued by collectors because of their excellent preservation.

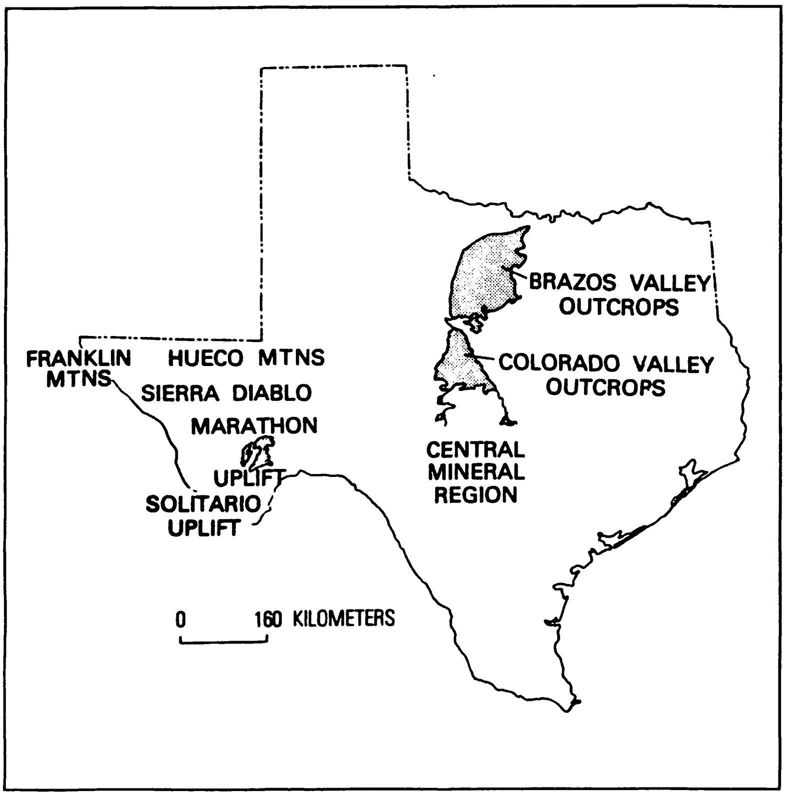


Figure 1. Texas Pennsylvanian Rock Outcrops
(after Kier, Brown and McBride, 1980)

Chonetids existed in large numbers in shallow, warm seas, world-wide, for over 200 million years from the Silurian Period through the Jurassic Period. These small brachiopods were well adapted for free (unattached) living on the ocean floor. Flat, wide shapes of chonetid shells probably kept them from sinking into the sediments from the bottom surface. Rudwick, 1970 felt muscle scars on shell interior indicated an ability to flap the valves, hence to move and right themselves when overturned.

Frequency of chonetids in Pennsylvanian sediments demonstrates their great success. Cate and Evans, 1992 conducted an investigation of six Texas brachiopod genera for population and life history studies. They concluded that chonetids often grew to maturity and were better adapted to their unattached, bottom dwelling life style than the attached spirifers.

Each Pennsylvanian depositional system or group had its own particular set of brachiopod genera and species. Different chonetids in each of the Texas Pennsylvanian Groups are shown in Figure 2. Knowledge of chonetid occurrence in geological formations is essential to identification.

Texas Group	Series	Chonetids
Marble Falls [a]	Morrow	*Chonetinella choteauensis, Lissochonetes derelictus and Neochonetes dominus.*
Smithwick [a]	Atoka	*Eolissochonetes keyesi and Lissochonetes derelictus.*
Strawn	Desmoines	*Chonetinella primitiva, Chonetinella robusta, Chonetinella verneuiliana, Chonetinella verneuiliana wyandottensis, Lissochonetes derelicta, Mesolobus decipiens, Mesolobus euampygus, Mesolobus inflexus, Mesolobus lioderma, Mesolobus mesolobus, Mesolobus rochellensis, Neochonetes acanthophorus, Neochonetes brazoensis, and Neochonetes granulifer.*
Canyon	Missouri	*Chonetinella alata, Chonetinella plebia, Chonetinella rostrata, Chonetinella verneuiliana, Lissochonetes primarius, Neochonetes brazosensis and Neochonetes granulifer.*
Cisco	Virgil	*Chonetinella alata, Chonetinella flemingi, Chonetinella rostrata, Chonetinella verneuiliana, Lissochonetes geinitzianus, Neochonetes granulifer , Neochonetes granulifer emaciatus, Neochonetes meekanus, Neochonetes puebloensis, Neochonetes transversalis, Quadrochonetes geronticus and Quadrochonetes plattsmouthensis.*

[a] = Undifferentiated from formation.

Figure 2. Chonetids in Different Texas Pennsylvanian Groups

Classification

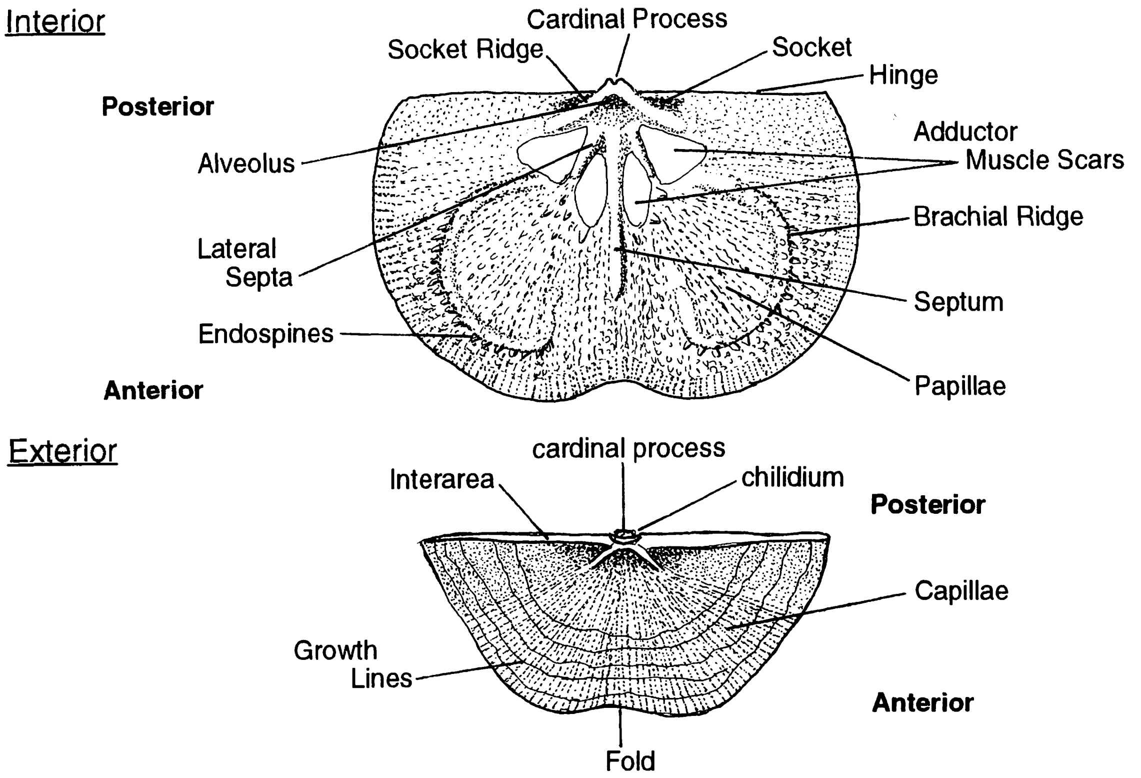
Three basic characteristics separate chonetids from other brachiopods: 1.) a medium septum in each valve; 2.) spines in single file on posterior edge of pedicle valve with roots penetrating the interarea and 3.) tiny spines or spinules, normally seen as scars.

Morphology

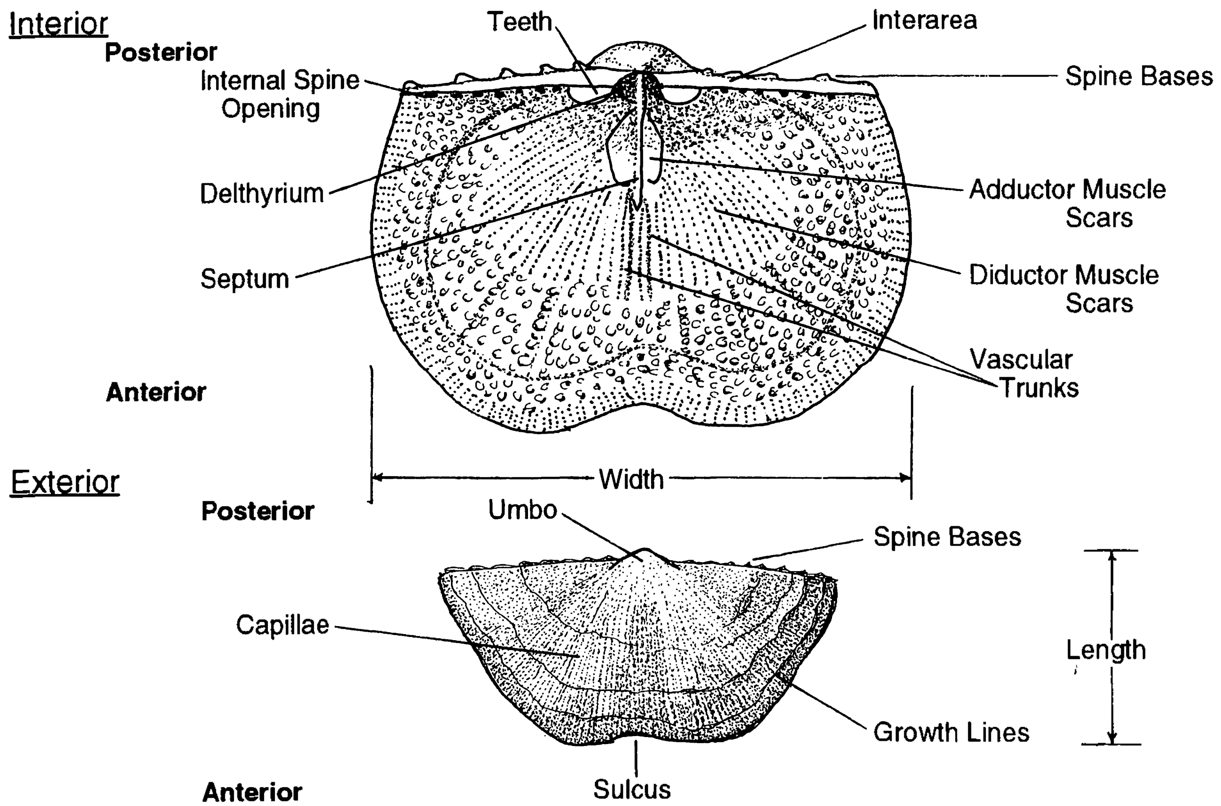
External chonetid shell shape ranges from nearly flat to cup-shaped. Pedicle valve (ventral side) is convex and brachial valve (dorsal side) is concave. Shape outlines are semicircular, alate, elongate and quadrate. Some chonetids have ears or triangular extensions of the cardinal extremities giving an alate shape. Hinge is found at the top of the shell and is considered posterior. Up to ten spines on a side can be found along the hinge in a single line. Spinules, tiny spines, occur on the shell surface, but are most often found as scars of their base. Hinge spines are speculated to extend the body area and lend stability in soft sediments. Spinules may have served as strainers. External ornament can be plain as in *Quadrochonetes*, *Lissochonetes* and *Eolissochonetes* or radial as in*Chonetinella, Neochonetes* and some *Mesolobus*. Radial ornament is broken down into three arbitrary strengths based on number of ridges/10 mm.

Internal structure is infrequently seen as both valves are normally found together but is essential for species identification. See Figures 3 for Features of Chonetid Shells and Figure 4 for Features of a Chonetid Hinge Line. Definitions of some internal and external features are as follows:

Adductor muscle scars indicate paired muscles that close the shell and are located close to either side of the medium septum.
Alate means shell shape is modified by extensions of the hinge line (ears or wings).
Alveolus is a round pit at the base of the cardinal process.
Beak is the usually pointed end of the umbo.
Brachial ridges are internal bilateral ridges extending in a semicircular pattern from the posterior of the adductor scar.
Brachial valve (dorsal side) is the plane or concave valve containing the cardinal process, sockets and septum.
Cardinal Process is a shell projection at the central posterior end of the brachial valve interior for the attachment of diductor muscles which are used to open the shell.



Brachial Valve



Pedicle Valve

Figure 3. Features of Chonetid Shells

Chilidium, or chilidial plates, are plate(s) partially covering the notothyrium externally.
Capillae is radial ornament of more than 25 ridges/10 mm.
Costae is radial ornament of less than 15 ridges/10 mm.
Costellae is radial ornament of 15 - 25 ridges/10 mm.
Delthyrium is the triangular opening in the pedicle valve for pedicle.
Dental sockets are hollows for hinge teeth.
Diductor muscle scars indicate paired muscles for opening the shell and extend from the cardinal process in the brachial valve to large scars in the pedicle valve.
Ears (or wings) are triangular extensions of the valve at the cardinal or hinge line extremities.
Fold is a large, medianly placed, radial elevation in either valve (usually brachial) affecting both inner and outer surfaces.
Hinge Line is the straight posterior margin of brachiopod shell.
Interarea is a plain or lined area along the hinge interrupted by the delthyrium in the pedicle valve and sometimes by the notothyrium in the brachial valve.
Lateral septa are ridges shorter than and diverging from the medium septum.
Notothyrium is a three sided opening in the brachial valve interarea.
Papillae, or endospines, are short internal projections.
Pedicle valve (ventral side) is the convex valve (usually larger) containing the teeth, septum, vascular and pedicle attachment (if present).
Reflexed means bent or turned back.
Septum (septa) is an internal ridge(s) such as the vertical median septum.
Socket ridges are next to the hinge sockets and are parallel to the hinge and extending from the cardinal process.
Spine angle is the angle spines form to the hinge line.
Spinules are tiny spines rarely preserved but seen as base scars.
Sulcus is a large, medianly placed, radial depression in either valve (usually pedicle) affecting both inner and outer surfaces.
Teeth are projections in the pedicle valve on either side of the delthyrium that articulate with dental sockets in the brachial valve.
Umbo is the posterior median portion of either valve containing the beak.
Vascular Trunks are branches of mantle canal system in the pedicle valve seen as ridges on either side the medium septum.

