

THE BIFOLIATE CRYPTOSTOME BRYOZOA (ECTOPROCTA) FROM THE
MIDDLE ORDOVICIAN LINCOLNSHIRE LIMESTONE,
ROCKINGHAM COUNTY, VIRGINIA

by

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Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

in

the Department of Geological Sciences

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December, 1973

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ACKNOWLEDGEMENTS

For secretarial assistance in preparing this manuscript, I am indebted to Susan Friddell of the Geology Department, Georgia State University, Atlanta, Georgia, and to Pat Fenten and Judy Smith of the Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. For editorial assistance in reviewing the manuscript, I am indebted to members of my academic committee: Dr. Richard K. Bambach, my advisor, Dr. Chauncey G. Tillman, and Dr. Dewey M. McLean of the Department of Geological Sciences, Virginia Polytechnic Institute and State University, and Dr. George T. Farmer of the Geology Department, Madison College, Harrisonburg, Virginia. Dr. Farmer gave encouragement to develop a study of the bryozoans from the Lincolnshire Limestone in Rockingham County, Virginia into a thesis topic. He provided advice for preparing specimens and made equipment available for photomicroscopy work. Dr. Bambach helped define the project and assisted in problems encountered in preparing the thesis. Dr. Tillman assisted in preparing the conodont fauna and in evaluating their stratigraphic significance. He also helped prepare the portion of this report dealing with the conodonts. Dr. McLean offered many helpful suggestions for organization of the manuscript, and assisted in preparing the photographic plates. I also wish to thank Dr. Olgarts L. Karklins of the United States Geological Survey and Dr. Richard S. Boardman of the United States National Museum who made available for study, type specimens from the collections at the United States National Museum, in their care. I am also grateful

to Mr. Don Dean of the United States National Museum staff for his professional advice in preparing study specimens.

For the assistance of these persons, I am greatly indebted, and I express to them my sincere thanks.

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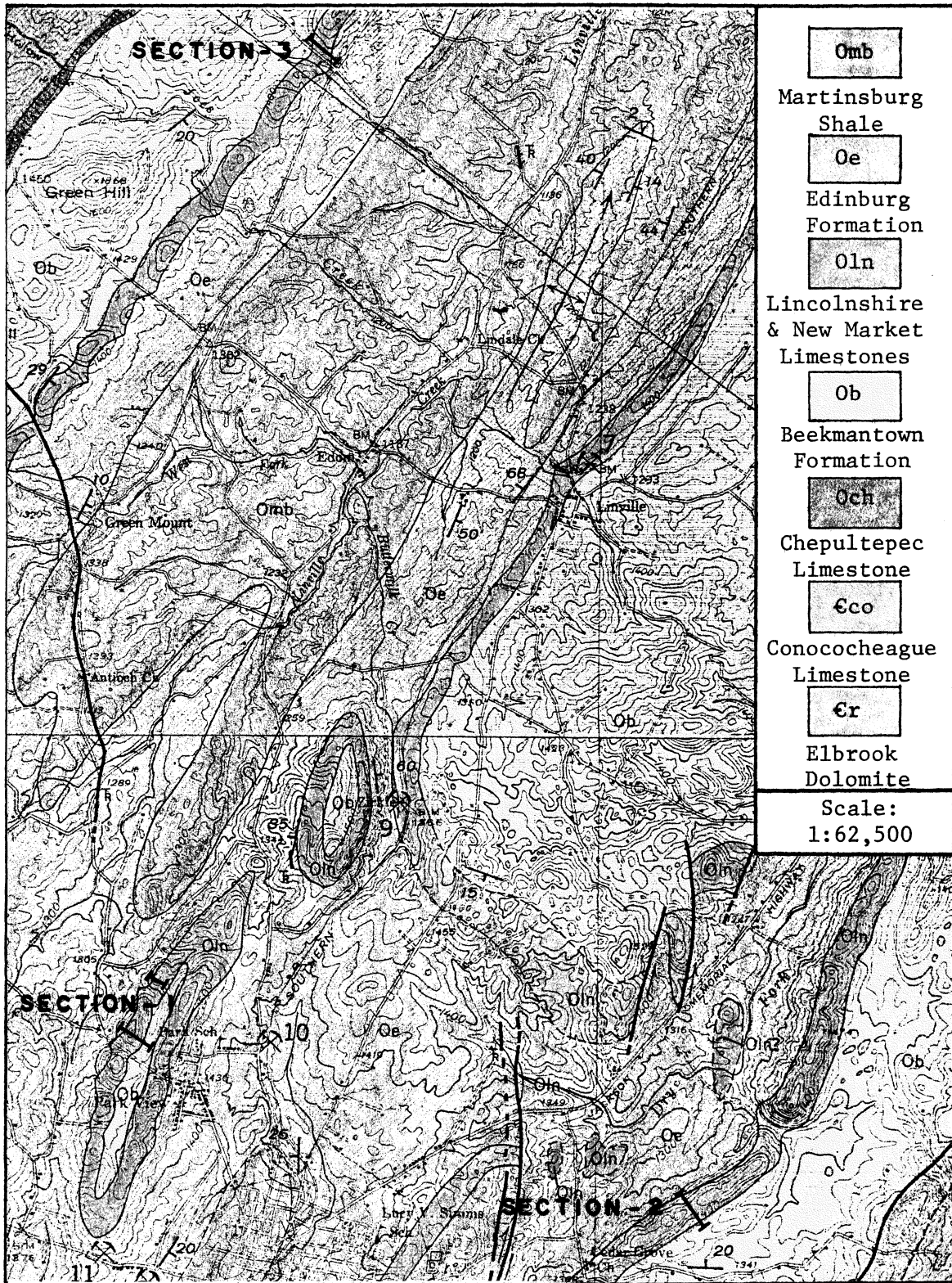
INTRODUCTION