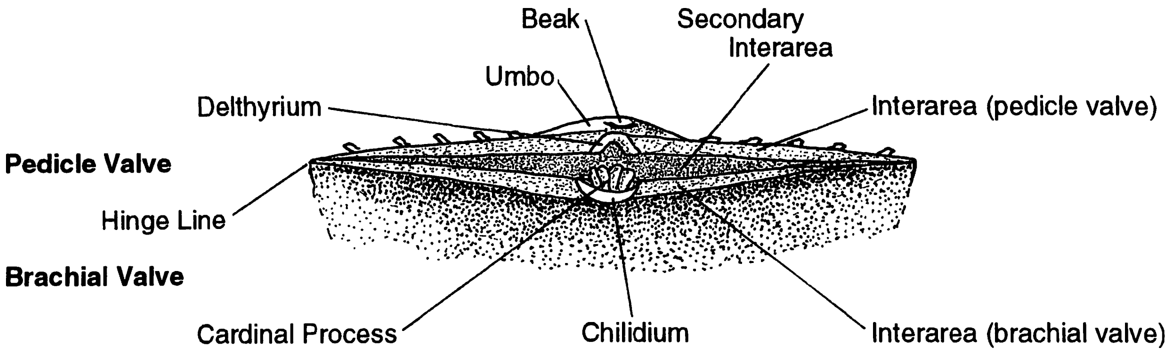
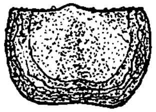
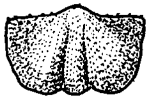
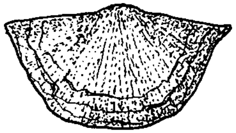


Figure 4. Features of an External Chonetid Hinge Line

See Figure 5 for A Comparison of the Six Genera of Suborder CHONETIDINA in the Texas Pennsylvanian.

Systematic Descriptions

Phylum BRACHIOPODA Dumeril, 1806
Class ARTICULATA Huxley, 1869
Order STROPHOMENIDA Opik, 1934
Suborder CHONETIDINA Muir-Wood, 1955
Superfamily CHONETACEA Shrock and Twenhofel, 1953
Family CHONETIDAE Bronn, 1862
Subfamily RUGOSOCHONETINAE Muir- Wood,1962

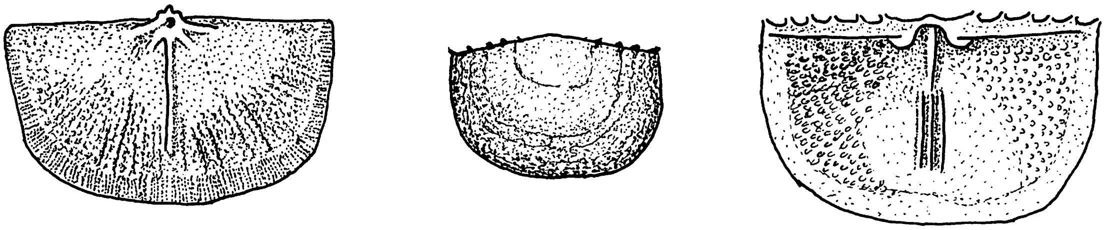
Genus	*Eolissochonetes*	*Lissochonetes*	*Mesolobus*	*Quadrochonetes*	*Chonetinella*	*Neochonetes*
Species	*keyesi*.	*derelictus*, *geinitzianus* and *primarius*.	*decipiens*, *euampygus*, *inflexus*, *lioderma*, *mesolobus* and *rochellensis*.	*geronticus* and *plattsmouthensis*.	*alata*, *choteauensis*, *flemingi*, *plebia*, *primitiva*, *robusta*, *rostrata*, *verneuiliana* and *v. wyandottensis*.	*acanthophorus*, *brazosensis*, *dominus*, *granulifer*, *granulifer emaciatus*, *meekanus*, *puebloensis* and *transversalis*.
Size	X1 	X2 	X2 	X1 	X1 	X1 
Shape	Like *Lissochonetes* but smaller. Pedicle valve sulcus less prominent. Less defined brachial ridges.	Slightly concavo-convex. Slight sulcus and fold.	Moderately concavo-convex. Pedicle valve median sulcus with fold. Brachial valve fold with sulcus.	Strongly concavo-convex. Quadrate. Prominent sulcus-fold. Large ears.	Large ears. Very concavo-convex. Deep sulcus-fold.	Plano-convex to slightly concavo-convex. May have pedicle valve sulcus.
Hinge Spines Spine Angle	5-7/side. 37°.	Spine row. 40°.	Oblique spines. 40°.	Spines. 75°.	Parallel to hinge. Low angle.	"Numerous." Low angle.
Internal Features	Long brachial valve median septum. Short lateral septa. Alveolus present. Cardinal process in contact with inner socket ridges. Vascular trunks.	Short pedicle valve median septum. Brachial valve septum anterior or absent. Short lateral septa. Socket ridges along hinge.	High pedicle valve median septum. Long brachial valve lateral septa. Narrow inner socket ridges parallel to hinge. Vascular trunks.	Low brachial valve median septum being half valve length. Brachial valve ridges obscure or absent. Socket ridges short and curved. Papillae in radiating rows.	Long median septum. Alveolus present. Socket ridges long. Cardinal process small. Brachial valve ridges prominent.	Brachial valve median septum elevated anteriorly. Short lateral septa. Inner socket ridges present and usually outer ridges.
Ornament	Smooth except for growth lines.	Smooth except for growth lines.	Capillae and growth lines or smooth. Many spinules.	Smooth.	Capillae. Growth lines. Spinules.	Capillae. Growth lines.
Texas Pennsylvanian Group	Smithwick [a].	Canyon, Cisco and Smithwick [a].	Strawn.	Cisco.	Canyon, Cisco, Strawn and Marble Falls [a].	Canyon, Cisco, Strawn and Marble Falls [a].

[a] = Undifferentiated from formation.

FIGURE 5. A Comparison of Different Genera of Suborder CHONETIDINA in the Texas Pennsylvanian

Genus *Eolissochonetes* Hoare, 1960

Smithwick Group in Texas
Pennsylvanian (Atoka, Desmoines and Morrow Series) Period World-wide



brachial valve interior X3 pedicle valve exterior X2 pedicle valve interior X3

Eolissochonetes keyesi Muir-Wood, 1962

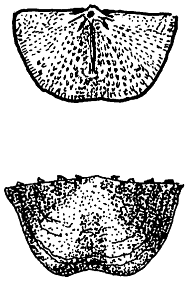
Type Species: *Chonetes laevis* Keyes, 1888 = *Eolissochonetes keyesi* Muir-Wood, 1962. *Eolissochonetes* are thought to be intermediate between *Mesolobus* and *Lissochonetes* and probably derived from *Mesolobus*. They are moderately sized and somewhat rectangular in shape with a wide low sulcus on the pedicle valve. Ornament consists only of growth lines. Spines number 5-7 on each side of the pedicle valve umbo. Two teeth, used in articulating the shell, are found at the base of the interarea. Medium septum is found between the teeth and extends anteriorly. Vascular trunks are found either side of the medium septum. Important Identifying Features: Brachial valve has a prominent median septum low brachial ridges. *Eolissochonetes* is smaller than *Lissochonetes* and has a shallower pedicle valve median sulcus. Occurrence: Iowa, Missouri, Oklahoma and Texas.

Texas Species: *Eolissochonetes keyesi* Muir-Wood, 1962. See Figure 6 for A Comparison of Different Texas Pennsylvanian *Eolissochonetes*, *Lissochonetes* and *Quadrochonetes* Species.

Genus *Lissochonetes* Dunbar and Condra, 1932

Canyon, Cisco and Smithwick Groups in Texas
Permian and Pennsylvanian (Atoka, Missouri and Virgil Series) Periods World-wide

brachial valve interior X2

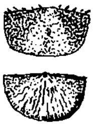
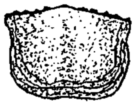


pedicle valve exterior X2

Lissochonetes geinitzianus (Waagen, 1884)

Type Species: *Chonetes geinitzianus* Waagen, 1884 = *Chonetes glaber* Geinitz, 1866. *Lissochonetes* are medium-sized and concavo-convex shaped. Hinge represents the greatest width and interarea is narrow. Ornament is fine growth lines. Brachial valve cardinal process is bilobate or quadrilobate. Brachial ridges are well developed. Medium sulcus and fold are gentle. Spines are at a 35-40 degree angle to the hinge and spinules are developed. Important Identifying Features: Brachial valve is often reduced and brachial ridges are prominent. *Lissochonetes* is more rounded in outline than *Qudrochonetes* and has less prominent ears and spines are at a lower angle. Occurrence: Asia, Australia, Europe, Idaho, Kansas, Nebraska, North Africa, South America, Texas and Wyoming.

Texas Species: *Lissochonetes derelictus* (King, 1938), *Lissochonetes geinitzianus* (Waagen, 1884) and *Lissochonetes primarius* King, 1938. See Figure 6 for A Comparison of Different Texas Pennsylvanian *Eolissochonetes*, *Lissochonetes* and *Quadrochonetes* Species.

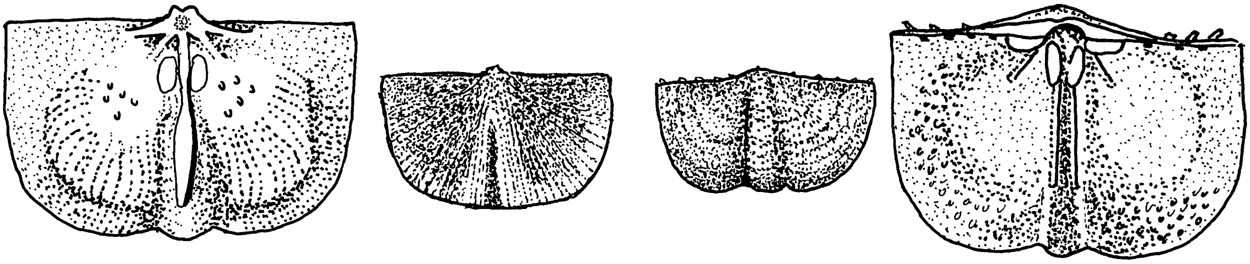
Genus	*Eolissochonetes*	*Lissochonetes*			*Quadrochonetes*	
Species	*keyesi* Muir-Wood, 1962	*derelictus* (King, 1938)	*geinitzianus* (Waagen, 1884)	*primarius* King, 1938	*geronticus* (Dunbar and Condra, 1932)	*plattsmouthensis* (Dunbar and Condra, 1932)
Size, X1						
Shape	Rectangular. Plano-convex.	Semicircular. Concavo-convex. High umbo.	Semicircular.	Quadrate. Very convex.	Quadrate. Quite concavo-convex. Big ears. Deep sinus-fold.	Quadrate. Sinus-fold.
Width Length	15 mm. 10 mm.	19 mm. 14 mm.	15 mm. 8 mm.	16 mm. 11 mm.	11 mm. 6 mm.	12 mm. 7.5 mm.
Hinge Spines Spine Angle	5-7/side. 37°.	5-6/side. 65°.	5-6/side. 37°.	7-8/side. 45°.	5/side. 75°.	Not reported. 75°.
Internal Features	Brachial valve has rows of papillae fusing into radial ribs. Strong brachial valve median septum separates it from *Lissochonetes*.	Pedicle valve has strong adductor muscle scars. Diductor scars are triangular. Brachial valve has papillae with some endospines.	Brachial valve cardinal process quadrilobate. Alveolus. Deep sockets. Papillae. Pedicle valve has short median septum. Teeth broad. Muscle scars obscure.	Pedicle valve teeth oblique. Median septum extends below shell mid-length. Brachial valve papillae in radial rows.	Similar to *Lissochonetes geinitzianus*.	Similar to *Lissochonetes geinitzianus*.
Ornament	Smooth except for growth lines.	Smooth but transparent shell reveals inner lirae.	Smooth. Concentric growth lines.	Smooth. Growth lines. Spinule scars.	Smooth. Growth lines.	Smooth. Growth lines.
Comparison	Similar to *Mesolobus* except for extra sinus-fold of *Mesolobus*.	No sinus like *Mesolobus*.	No comparison discussed.	More convex than *geinitzianus*.	Strong lobation. Small size. Pedicle valve larger than brachial valve.	More semi-circular than *geronticus*. More concavo-convex than *geinitzianus*.
Group	Smithwick [a].	Marble Falls [a] and Smithwick [a].	Cisco.	Canyon.	Cisco.	Cisco.
Formation	Smithwick.	Lemons Bluff Member and Smithwick.	Harpersville.	Caddo Creek.	Harpersville.	Graham and Thrifty.

[a] = Undifferentiated from formation.

Figure 6. A Comparison of Different Texas Pennsylvanian *Eolissochonetes*, *Lissochonetes* and *Quadrochonetes* Species

Genus *Mesolobus* Dunbar and Condra, 1932

Strawn Group in Texas
Permian and Pennsylvanian (Desmoines Series) Periods World-wide



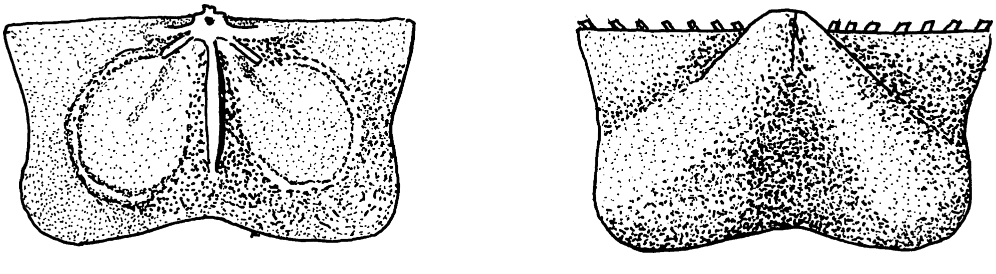
interior X6 exterior X4 exterior X4 interior X6
brachial valve **pedicle valve**
Mesolobus mesolobus (Norwood and Pratten, 1855)

Type Species: *Chonetes mesolobus* Norwood and Pratten, 1855. *Mesolobus* are very small and fairly concavo-convex shaped shells. A sulcus in the pedicle valve has a middle fold and a corresponding fold in the brachial valve has a middle sulcus as indicated by the name. A reflexed dorsal interarea, pseudodeltidium and chilidium or chilidial plates are present. Ornament is smooth or capillate with many spinules on the shell. Spines protrude at a 30-35 degree angle to the hinge. Brachial valve internal features include a modest bilobed cardinal process, a long median septum and narrow, long sockets parallel to the hinge. Important Identifying Features: Median fold is in the pedicle valve and a median sulcus is in the brachial valve. Capillate surface separates *Mesolobus* from the smooth *Lissochonetes*. Occurrence: Europe, Idaho, Illinois, Indiana, Iowa, Kansas, Missouri, Ohio, Oklahoma and Texas.

Texas Species: *Mesolobus decipiens* (Girty, 1911), *Mesolobus euampygus* (Girty, 1911), *Mesolobus inflexus* (Girty, 1927), *Mesolobus lioderma* Dunbar and Condra, 1932, *Mesolobus mesolobus* (Norwood and Pratten, 1855 and *Mesolobus rochellensis* King, 1938. See Figure 7 for A Comparison of Different Texas Pennsylvanian *Mesolobus* Species.

Genus *Quadrochonetes* Stehli, 1954

Cisco Group in Texas
Permian and Pennsylvanian (Virgil Series) Periods World-wide



brachial valve interior X4.5 pedicle valve exterior X4.5
Quadrochonetes gertyi Stehli, 1954

Type Species: *Quadrochonetes girtyi* Stehli, 1954 = *Chonetes quadratus* Girty, 1929. *Quadrochonetes* are rectangular shaped and very concavo-convex. A deep ventral sulcus is matched by an outstanding dorsal fold. Ears are prominent and the ventral umbo is incurved. No ornament exists except for fine growth lines. Spines are about seven/side and lie at a 75 degree angle to the hinge. Internally, medium septum is short and heavy. Brachial valve cardinal process is small and an alveolus exists beneath it. Medium septum is about half total shell length and lateral septa are short. Brachial ridges are obscure and papillae occur in radiating rows. Important Identifying Features: Quadrate shape, deep sulcus-fold and flat ears separates *Quadrochonetes* from the other chonetids. Occurrence: Arizona, Kansas, Nebraska, Russia and Texas.

Texas Species: *Quadrochonetes geronticus* (Dunbar and Condra, 1932) and *Quadrochonetes plattsmouthensis* (Dunbar and Condra, 1932). See Figure 6 for A Comparison of Different Texas Pennsylvanian *Eolissochonetes*, *Lissochonetes* and *Quadrochonetes* Species.

Genus *Mesolobus*

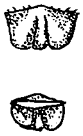
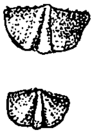
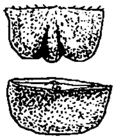
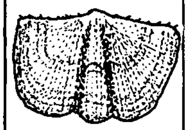
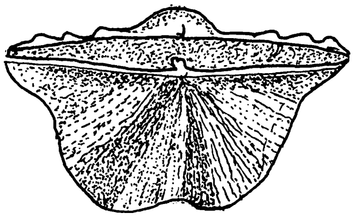
Species	*decipiens* (Girty, 1911)	*euampygus* (Girty, 1911)	*inflexus* (Girty, 1911)	*lioderma* (Dunbar and Condra, 1932)	*mesolobus* (Norwood and Pratten, 1855)	*rochellensis* King, 1938
Size	X1 	X1 	X1 	X1 	X1 	X2 
Shape	Subquadrate. Umbo not prominent.	Small. Deep lobation. Strong convexity.	Prominent median and lateral lobes. Median lobe narrow and depressed.	Transversely subquadrate. Median sulcus 1/5th shell width.	Transversely subquadrate. Moderately arched.	Large and long. Deep, narrow sinus with sharp fold. Low convexity.
Width Length	12-13 mm. 7-8 mm.	7-8 mm. 5-6 mm.	16 mm. 11 mm.	11 mm. 6 mm.	14 mm. 8 mm.	15 mm. 10 mm.
Hinge Spines Spine Angle	6-7/ side. 30°.	6-7/ side. 30°.	6-7/ side. 30°.	Up to 7/side. 27°.	6-7/ side. 30°.	9/side. 35°.
Internal Features	Not described. Was *mesolobus* subspecies.	Not described. Was *mesolobus* subspecies.	Not described. Was *mesolobus* subspecies.	Muscular and vascular markings distinct. Median septum 3/4th shell length. Radial rows of papillae.	Radial rows of papillae.	Radial rows of papillae.
Ornament	Smooth. Rare spinules. Growth lines.	Usually smooth. Some with faint radial lines.	Radial capillae.	Smooth. Spinules.	5 radial lines/mm. Spinules.	Smooth. Growth lines.
Comparison	Similar to *mesolobus* but less convex. Feeble lobation. Nonlobate ones are like *Eolissochonetes keyesi.*	Smaller than *decipiens* and shows deeper lobation.	Most similar to *rochellensis*. Radial lines and depressed median lobe separate it.	Similar to *mesolobus* but smooth. Less arched than *euampygus* and more than *decipiens*.	Similar to *lioderma* but not smooth. Also median sulcus ridges not so steep.	Similar to *inflexus* but without ornament. Strong lobation and low convexity separate it.
Group	Strawn.	Strawn.	Strawn.	Strawn.	Strawn.	Strawn.
Formation	Mineral Wells.	Mineral Wells.	Millsap Lake.	Mineral Wells.	Mineral Wells.	Millsap Lake.

Figure 7. A Comparison of Different Texas Pennsylvanian *Mesolobus* Species

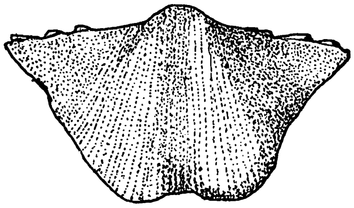
Subfamily CHONETINELLINAE Muir-Wood, 1962

Genus *Chonetinella* Ramsbottom, 1952

Canyon, Cisco, Marble Falls and Strawn Groups in Texas
Permian and Pennsylvanian (Desmoines, Missouri, Morrow and Virgil Series) Periods World-wide

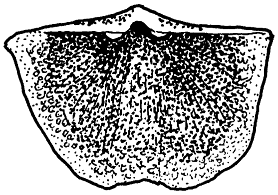


brachial valve exterior X4



pedicle valve exterior X4

Chonetinella verneuiliana wyandottensis (Newell, 1934)



pedicle valve interior X2

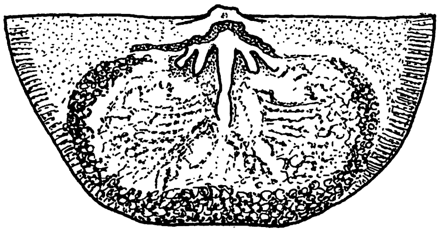
Chonetinella robusta (King, 1938)

Type Species: *Chonetes flemingi* Norwood and Pratten, 1855. *Chonetinella* are small and markedly concavo-convex with a prominent sulcus-fold. Greatest width is at the hinge line and ears are outstanding. Six to seven spines are on each side of the beak with the angle to the hinge of about 31 degrees. Spinule scars mar shell exterior. Pedicle valve interior has a very elevated medium septum ending mid-length. Diductor scars are large and endospines are present. Brachial valve interior has a bilobate cardinal process with a depression at the base. Inner socket ridges are weak and outer ridges are small. Brachial ridges are prominent and endospines are in radial rows. Important Identifying Features: Pedicle valve has a marked median sulcus usually bordered by high ridges. Occurrence: Asia (India), Europe (the Alps and Great Britain), Kansas, Maryland, Missouri, Nebraska, Oklahoma, South America and Texas.

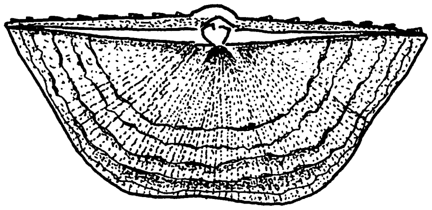
Texas Species: *Chonetinella alata* (Dunbar and Condra, 1932), *Chonetinella choteauensis* (Mather, 1915), *Chonetinella flemingi* (Norwood and Pratten, 1855), *Chonetinella plebeia* (Dunbar and Condra, 1932), *Chonetinella primitiva* (King, 1938), *Chonetinella robusta* (King, 1938), *Chonetinella rostrata* (Dunbar and Condra, 1932), *Chonetinella verneuiliana* (Norwood and Pratten, 1855) and *Chonetinella verneuiliana* var. *wyandottensis* (Newell, 1934). See Figure 8 for A Comparison of Different Texas Pennsylvanian *Chonetinella* Species.

Genus *Neochonetes* Muir-Wood, 1962

Canyon, Cisco, Marble Falls and Strawn Groups in Texas
Permian and Pennsylvanian (Desmoines, Missouri, Morrow and Virgil Series) Periods World-wide

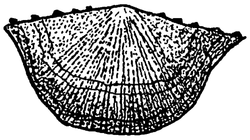


brachial valve interior X2



brachial valve exterior X2

Neochonetes puebloensis (King, 1938)



pedicle valve exterior X1

Neochonetes meekanus (Girty, 1915)

Type Species: *Chonetes dominus* King, 1938. *Neochonetes* are subquadratic to alate in shape, small to medium in size and plano-convex to slightly concavo-convex. Greatest width is hinge line. Sulcus and fold varies from obscure to quite noticeable. Umbo is wide and low. Shells are thick being up to a fourth of width. About 11 spines/side are present extending at low angle. Ornament is capillae which may divide and/or be of unequal length. Concentric growth lines are present. Pedicle valve interior has a short medium septum. Brachial valve interior has a brief cardinal process. Alveolus, lateral septa and brachial ridges are evident as are small papillae. Important Identifying Features: Spines are at a low angle, ornament is finely capillate, a long median septum is in both valves and both inner and outer socket ridges are present. Occurrence: Alabama, Arizona, Asia, Australia, Europe, Iowa, Illinois, Kansas, Maryland, Missouri, Nebraska, Nevada, Oklahoma, South America and Texas.

Texas Species: *Neochonetes acanthophorus* (Girty, 1934), *Neochonetes brazosensis* (King, 1939) [=

Genus *Chonetinella*

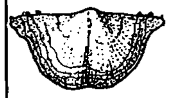
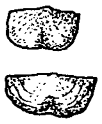
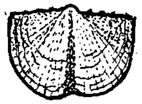
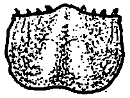
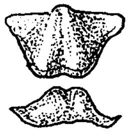
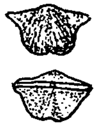
Species	*alata* (Dunbar and Condra, 1932)	*choteauensis* (Mather, 1915)	*flemingi* (Norwood and Pratten, 1855)	*plebeia* (Dunbar and Condra, 1932)	*primitiva* (King, 1938)	*robusta* (King, 1938)	*rostrata* (Dunbar and Condra, 1932)	*verneuiliana* (Norwood and Pratten, 1855)	*verneuiliana wyandottensis* (Newell, 1934)
size, X1									
Shape	Broad. Alate. Moderate convexity. Shallow sulcus.	Sub-semicircular. Convex. Shallow sulcus.	Widest at hinge. Deep sulcus. Ears prominent.	Thin shells.	Large for genus. Prominent, low beak. Nearly quadrate. Deep sulcus.	Long relative to width. Thick shell. Sinus low. Strong, narrow umbo. Very convex.	Prominent ventral beak. Deep sulcus. Broadens anteriorly.	Greatest width at hinge. Deep sulcus. Large, high beak.	Transverse. Small. Alate. Very convex. Deep, narrow sulcus.
Width Length	22 mm. 11 mm.	9.7 mm. 5.8 mm.	17 mm. 10 mm.	12 mm. 7 mm.	11-19 mm. 7-13 mm.	14-16 mm. 9-12 mm.	18 mm. 11 mm.	12 mm. 7 mm.	11.7 mm. 6.2 mm.
Hinge Spines Spine Angle	9-10/side. Low.	4-5/side. -	6-7/ side. 31°.	5-6/side. Oblique.	7/side. -	8-9/side. Flat. -	8-9/side. 30°.	4-7/side. Flat. Horizontal.	4-7/side. Flat. Horizontal.
Internal Features	"Typical" per Dunbar and Condra, 1932.	Short, broad brachial valve. Median septum halfway. Pedicle valve short, low median septum. Alveolus. Papillae in radiating rows.	Brachial ridges. Brachial valve cardinal process bilobed. Pedicle valve has long teeth and large diductor scars. Endospines.	Not described.	Vertical striation of hinge teeth. Abundant papillae in radiating rows.	Not described.	Vertical striation of hinge teeth. Brachial valve median septum long. Papillae in rows.	Not described.	Not described.
Ornament	4-5 capillae/mm.	Concentric growth lines . Finely punctate.	4 capillae/mm. Faint.	4-5 capillae/mm.	4-5 capillae/mm.	4 capillae/mm. Growth lines.	6-7 capillae/mm.	"100 fine capillae".	6 capillae/mm.
Comparison	Larger, more transverse and alate than *flemingi.*	No comparison found.	Bigger sulcus than *alata* or *plebia*. Larger, less transverse than *verneuiliana*.	Smaller and less strongly arched than *flemingi*.	Like *rostrata* but sulcus narrower.	Heavier and longer than *flemingi*. Also broader and deeper sulcus.	Character of sulcus and prominent beak make this fossil different.	Depth of sinus, height of ridges and number of spines set this species apart.	Somewhat smaller than *verneuiliana*. Exceptionally heavy shells.
Group	Cisco.	Marble Falls.	Canyon and Cisco.	Canyon (Strawn).	Strawn.	Canyon, Cisco and (Strawn).	Strawn.	Canyon, Cisco and Strawn.	Strawn.
Formation	Harpersville.	Marble Falls.	Brad, Graford and Graham.	Brownwood.	Mineral Wells.	Brownwood and Graham.	Millsap Lake.	Graford, Graham and Mineral Wells.	Mineral Wells.