This is the first detailed study of the bryozoan fauna of the Lincolnshire Limestone in Virginia. It is a broad survey of the fauna with particular emphasis on the bifoliate Cryptostomata.

The Lincolnshire Limestone is a distinctive, cherty, carbonate unit of Middle Ordovician (Champlainian) age in the Central Appalachians and is noted for its abundant, diverse marine fauna of bryozoans, brachiopods, mollusks, trilobites, and pelmatozoans.

The present study deals with a portion of the bryozoan fauna from three stratigraphic sections of the Lincolnshire Limestone in Rockingham County, west-central Virginia. These sections were selected because of: presence of well exposed sections of the Lincolnshire, the abundance of well preserved fossil bryozoan material, the structural setting of the sections, and the extent to which sedimentary units immediately below and above the Lincolnshire were exposed. The latter was an aid in providing stratigraphic control for the study.

The first geologic section, designated the Park View section, (Section 1, Text-Fig. 1), is about 1.6 km. (1 mi.) northwest of the Harrisonburg City limits, just west of the village of Park View. The second section, designated the Cedar Grove section, (Section 2, Text-Fig. 1), is about 4.02 km. (2.5 mi.) east of the Harrisonburg City limits and 1.6 km. (1 mi.) north of Cedar Grove Church. The third section, designated the Edom section (Section 3, Text-Fig. 1), is about 4.02 km. (2.5 mi.) north of Edom, Virginia, just west of the junction of County Roads 753 and 716.



Text-Fig. 1 - Portion of the geologic map of Rockingham County, Virginia showing locations of stratigraphic sections. (After Brent, 1960)

Descriptions of these measured sections are given in the Appendix, page 97 of this report.