Figure 8. A Comparison of Different Texas Pennsylvanian *Chonetinella* Species

Genus *Neochonetes*

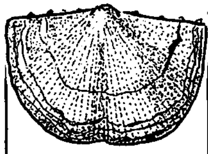
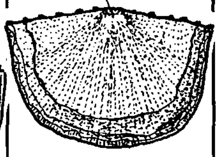
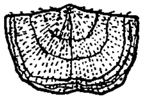
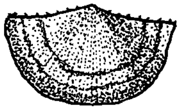
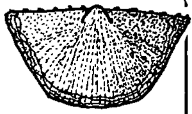
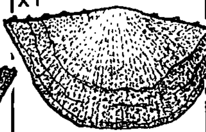
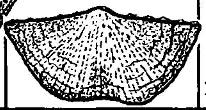
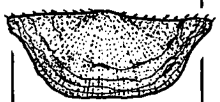
Species	*acanthophorus* (Girty, 1934)	*brazosensis* (King, 1939)	*dominus* (King, 1938)	*granulifer* (Owen, 1852)	*granulifer emaciatus* (King, 1938)	*meekanus* (Girty, 1915)	*puebloensis* (King, 1938)	*transversalis* (Dunbar and Condra, 1932)
Size	X2 	 X2	 x1	x1 	x1 	x1 	x1 	 x1
Shape	Semicircular. Very convex.	Semicircular to quadrate.	Subquadrate.	Subquadrate	Transverse. No sulcus. Slight convexity.	Almost triangular outline.	Alate. Faint sulcus.	Transverse. Broad, shallow sulcus.
Width Length	10-15 mm. 7.5-10 mm.	15-18 mm. 10-12 mm.	15-20 mm. 10-14 mm.	23 mm. 14 mm.	7-16 mm. 4-8 mm.	30 mm. 16 mm.	26-28 mm. 13-15 mm.	20 mm. 10 mm.
Hinge Spines Spine Angle	7/side. -	7/side. 35°.	11/side. -	7-8/side. 30°.	6/side. 40°.	10-12/side. 30°.	11-12/side. 40°.	8-10/side. 30°.
Internal Features	Not described.	Brachial valve median septum extends to mid-length. 2 short lateral septa. Radial rows of papillae.	Brachial valve median septum higher anteriorly. Interarea striate. Pedicle valve median septum is a low ridge. Papillae cover valve inner surface except for muscle scars.	Small cardinal process. Brachial valve low median septum to half valve. Pedicle valve with broad, short teeth. Radial rows of papillae.	Muscle scars not deeply impressed. Papillae fine, radial and not found in body cavity area.	Deep muscle scars. Short pedicle valve median septum. Radial rows of papillae.	Big hinge teeth. Short sockets. Median septum 2/3 valve length. Low, short lateral ridges. Radial rows of papillae.	Pedicle valve interarea broad and triangular Vestigial pseudo-delthyrium. Chilidium large. Brachial valve interarea low, reflexed.
Capillae	5-6/mm. Faint.	4-5/mm.	5-6/mm.	5/mm.	4-5/mm.	5/mm.	4/mm.	4-5/mm.
Comparison	Small. Sinuous. Quite convex. Smaller than *granulifer* and less projecting beak. Spinules. Beak prominent.	Less convex than other species except *dominus* and *granulifer emaciatus*.	*dominus* has been compared to *Neochonetes multicosta* which is not a Texas species.	Less alate and transverse than *transversalis*. Longer, heavier, more quadrate and stronger umbo than *g. emaciatus*.	Smaller than *brazosensis* and more arc-like. Less transverse and convex than *transversalis*.	Larger and heavier shells than *transversalis*.	More transverse than *granulifer* and *meekanus*. Less convex than *meekanus*. Larger than *transversalis*.	Proportionally broader at the hinge line than *granulifer*.
Group	Strawn.	Canyon and Strawn.	Marble Falls.	Canyon, Cisco and Strawn.	Cisco.	Cisco.	Cisco.	Cisco.
Formation	Mineral Wells	Brad, Graford and Mineral Wells (East Mountain Shale).	Lemons Bluff and Soldiers Hole Members.	Brad, Caddo Creek, Graford, Graham and Mineral Wells.	Graham.	Graham and Harpersville.	Harpersville.	Harpersville and Thrifty.

Figure 9. A Comparison of Different Texas Pennsylvanian *Neochonetes* Species

Neochonetes fragilis (King, 1938)], *Neochonetes dominus* (King, 1938), *Neochonetes granulifer* (King, 1938), *Neochonetes granulifer emaciatus* (King, 1938), *Neochonetes meekanus* (Girty, 1915), *Neochonetes puebloensis* (King, 1938) and *Neochonetes transversalis* (Dunbar and Condra, 1932). See Figure 9 for A Comparison of Different Texas Pennsylvanian *Neochonetes* Species.

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FALLS OF THE OHIO

ANCIENT SHELLS PART I

BRACHIOPODS

Alan Goldstein
Falls of the Ohio State Park
201 West Riverside Drive
Clarksville, IN 47129

What would it have been like to be a shell collector during the Devonian period, between 408 and 360 million years ago? Today collector's find shells in a variety of shapes, sizes and colors washed up on a beach. Those are shells of mollusks, usually gastropods (snails) and pelecypods (clams).

The fossil-bearing rocks at the Falls of the Ohio indicate that a Devonian beachcomber would have found mollusks and other types of shells washed up. The most common shell-bearing creature in the Devonian at the Falls is virtually never found washed up on a beach today-that is the **brachiopod** (pronounced brak - e- o-pod). They are often called lampshells because some varieties resemble a Roman oil lamp.

Brachiopods are **invertebrates**--- animals without a backbone -- in the phylum Brachiopoda. They have two shells that may be composed of calcium carbonate (the minerals calcite and aragonite) or a phosphatic mineral (like your teeth). Most brachiopods live on the ocean floor, though some burrow. Fossil records indicate that they have never lived in a freshwater ecosystem (like the Ohio River).

Perhaps the easiest method to differentiate a brachiopod from a clam is by shell symmetry (see figure 1). Each clam shell or **valve** is a mirror image of one another. Brachiopods are symmetrical from side to side, so that the top and bottom shells look different.

The internal anatomy of brachiopod is very different from a clam. Brachiopods have a coiled feeding organ called a **lophophore**. The lophophore may be occasionally preserved in some Devonian brachiopods found at the Falls of the Ohio and elsewhere in the country (see figure 2).

There are two major divisions or classes of brachiopods: **Inarticulate** brachiopods were the first to develop, and can be found in rocks dating back to the earliest Cambrian period, more than 570 million years ago. These brachiopods are not abundant in the local Devonian rocks. *Petrocrania hamiltonae* (Hall) is perhaps the most common inarticulate brachiopod (see figure 3).

Inarticulate brachiopods open and close their valves with muscles and do not rely on sockets and teeth that are a characteristic of articulate brachiopods. Devonian species sockets and teeth that are a characteristic of articulate brachiopods. Devonian species of this class are often found attached to other organisms -- such as another brachiopod shell or horn coral. The bottom **ventral valve** may be cemented to a firm surface, while the upper **dorsal valve** is opened for feeding.

Articulate brachiopods have two valves that are different size. The larger shell is called the **pedicle valve**. It contains a hole through which a fleshy stalk called a **pedicle** attaches to a **substrate** (rocks or sediment on the sea floor). The pedicle acts as an anchor which firmly holds the brachiopod in place. (Unlike clams which can move through sediment, the brachiopod is fixed throughout its adult life.) The pedicle valve contains projections called **teeth** (see figures 4a & b), that fit into sockets on the opposite **brachial valve**.

The inside of some brachiopod shells contain muscle scar pattern (see figures 4a & b). The placement of these scars help paleontologists determine the placement of important muscles.

Articulate brachiopods come in a variety of shapes. Valves may be convex (bow out), concave (bow inward) or flat. There can be variation in the shape of the brachial and pedical valve. One might be concave, the other flat or convex. The **hinge line** is where the two valves of articulate brachiopods come together. It can be straight (as in figures 4a, 5, 6a) or curved (as in figures 6b, 7a, & b). It can be short, relative to the width of the shell (figure 8b), or long (figure 4a).

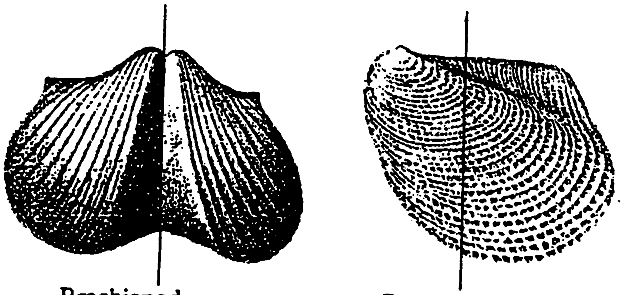
Brachiopod shells often show interesting external ornamentation. *Brevispirifer gregarius* (Clapp) often shows pronounced growth lines and is strongly rigged (see figure 5). *Protoleptostrophia perplana* (Conrad) and *Rhipidomella penelope* (Hall) are examples of brachiopods that have **costae**, which are very fine ridges on the outer surface of the shell (see figure 6. *Invertrypa spinosa* (Hall) and *Productella spinulicosta* Hall are two brachiopods with spines on the external surface of the shell (see figure 7). *Invertrypa* spines are usually not preserved. Spines helped stabilize brachiopods in muddy sediment. Some brachiopods, like *Athyris* and *Cryptonella* are very smooth (see figure 8). Evidence of color patterns on valves are very rare from brachiopods of this age.

Types fo brachiopods at the Falls

There are six types of Orders of articulate and two orders of inarticulate brachiopods that may be found at the Falls (see table 1). Most brachiopods are found on the "upper fossil beds." rather than the coral-rich "lower fossils beds." As a result, this group of fossils is visible for much of the year. Although brachiopods are common in rocks at the Falls, *please remember that fossil collecting here is prohibited.*

FIGURES

1-4



Brachiopod - *Paraspirifer acuminatus* (Conrad)

Clam - *Actinoptera boydi* (Conrad)

Figure 1: Shell Symmetry

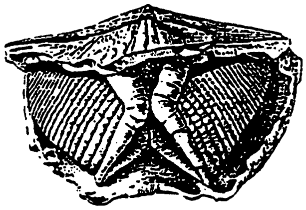
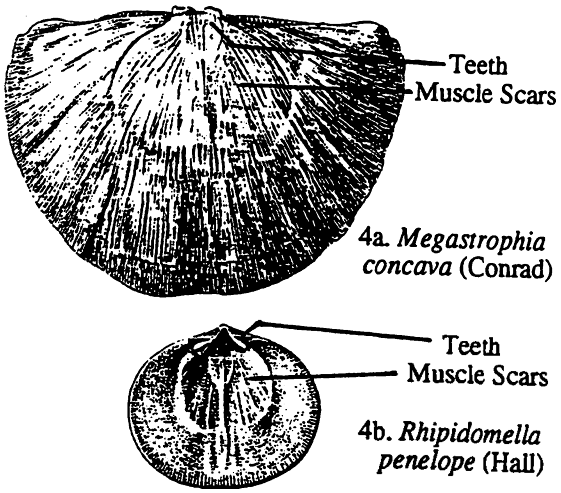


Figure 2: *Orthospirifer fornacula* (Hall) showing lophophores

Figure 3: *Petrocrania hamiltonae* (Hall) an inarticulate brachiopod



4a. *Megastrophia concava* (Conrad)

4b. *Rhipidomella penelope* (Hall)

Figure 4: Brachiopod teeth and muscle scars

FIGURES

5-8

Suggested Reading

The Audubon Society Field Guide to North American Fossils, I. Thompson. Published by Alfred A. Knopf, 1982. Good general fossil book.

The Devonian Fossils and Stratigraphy of Indiana, E. M. Kindle, Indiana Dept. of Natural Resources, 1901. Out of print. Identifies most Devonian brachiopods found in Indiana. May be found in college, university and large public libraries.

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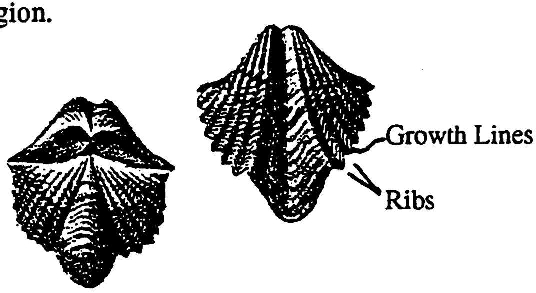

Figure 5: *Brevispirifer gregarius* (Clapp)

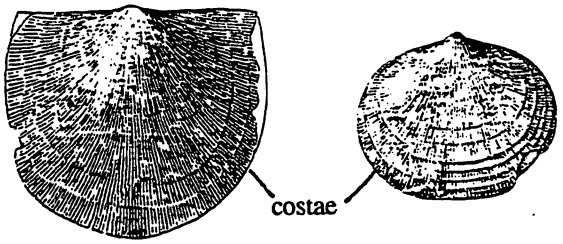

Figure 6a: *Protoleptostrophia perplana* (Conrad) 6b: *Rhipidomella penelope* (Hall)

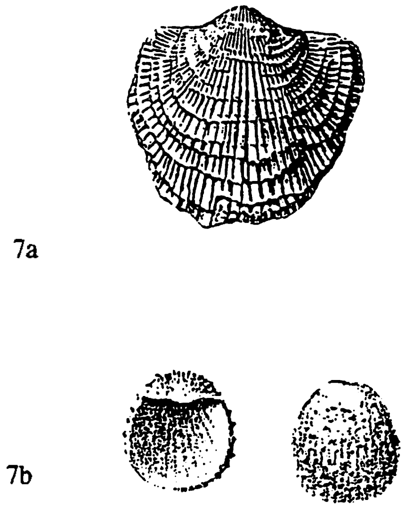

Figure 7: Brachiopods with external spines
7a: *Invertrypa spinosa* (Hall)
7b: *Productella spinulicosta* Hall

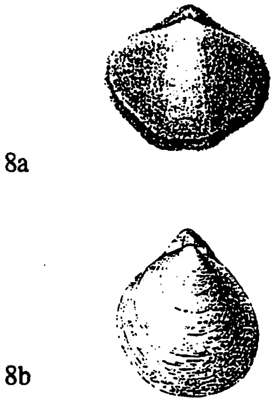

Figure 8: Smooth-shelled Brachiopods
8a: *Athyris fultonensis* (Swallow)
8b: *Cryptonella*(?) *lens* (Hall)

Figures from *The Devonian Fossils and Stratigraphy of Indiana* or *Kentucky Fossil Shells.*

Table 1 Brachiopods of the Falls area

Inarticulate (Class Inarticulata)
Acrotretids (Order Acrotretida)
Acanthocrania granosa (Hall and Clarke)
Craniella hamiltoniae (Hall)
Craniops sp.
Orbiculidea doria (Hall)
**O. lodiensis* (Vanuxem)?
Petrocrania greenei (Miller)
P. hamiltoniae (Hall) (see figure 3)
P. sheldoni (White)
Philhedra crenistria (Hall)
Roemerella grandis (Vanuxem)
**Schizobolus concentrica* (Vanuxem)

Lingulids (Order Lingulida)
Glossina triangulae (Nettleroth)
**Lingula spatula* Vanuxem

Articulate (Class Articulata)
Orthids (Order Orthida)
Rhipidomella penelope (Hall) (see figure 4b, 6b)
Tropidoleptus carinatus (Conrad)
Schizophoria striatula (Schlotheim)

Pentamerids (Order Pentamerida)
Pentamerella arata (Conrad)
P. indianaensis (Kindle)
P. pavilionensis Hall
P. thusnelda (Nettelroth)

Rhynchonellid (Order Rhynchonllida)
Attribonium gainesi (Nettleroth)
Cupularostrum carolina (Hall)
C. depressa? (Kindle)
C. louisvillensis (Kindle)
C. nitida (Kindle)
C. sappho (Hall)
C. tethys (Billings)
Cyclorhina nobilis Hall

Spiriferids (Order Spiriferida)
Acrospirifer duodenaris (Hall)
Ambocoelia umbonata (Conrad)
Athyris fultonensis (Swallow) (see figure 8a)
Atryparia devoniana (Webster)
A. ellipsoida (Nettelroth)
Brevispirifer (?) *davisi* (Nettelroth)
Brevisprifer gregarius (Clapp) (see figure 5)
Cyrtina crassa (Hall)
C. hamiltonensis (Hall)
C. hamiltonensis var. *recta* (Hall)
Elyta fimbrata (Hall)
E. wabashensis (Kindle)
Emanuella subumbona (Hall)
Fimbrispirifer divaricatus (Hall)
F. grieri (Hall)
Invertrypa spinosa (Hall) (see figure 7a)
Mediospirifer audaculus (Conrad)
M. (?) *manni* (Hall)
M. (?) *segmentum* (Hall)
Megakoglowskiella raricosta (Conrad)
Meristella barrisi (Hall)
M. nasuta (Conrad)
Nucleospira concinna (Hall)
Orthostrophia fornacula (Hall) (see figure 2)
Paraspirifer acuminatus (Conrad)
Parazyga hirsuta (Hall)
Pentagonia unisulcata (Conrad)
Spirifer(?) *arctisegmentum* (Hall)
Spirifer(?) *varicosus* (Hall)

Strophomenids (Order Strophomenida)
"Chonetes" acutiradiatus (Hall)
**Chonetes lepidus* Hall
"C." subquadratus (Nettelroth)
Devonochonetes coronatus (Conrad)
Eodevonaria arcuata (Hall)
Floweria chemungensis var. *arctostriatus* (Hall)
Leptaena rhomboidalis (Wilckens)
Longirostra mucronatus (Hall)
Megastrophia concava (Hall) (see figure 4a)
Protodouvillina inequistrata (Conrad)
Protoleptostrophia perplana (Conrad) (see figure 6a)
Productella semiglobosa (Nettelroth)
P. spinulicosta Hall (see figure 7b)
Stropheodonta inequistriata (Conrad)
S. demissa (Conrad)
S. plicata Hall

Terebratulids (Order Terebratulida)
Camarospira eucharis (Hall)
Centronella glansfagea (Hall)
Cranaena (?) *jucunda* (Hall)
C. harmonia (Hall)
C. lincklaeni (Hall)
C. romingeri (Hall)
Cryptonella(?) *lens* (Hall) (see figure 8b)
C. ovalis (Miller)
C. (?) *sullivanti* (Hall)

* From the New Albany Shale

SPEED'S QUARRY

THE BRACHIOPOD FAUNA AND BIOSTRATIGRAPHY

of the

DEVONIAN STRATA, SELLERSBURG INDIANA

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SITE LOCATION AND HISTORY

The Speed's Quarry is located in southern Indiana in the town of Sellersburg, Clark County, Indiana. The Quarry is currently operated by ESSROC Materials, Inc. The Quarry has been in operation for approximately 125 years and has projected reserves for another 300 years. The stone quarried here is used for feed stock for cement kilns located on the site.

SITE DESCRIPTION AND COLLECTING TECHNIQUES

Generally most groups prefer to collect in a bright red sandy clay-soil at the top of the pit. Usually there is about 25 acres of this area open to collecting. The red clay is exposed as part of the overburden removal operation which precedes the actual quarring operations. This soil is the result of the rotting or deliterifaction of the local limestones and shales which has taken place over the last 8,000 to 10,000 years. Deliterifaction means that all the soluble minerals have been dissolved by surface and groundwater. What remains is the insoluble residuum - silica, iron-stained clay, manganese pellets etc. Consquently there are numerous fossils that can be found on the surface of the red clay deposits. About half of the fossils contained within the variuos limestone formations in this area are silicified.

Covering this red clay layer is anywhere from a few inches to 20 feet of glacial deposits. This outwash is composed of soil, sand, gravel and numerous geodes stripped from the Knobs to the north and northwest of the quarry area. There are also erratics - metamorphic, igneous and sedimentary rock types that came from much futher north - Canada and the Great Lakes area. Occasionally, Devonian petrified wood is found near the interface of the glacial outwash and the red clay deposits. The origin of this wood may be very local or may have been transported with the geodes from the Knobs.

The red clay deposits contain fossils from the Upper Jeffersonville Limestone, the North Vernon Limestone and perhaps petrified wood from the New Albany Shale.

The other method of collecting fossils is to chisel or cut them from the hard limestone matrix -- usually difficult at best. The lower pit floor of the quarry is in the hard Jeffersonville Limestone. High magnesium limestone in the lower Jeffersonville Formation limits the depth of the quarry. These high magnesium content lomestones are not suitable for the manufacture of cement. Thus most areas in the pit floor do not intersect the lower coral zone. However, a few of the old workings and some of the drainage ditches do.

BIOSTRATIGRAPHY - THE JEFFERSONVILLE LIMESTONE

The Jeffersonville Limestone was named by Kindle in 1899 for fossiliferous limestone deposits located at the Falls of the Ohio. The Jeffersonville Limestone is divided into five bi-zones (Perkins 1963). These bizones are termed the; Coral Zone, Amphipora ramosa Zone, Brevispirifer gregarius Zone, Fenstrate Bryozoan-Brachiopod Zone and the Paraspirifer acuminatus Zone in ascending order.

THE CORAL ZONE - LIMESTONE

The Coral Zone (approximately 5 feet of exposure) is poorly represented in the Speed's Quarry. Only a few ditches and old workings provide exposure. The limestone is buff colored, crystalline and laced with carbonaceous material. Fossils include abundant solitary and colonial corals, mound-like stromatropoids and disarticulated crinoidal debris. Brachiopods are uncommon.

THE AMPHIPORA RAMOSA ZONE LIMESTONE

This zone (approximately 9 feet of exposure) is named after the abundance of a small tube-like stromatropoids. Other fossils include mat-like stromatropoids, solitary rugose corals, colonial corals, crinoid debris, branching corals, mollusks and infrequent brachiopods.

THE BREVISPIRIFER GEGARIUS ZONE LIMESTONE

This zone (approximately 3-4 feet of exposure) is named for the abundance of a small brachiopod. Single valves protude from every square inch of weathered surfaces. Oddly whole shells (both valves) are very uncommon. Other fossils include mat-like stromatropoids, crinoid debris, solitary rugos corals, fenstrate bryozoans, branching corals, large colonial corals, large gastropods (Turbonopsis shumardi), pelecypods,occasional articulated crinoids and numerous species of brachiopods. Of particular note are specimens of the moderatly large brachiopod (Stropheodonta sp). Also of interest, near the lower part of the zone near the contact with the Amphipora ramosa zone, charophyte ogonia may be found (microscopic green algae oospores, this algae has male and female sexes).

THT FENSTRATE BRYOZOAN - BRACHIOPOD ZONE LIMESTONE

This is the first biozone, (approximately 6-7 feet of exposure) in the exposed section to have an abundance of brachiopods of various species, and consequently has been recognized in the name of the zone. Almost every bedding plane is covered with fan-like fenstrate bryozoans and brachiopods - Atyparia devoniana, Stropheodonta sp. Paraspirifer acuminatus, and Brevispirifer gregarius.

Other fossils include; branching coral, crinoid debris,soloitary rugos corals, gastropods, trilobites blastoids, pelecypods, fish teeth, stromatropoids and other types of bryozoan. The lower contact is marked by a very cherty bed of limestone.

THE PARASPIRIFER ACUMINATUS ZONE

So named for the presence of a large spiriferid brachiopod - Paraspirifer acuminatus . Perkins (1963) noted that the Paraspirifer acuminatus Zone (approximately 7 feet exposure) and the underlying Fenstrate Bryozoan - Brachiopod Zone were identical in most respects, except for the abundance of Paraspirifer acuminatus in these upper beds. Perkins divided this lithology into two zones not because they are biologically different or that they represent different depositional units, but because the uppermost beds were present over a wider geographic area. Generally only single valves are found, but occasionally whole specimens of P. acuminatus are found loose or can be broken free from the enclosing matrix. These relatively large brachiopods make for striking display specimens. Other commonly encountered fossil groups include; solitary rugose coral, branching coral colonies, fenstrate bryozoans, crinoid columnal sections, gastropods and pelecypods.

BRACHIOPODA FAUNA OF THE JEFFERSONVILLE LIMESTONE

CURRENT NAME	PREVIOUS NAME	
ACANTHOCRANIA granosa (Hall & Clark)	CRANIA	very rare
ATHYRIS fultonensis (Swallow)	A. vittita	common
ATRIBONIUM ganiesi (Nettleroth)	RHYNCHONELLA	very rare
ATRIBONIUM ganiesi cassennsis (Kindle)	RHYNCHONELLA	very rare
ATRYPARIA devonian (Webster)	Atrypa reticularis	common
BREVISPIRIFER gregarius (Clapp)	Spirifer	common
BREVISPIRIFER gregarius greeni	Spirifer	very rare
CAMAROSPIRA eucharis (Hall)		very rare
CHONETES acutiradiatus (Hall)		very rare
CHONETES subquadratus (Nettleroth)		very rare
CRANAENA (?) jucunda (Hall)	Terebratula	very rare
CRANAENA harmonia (Hall)	Eunella, Terebratula	very rare
CRANAENA linklaeni (Hall)	Eunella, Terebratula	very rare

CURRENT N AME	PREVIOUS NAME	
CRANAENA romingeri (Hall)	Terebratula	very rare
CRANIOPS sp.	Pholidops	very rare
CRYPTONELLA (?) lens (Hall)	Cranaena (?)	very rare
CRYPTONELLA ovalis (Miller)		very rare
CRYPTONELLA (?) sullivanti (Hall)	Eunella	very rare
CUPULAROSTRUM carolina (Hall)	Camarotoechia	infrequent
CUPULAROSTRUM depressa (?)	Rhynchonella	infrequent
CUPULAROSTRUM louisvillensis (Nettleroth)	Rhynchonella	infrequent
CUPULAROSTRUM nitida (Kindle)	Camarotoechia	infrequent
CUPULAROSTRUM sappho (Hall)	Camarotoechia	infrequent
CUPULAROSTRUM tethys (Billings)	Camarotoechia Rhynchonella	infrequent
CYCLORINA (?) noblis (Hall)	(Cyclorhina)	very rare
CYRTINA crassa (Hall)		very rare
CYRTINA hamiltonensis (Hall)		very rare
CYRTINA hamiltonensis recta (Hall)		very rare
DEVONCHONETES coronatus (Conrad)	Chonetes	abundant
ELYTA fibrata (Conrad)	Reticularia Spirifer	common
ELYTA wabashensis (Kindle)	Reticularia	very rare
EODOVENARIA arcuatus (Hall)	Chonetes	very rare
FIBRISPIRIFER divaricatus (HALL)	Spirifer	rare
FIBRISPIRIFER grieri (Hall)	Spirifer	rare
FLOWERIA chemungensis arctostriatus (Hall)	Streptorhychus Schuchertella Orthotetes	rare
LEPTAENA rhomboidalis ? (Wilckens)	Strophomena	very rare
LONGIROSTRA mucronatus (Hall)	Chonetes	rare
MEDIOSPIRIFER audaculus (Conrad)	Spirifer	infrequent
MEDIOSPIRIFER (?) manni (Hall)	Spirifer	infrequent
MEDIOSPIRIFER (?) segmentum (Hall)	Spirifer	infrequent
MEGASTROPHIA concava (Hall)	Stropheodonta	abundant
MERISTELLA barrsi (Hall)		rare
MERISTELLA nasuta (?) (Conrad)		common

CURRENT NAME	PREVIOUS NAME	
NUCLEOSPIRA concinna (Hall)		rare
ORTHOSPIRIFER fornacula (Hall)	Spirifer Platyrachella	abundant
PARASPIRIFER acuminatus (Conrad)	Spirifer	common
PARAZYGA hirsuta (Hall)	Trematospira	very rare
PENTAGONIA unisulcata (Conrad)	Meristella	very rare
PENTAMERELLA arata (Conrad)		very rare
PENTAMERELLA indianaensis (Kindle)	Gypidula	very rare
PENTAMERELLA pavilionensis (Hall)		common
PENTAMERELLA thusnelda (Nettleroth)		very rare
PETOCRANIA hamiltoniae (Hall)	Craniella	common
PHILHEDRA crenistra (Hall)	Crania	very rare
PHOLIDOSTROPHIA iowaensis (?) (Owen)	Strophodonta nacrea	rare
PRODUCTELLA semiglobosa (Nettleroth)		common
PROTOLEPTOSTROPHIA perplana (Conrad)	Stropheodonta Leptostrophia	abundant
PROTOVILLINA inquistrata	Stropheodonta	abundant
RHIPIDOMELLA penelope (Hall)	R. vanuxemi R. livia	common
SPIRIFER (?) arctisegmentum (Hall)		infrequent
SPIRIFER (?) davisi (Nettleroth		infrequent
SPIRIFER (?) duodenarius (Hall)		infrequent
SPIRIFER (?) varicosus (Hall)		infrequent
STROPHEODONTA demiassa (Conrad)		very rare
STROPHEODONTA plicata (Hall)		very rare

Although there are over sixty five (65) brachiopods listed for the Jeffersonville Limestone, only 15 of these are abundant or commonly found. There are several different reasons for this apparent disparity. Some species are truly rare or infrequent. However, the very nature of the Jeffersonville Limestone; being hard, massive and cliff forming does not lend itself well for easy collecting. The Falls of the Ohio was one of the few outcrops in the area where one could examine large expanses of the Jeffersonville Limestone. Area quarries have exposures of the Jeffersonville Limestone, but these are erratic and access is somewhat limited. Weathered outcrops, including the Falls of the Ohio also have drawbacks in that most of the brachiopods are calcarceous and decompose quite easily. Another factor usually overlooked is at any given time there are only a few collections being assembled for a specific stratigraphic sequence. For example in my lifetime I know of only three systematic and well documented collections being assembled in the Louisville area; Margaret Kahrs', Alan and Debbie Goldstein's, Charles Oldham's and Charles Gaus has the beginning of one. Alan Goldstein, Charles Gaus and myself save many, so very fragmented fossils that the only representation of a particular fossil from a specific layer or bed within a formation. Most collectors would discard these fossils or not even collect them at all.

After thirty-two years of collecting in the Louisville area, I only have a small collection of brachiopods from the Jeffersonville Limestone. On the other hand I have hundreds of coral specimens.

THE NORTH VERNON LIMESTONE

The North Vernon Limestone was named by Borden in 1976 it is synoymous with the Sellersburg Limestone. The North Vernon Limestone unconformably overlies the Jeffersonville Limestone. The North Vernon Limestone is divided into three members; The Speed's Limestone, The Silver Creek Limestone and the Beechwood Limestone.

THE SPEED'S LIMESTONE MEMBER

The Speed member of the Speed's "Limestone" approximately 5 feet of exposure, was named by Sutton and Sutton in 1937 for limestone exposures located in the Speed's Quarry. The Speed's Limestone is a crinoidal, brachiopod - bryozoan rich limestone of about five feet in thickness. the presence of abundant "button corals" (Hadrophyllum orbignyi), coupled with the brachiopod Athyris sp. is a sure marker for the Speed's Limestone. Other fossils found in the Speed's Limestone are; fenstrate bryozoans, stromatropoids, solitary rugose corals, platy bryozoans, purplish-pink brachiopods and arenaceous forminifera.

THE SILVER CREEK LIMESTONE

The Silver Creek Limestone (approximately 25 to 30 feet of exposure), was named by Siebenthal in 1901 for exposures along Silver Creek near the Falls of the Ohio. The lower portion is variably fossiliferous, while the upper portion is very fossilferous. Also within the top five feet are abundant chert beds that contain silicfied fossils. Some of the most spectacular fossils preservations of the Speed's Quarry exist in these chert beds.

Brachiopods such as Atryparia (Atrypa), Spinocyrtia (Platyrachella), Athyris, have their internal anatomy (soft parts) preserved. As a rule these organs are not preserved in most brachiopods. But, in the Silver Creek Limestone and to some extent in the Speed's Limestone these types of preservetion are common. In fact to find a brachiopod that is whole (both valves) that does not have the internal organs preserved to some extent is somewhat unusual.

The most common organ that is present in these brachiopods is the lophophore - a coiled feeding organ that was used to filter micro plants and animals from the seawater for food. Solid chert filled brachiopods can be sawn to reveal the presence of the lophophore. However about five out of every hundred brachiopods are hollow and the delicate coils of the lophophores are easily displayed in carefully cracked shells. They have the appearance of tiny conical coiled springs set end to end. Sometimes the silica that replaced them, not true to life, created very heavy coils.

THE NEW CHAPEL CHERT BEDS

The upper five feet or so of the Silver Creek Limestone, where the chert beds are prevalent, are referred to by some as the New Chapel Chert. Collecting in one of these chert layers is one of the most productive areas of the Speed's Quarry. Many different species of brachiopods, trilobites, pelecypods, gastropods, and other desirable types of fossils can be found.

The best way to collect these beds is to wear a large straw hat to shade your eyes and the ground, sit, squat or just get down and crawl around. turn over the large pieces of chert and examine them for partially exposed fossils. Small fragments of trilobites are very common. Many of the chert layers are covered with small Chonetid brachiopods, primarily <u>Chonetes yandellanus</u>.

BRACHIOPOD FAUNA OF THE SILVER CREEK LIMESTONES AND SHALES

CURRENT NAME	PREVIOUS NAME	OCCURENCE
ACANTHOCRANIA (?) granosa (Hall & Clark)	Crania	infrequent
AMBOCOELIA umbonata (Conrad)		infrequent
ATHYRIS fultonensis (Swallow)	A. vittata	common
ATHYRIS spiriferoides (Eaton)		common
ATRYPARIA (?) devoniana (Webster)	Arypa reticilaris	common
ATRYPARIA (?) spinosa (Hall)	Atrypa	common
CHONETES yandellanus (Hall)		common
CRANAENA harmonia (Hall)	Eunella Terebratula	infrequent
CRANAENA linklaeni (Hall)	Eunella Terebratula	infrequent
CUPULAROSTRUM louisvillensis (Nettleroth)	Camarotoechia	infrequent
CUPULAROSTRUM tenuistriata (Nettleroth)	Camarotoechia	common
CYTRIAN hamiltonensis (Hall)		infrequent

CURRENT NAME	PREVIOUS NAME	OCCURENCE
CYTRIAN hamiltonensis recta (Hall)		infrequent
DEVONOCHONETES (?) coronatus (Conrad)	Chonetes	common
DEVONOCHONETES (?) manitobensis (Whiteaves	Chonetes	infrequent
ELYTA fimbrata (Conrad)	Reticularis	infrequent
EMANUELLA subumbona (Hall)	Martina, Spirifer	infrequent
FIBRISPIRIFER divaricatus (Hall)	Spirifer	infrequent
FLOWERIA chemungensis arctistriata (Hall)	Schuchertella Streptorhynchus, Orthotetes	infrequent
GLOSSINA triangulata (Nettleroth)	Lingula	infrequent
LEPTAENA (?) rhomboidalis (?) (Wilckens)		infrequent
MEDIOSPIRIFER audaculus (Conrad)	Spirifer	infrequent
MEDIOSPIRIFER manni (Hall)	Spirifer	infrequent
MEDIOSPIRIFER segmentum (Hall)	Spirifer	infrequent
MEGASTROPHIA concava (Hall)	Stropheodonta	common
NUCLEOSPIRA concinna (Hall)		infrequent
ORBICULOIDEA (?) ampa (Hall)		rare
ORBICULOIDEA (?) doria (Hall)	Discina	rare
ORTHOSPIRIFER fornacula (Hall)	Spinocyrtia granulosa	common
ORTHOSPIRIFER oweni (Hall)	Platyrachella, Spirifer	common
PENTAMERELLA pavilionensis (Hall)		rare
PHILHEDRA sheldoni (White)	Crania bordoni (Hall & Whitfield)	infrequent
PHOLIDOSTROPHIA iowaensis (?) (Owen)	Strophodonta nacrea	infrequent
PRODUCTELLA spinulicosta (Hall)		common
PROTLEPTOSTROPHIA perplana (Conrad)	Stropheodonta, Leptostrophia	infrequent to common
PUSTULINA pustulosa (Hall)	Vitulina	infrequent
RHIPIDOMELLA vanuxemi (Hall)	R. leucosta, Orthis	common
RHIPIDOMELLA penelope (Hall)	R. livia, Orthis	common
SCHIZOPHORIA sp.	Orthis	infrequent

CURRENT NAME	PREVIOUS NAME	OCCURENCE
SPIRIFER (?) byrnesi (Nettleroth)		infrequent
SPIRIFER (?) hobbsi (Nettleroth)		inferquent
SPIRIFER (?) macra (Hall)		infrequent
SPIRIFER (?) varicosus (Hall)		infrequent
TROPIDLEPTUS carinatus (Conrad)		common

THE BEECHWOOD LIMESTONE

The Beechwood Limestone (approximately 10 feet of exposure), was names by Butts in 1915 for limestone exposures located at Beechwood Station in Jefferson County, Kentucky. The Beechwood unconformably overlies the Silver Creek Limestone. The Beechwood can be distinguished from the Silver Creek, as being a coarsely crystalline, dense thick bedded, dark to light gray crinoidal limestone. The Beechwood in the area of the Speed's Quarry has the characteristic DOLATOCRINUS columnals dotting the exposed bedding planes. DALATOCRINUS columnals have fins at 120 degrees to each other. The Beechwood is abundantly fossilferous; commonly occuring fossils include: crinoids, fish bones, and teeth, colonial corals, bryozoans, brachiopods, pelecypods, gastropods, pteropods and trilobites.

The base of the Beechwood is usually marked by a lag zone composed of phosphate nodules, quartz sand, and fish bones and teeth. Isolated boulders of the Beechwood have produced very fine crinoids, but most of these needed to be sawn out with a concrete saw, due to the hardness of the limestone and the brittleness of the fossil crinoids. So if you find one of these take extreme caution in removing them. In some groups of collectors one of more persons will have a gasoline powered cement saw, it is far safer to saw them out, than to chip or chisel them out.

THE BRACHIOPOD FAUNA OF THE BEECHWOOD LIMESTONE

CURRENT NAME	PREVIOUS NAME	OCCURENCE
AMBOCOELIA umbonata (Conrad)		locally common

CURRENT NAME	PREVIOUS NAME	OCCURENCE
ATHYRIS fultonensis (Swallow)	A. vittata	common
ATRYPARIA (?) devoniana (Webster)	Atrypa retucularis	common
ATRYPARIA (?) (Hall)	Atrypa	common
CUPULAROSTRUM sappho (Hall)	Camarotoechia	infrequent
CENTRONELLA campbelli (Cloud)	C. glansfagea	infrequent
CHONETES (?) acutiradiatus (Hall)		locally common
CHONETES (?) yandellanus (Hall)		common
CRANAENA harmonia (Hall)	Eunella, Terebratula	infrequent
CUPLAROSTRUM louisvillensis (Nettleroth)	Rhynchonella	infrequent
CUPLAROSTRUM tenuistriata (Nettleroth)	Rhynchonella	infrequent
CYRTINA hamiltonensis (Hall)		infrequent
CYRTINA hamiltonensis recta (Hall)		infrequent
DELTHYRIS (?) sculptis (Hall)	Spirifer	infrequent
DEVONCHONETES (?) manitobiensis (Whiteaves)	Chonetes	locally common
DEVONCHONETES (?) cornatus (Conrad)		locally common
ELYTIA fimbrata (Conrad)	Fimbraspirifer	infrequent
EMANUELLA subumbona (Hall)	Martinia, Spirifer	infrequent
FLOWERIA chemungensis arctistriata (Hall)	Schuchurtella Streptorhynchus Orthotetes	infrequent
GLOSSINA triangulata (Nettelroth)	Lingula	rare
Leptaena (?) rhomboidalis (Wilckens)		common
MEDIOSPIRIFER audaculus (Conrad)	Spirifer Brachyspirifer	infrequent
MEDIOSPIRIFER segmentum (Hall)	Spirifer	infrequent
MEGAKOGLOWSKIELLA raricosta (Conrad)	Delthyris	rare
MEGASTROPHIA concava (Hall)	Stropheondata	common
MUCROSPIRFER sp. (?)	Spirifer pennatus	infrequent

CURRENT NAME	PREVIOUS NAME	OCCURENCE
NUCLEOSPIRA concinna (Hall)		infrequent
ORBICULOIDEA ampla		very rare
ORBICULOIDEA doria (Hall)		very rare
OTHOSPIRIFER oweni (Hall)	Platyrachella, Spirifer granulosus	common
PARAZYGA hirsuta (Hall)		rare
PENTAGONIA unisulcata (Conrad)	Meristella	infrequent
PENTAMERELLA pavilionensis (Hall)		infrequent
PHILHEDRA shedoni (White)	Crania boweni	rare
PHOLIDISTROPHIA iowaensis (?) (Owen)		rare
PRODUCTELLA spinulicosta (Hall)		common
PROTOLEPTOSTROPHIA perplana (Conrad)		infrequent
PUSTULINA pustolosa (Hall)	Vitulina	infrequent
RHIPIDOMELLA penelope (Hall)	Orthis	common
RHIPIDOMELLA vanuxeumi (Hall)	Orthis	common
SCHIZOPHORIA sp.	Orthis	rare
SPIRIFER (?) byrnesi (Nettelroth)		infrequent
SPIRIFER (?) duodenarius (Hall)		infrequent
SPIRIFER (?) hobbsi (Nettelroth)		infrequent
SPIRIFER (?) maconnathi (Nettelroth)		infrequent
SPIRIFER (?) macra (Hall)		infrequent
SPIRIFER (?) varicosus (Hall)		infrequent
STROPHEODONTA (?) demissa (Conrad)		common

THE NEW ALBANY BLACK SHALE - Oil Shale

The New Albany Shale (appx. 10-20 feet exposure) was named by Borden in 1874 from exposures in the town of New Albany, Floyd County, Indiana. Which at that time was known in southern Indiana and Kentucky as the "Black Slate", or the "Louisville-Delphi Black Slate". Since the use of the term "Slate" was geologically incorrect, these names were dropped.

The New Albany Shale is typically a black to brownish, hard when fresh, carbonaceous, laminated, and well jointed. Generally small mica flakes can be seen on bedding planes and pyrite occurs throughout the formation. The "pyrite" is generally marcasite which is unstable in the humid Ohio Valley climate and breaks down rapidly, staining the underlying limestones with iron and sulfate compounds. A two inch or more bed of "pyrite" is generally located at the base of this formation.

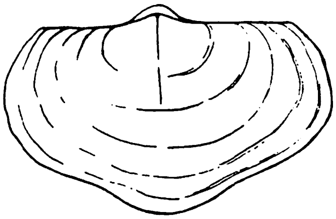
The New Albany Shale represents a foul, oxygen-poor, reducing enviroment. Probably the upper few feet of the sea was oxygenated, but below that most life forms would probably suffocate. Few fossils are found associated with black shales. And when communities of life are encountered, they are usually clustered together in little mounds that probably extended up from the foul bottom into oxygenated water.

Although many different forms of life are collectively represented in the New Albany Shale, no where are fossils common. Fossil types that may be encountered in the black shales are; fish plates, fish teeth, inarticulate brachiopods, conodonts, plant spores, petrified wood, burrows, algae, pteropods, scolecpdpmts, pelecypods, gastropods, etc.

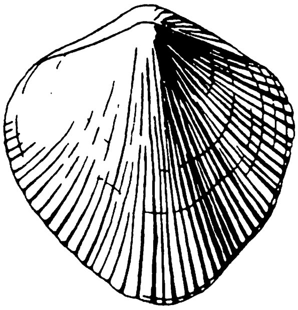
BRACHIOPOD FAUNA OF THE NEW ALBANY SHALE

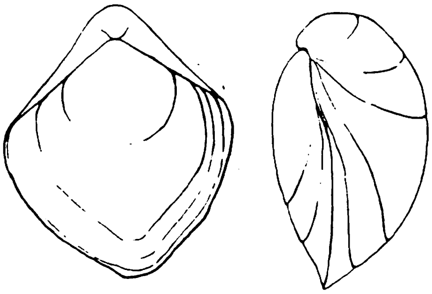
CHONETES sp
LEIORHYNCHUS sp

TYPICAL BRACHIOPODS FOUND AT THE SPEEDS' QUARRY, SELLERSBURG, INDIANA



Athyris





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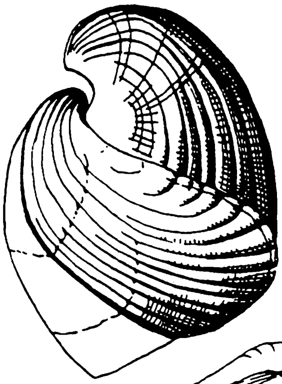

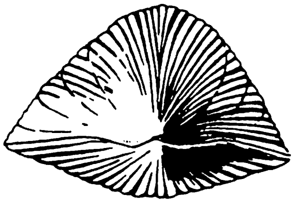

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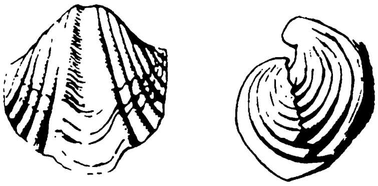

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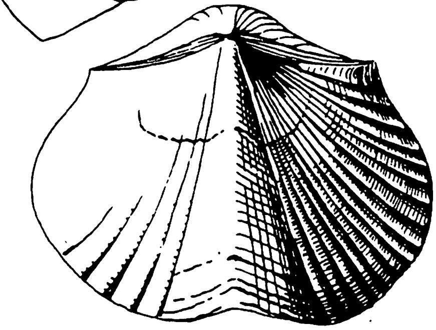

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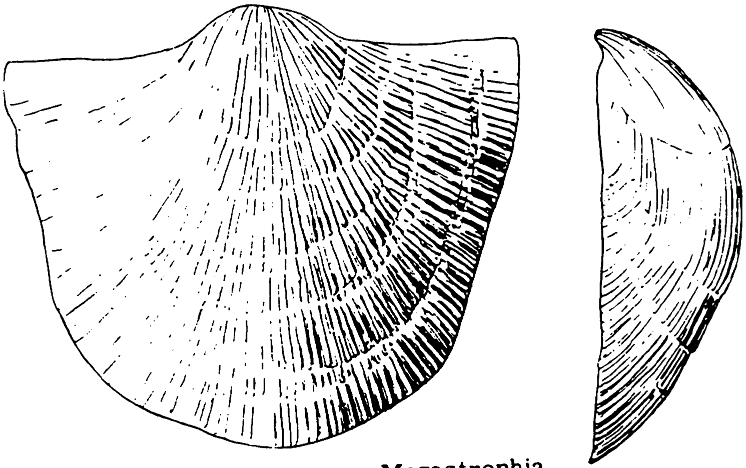

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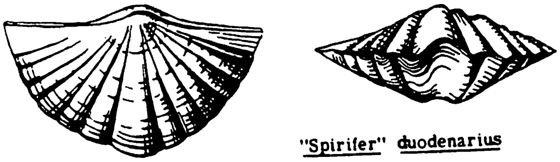

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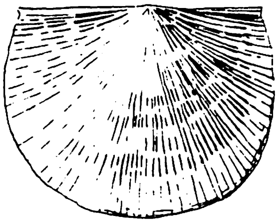

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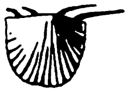

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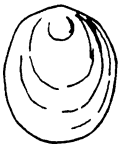

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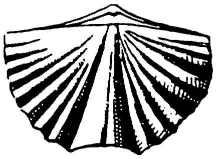
Orbiculoidea



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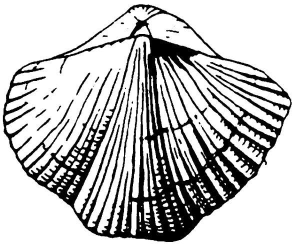

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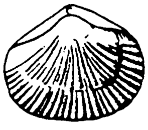

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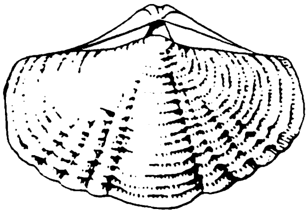

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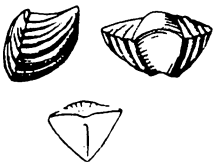

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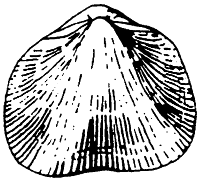

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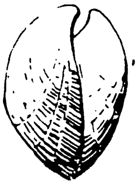

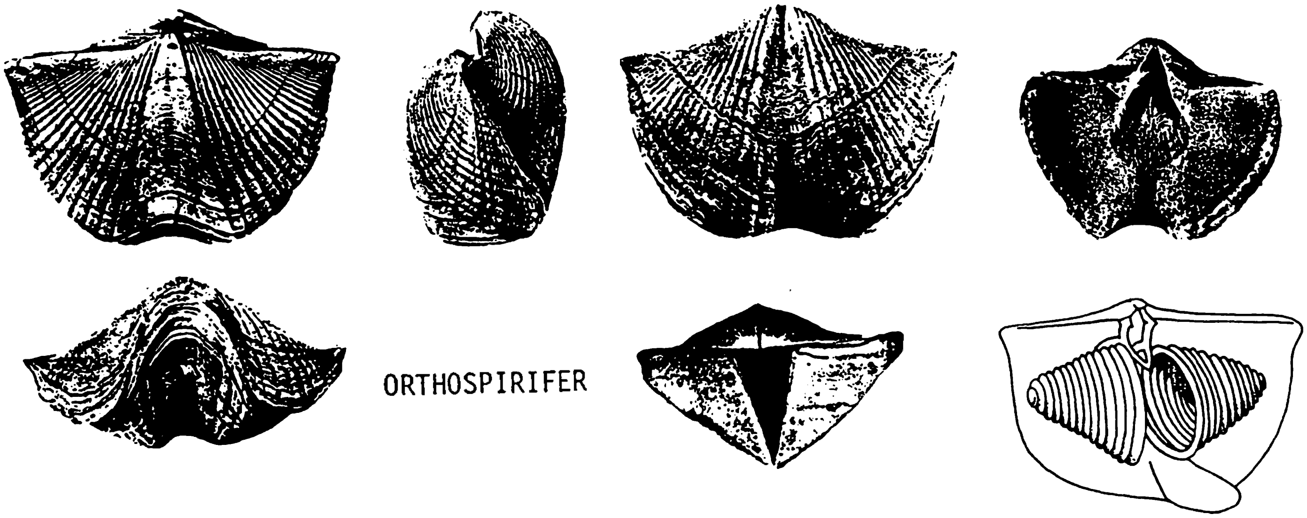

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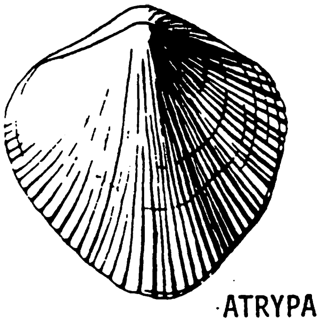

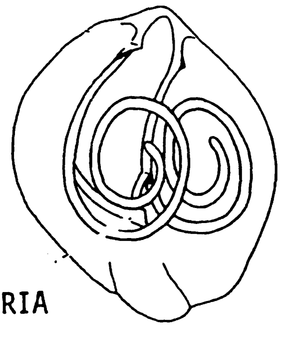

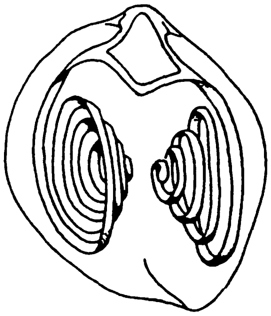

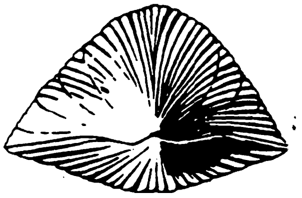

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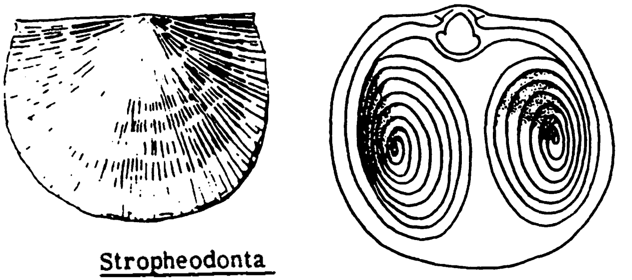

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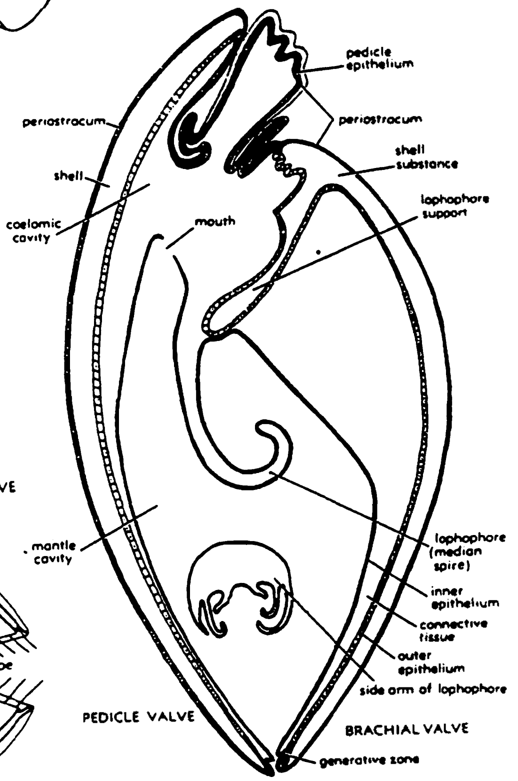
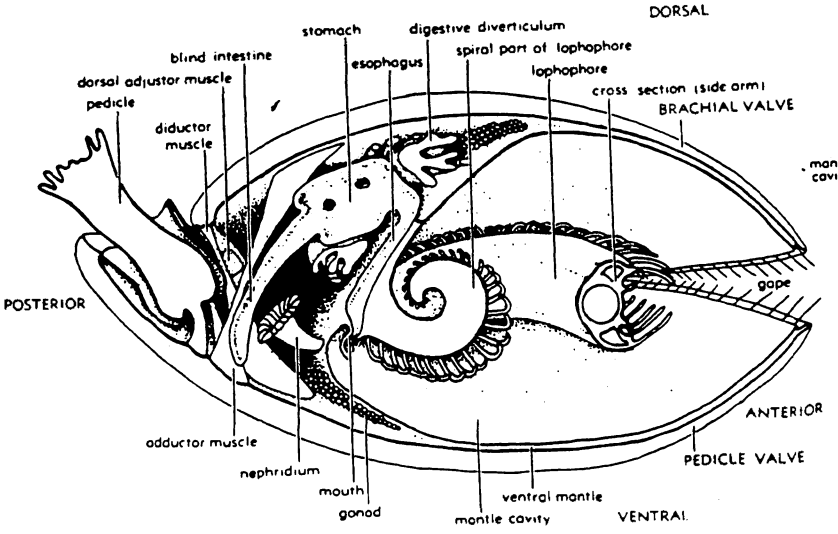
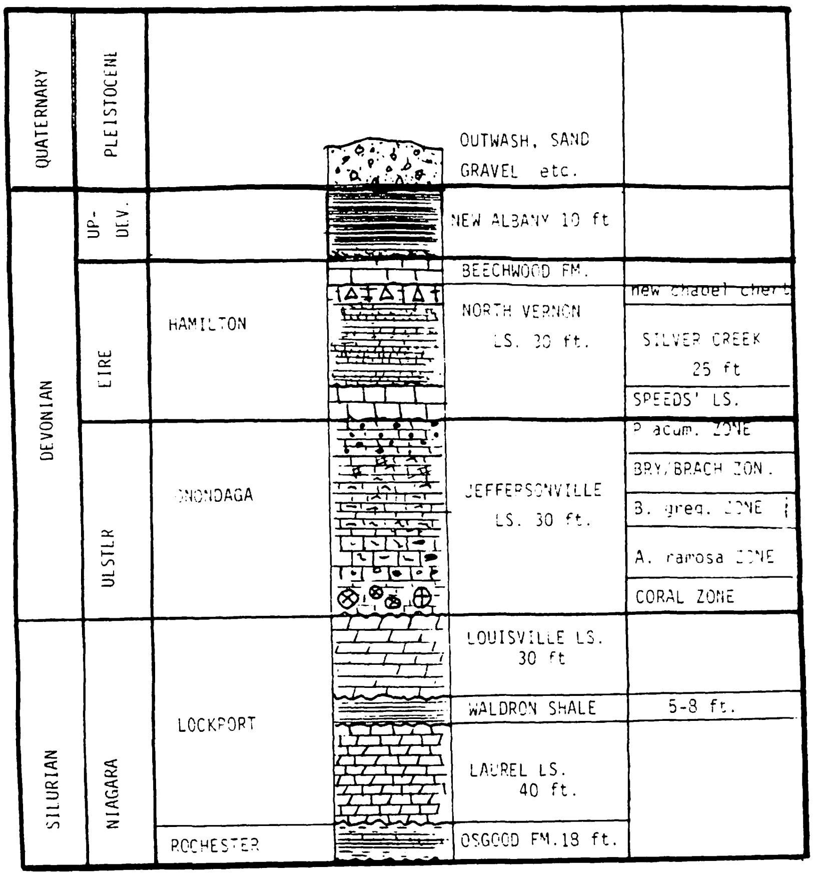


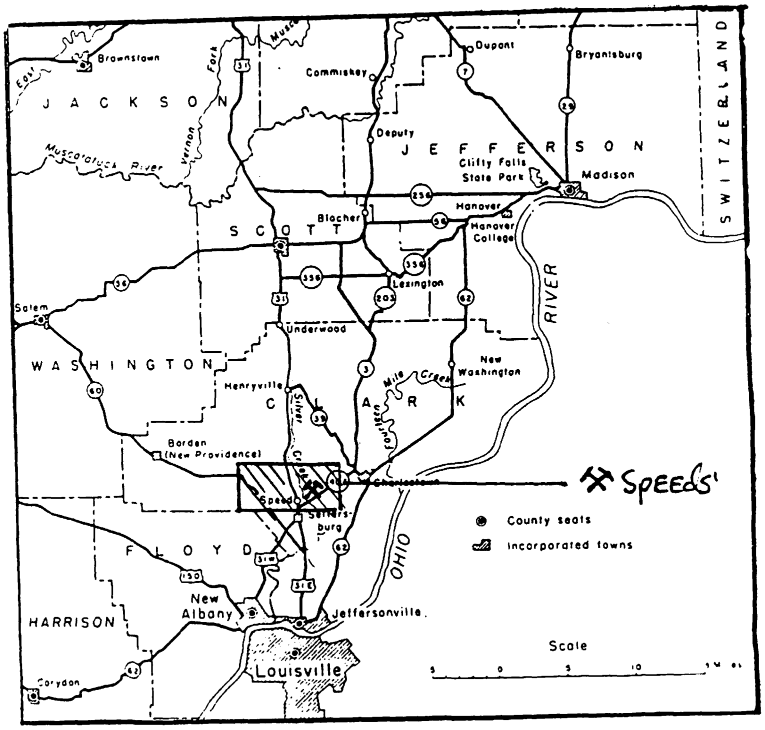




GENERALIZED STRATIGRAPHY IN THE VICINITY OF THE SPEEDS' QUARRY

GENERAL LOCALITY MAP

NOTE: Interstate highways are not included



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Many thanks to ESSROC for allowing me to collect the fossils and to study the geology of the Speeds' Quarry. And to Margaret Kahrs and Alan Goldstein for all their help and encouragement. Without Alan's fauna lists and Margaret's fossils and editorial skills and dedication this paper would not have been possible.

Early Paleozoic Color Patterns

Gerald Gunderson
6413 Elmwood Avenue
Middleton, WI 53562

The desire to collect ancient fossils that still have the original shell preserved got this long-time collector hooked on inarticulate brachiopods.

A quarry near Kaukauna, Wisconsin, was the source of the first specimens. They were glossy, phosphatic brown shells of fingernail size, and Middle Ordovician age. Even more fascinating, this fossil belonged to the oldest known genus, Lingula. Living members of this brachiopod genus can be found dwelling in mud burrows along oceanic coastlines.

During the ensuing years the bedding planes of sedimentary rocks in the Midwest were thoroughly checked for complete phosphatic shells. About seventeen years ago while prospecting in the Late Cambrian, Eau Claire Formation, of western Wisconsin, the author discovered complete specimens of Lingulella ampla. Surprisingly, some of the fossils exhibited alternating light and dark bands (Figure 1). Then another inarticulate brachiopod, Dicellomus politus, was found in the same formation - complete, and banded as well (Figure 2). By all indications, these bands represent the original color patterns one would have found on the living animal's shell; it may even be the oldest known fossil color pattern on record.

Another twist to this search occurred when Nigel Hughes, a graduate student in paleontology, while studying trilobites in the midwestern states, attended a lecture by Noreen Tuross, a biochemist at the Smithsonian Institution. She had come across a group of brachiopods on a piece of rock from Minnesota. Her analysis of the specimens revealed the presence of organic remnants in the shells. Hearing this, Nigel suggested that she ought to also take a look at material from Wisconsin. Samples from a variety of geologic settings were subsequently sent to her. Preliminary chemical tests indicated that some of the shells contained amino acids, the building blocks of protein, and these organic substances matched up with the protein chemistry of brachiopods living today, through a process similar to the typing of a person's blood.

Hughes, Tuross, other scientists, and the author then met in Eau Claire, Wisconsin, during the summer of 1993. Over a period of two weeks, we collected hundreds of kilograms of sandstone and shale, and eventually hauled it back to the Smithsonian. High school students in the Washington, D. C., area have since been carefully removing the phosphatic pieces from the matrix. After the chemical analysis of many brachiopods, much more may be learned about this animal's ancient proteins. Are these the oldest known organic materials associated with a specific fossil? Only time will tell.

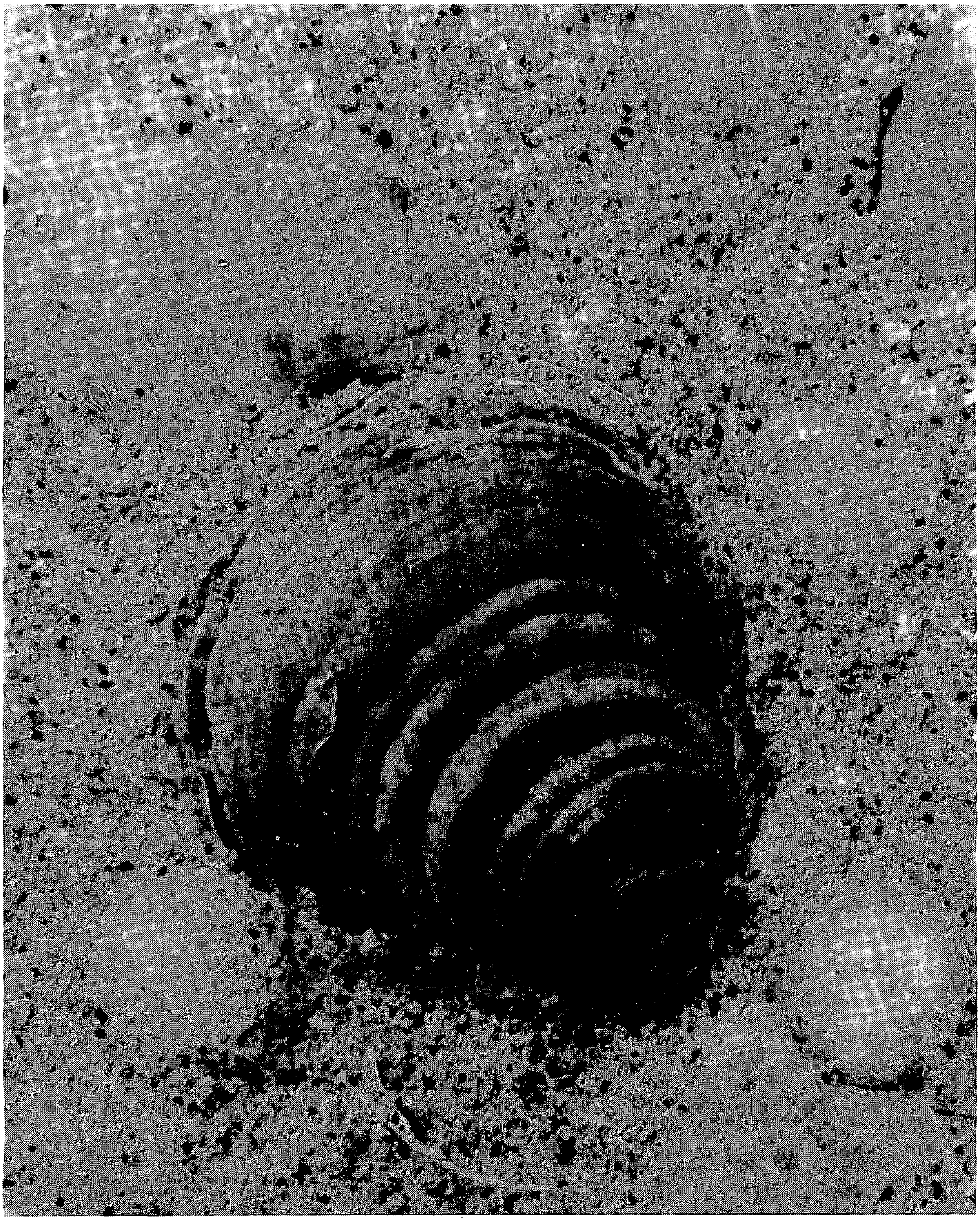

Figure 1. Linguella ampla, 8.5x, Late Cambrian
Eau Claire Formation, Colfax, Wisconsin

Additional Reading

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Figure 2. Dicellomus politus, 8x, Late Cambrian, Eau Claire Formation, from Strum, Wisconsin.