Purpose.- The purpose of this study is to evaluate, describe, and illustrate bifoliate bryozoans of the order Cryptostomata, and to list and illustrate forms of the orders Trepostomata and Cystoporata from the Lincolnshire Limestone. The distribution of various species of cryptostomes is evaluated to provide information that may be useful in correlating the Lincolnshire Limestone of Rockingham County with rocks of other areas. Consideration is also given to the physical characteristics and distribution of facies throughout the sections to formulate an interpretation for the environments of deposition and their distribution through space and time. For this latter purpose, the three stratigraphic sections chosen include: the New Market Limestone of the Marmor Stage, the Lincolnshire Limestone of the Ashby Stage, and the basal portion of the Edinburg Formation of the Porterfield Stage (Cooper, 1956, p. 8).

Previous Work.- Except for several general faunal lists that include bryozoans, there are no known publications on descriptive morphology or bryozoans from the Lincolnshire Limestone in Virginia. Butts (1940, p. 143) published a list of bryozoan species from various localities in the Valley and Ridge Province of Virginia, but did not give a morphologic description of these species. Collections were made by Butts and his coworkers and sent to the U. S. National Museum in Washington, D. C. where they were identified and catalogued. Illustrations of the bryozoans by Butts (1940, Pl. 74 and 76) are external views of colonies with the exception of one line-drawing of

an internal view of Batostoma varium (Butts, 1940, pl. 76, fig. 7). Cooper and Cooper (1946, p. 77) list bryozoans identified from the Lincolnshire Limestone, but no descriptions were published. Several reports which include descriptions of new species of bryozoans from Middle Ordovician limestones in Virginia were published by Bassler (1934 and 1952).

Although no reports on bryozoans of the Lincolnshire Limestone of Virginia have been published, important systematic studies of Paleozoic bryozoans were conducted by Nicholson, Ulrich, Bassler and others in the late 1800's and early 1900's. These early studies provide the basic information on morphology of early Paleozoic bryozoans upon which much of the present classification of bryozoans is based. Nicholson (1876) published some of the first illustrations of thin sections of bryozoans and, in 1879, recognized the minor taxonomic value of external zoarial growth forms. An early monograph on Paleozoic Bryozoa by Ulrich (1890) is considered by Boardman (1960, p. 25) to be the most important single work on the Order Trepostomata. This monograph, however, is quite limited in its treatment of the Order Cryptostomata. In 1911, Bassler published a report on early Paleozoic bryozoans from the Baltic Provinces of Russia in which he provided information on wall structure and skeletal morphology of many taxa. In 1921, Coryell published a report on bryozoan faunas of the Stones River Group of central Tennessee. Coryell's study laid the groundwork for many of the more recent studies of Ordovician bryozoans in the Appalachians. Loeblich (1942) reported on bryozoa from the Ordovician Bromide

Formation of Oklahoma in which several new species were named and described.

Recent studies of Middle Ordovician bryozoans have been conducted in the northern and southern Appalachians, and in the central and southwestern United States. Dr. J. R. P. Ross (Phillips, 1960; Ross, 1960, a, b, c; 1961; 1963; 1964, a, b,; 1966; 1967, a, b; 1969; and 1970) has published on Middle and Upper Ordovician bryozoan faunas from north-central and eastern New York. Many of these studies, made in the type areas of the Chazy and Black River Groups, have provided information on the distribution, morphology, and phylogenetic relations of various taxa.

Perry (1962), Utgaard (1968, a, b; 1969), and Bork and Perry (1967 and 1968, a, b) have published on trepostome and cystoporate bryozoans of Middle Ordovician age from Illinois and Wisconsin. Boardman (1960, a, b) and Boardman and Utgaard (1966) have restudied much of the early literature on Middle Ordovician bryozoans and, from studies of specimens housed at the National Museum of Natural History in Washington, D. C., have revised and redescribed many taxa. Boardman (1971) and Boardman and Cheetham (1969) have made extensive studies of functional morphology of bryozoan skeletons. McKinney (1971) reported the stratigraphic distribution of trepostome bryozoans from the Lower Chickamauga Group (Middle Ordovician) from Alabama. Currently, studies of Middle Ordovician bryozoan faunas are being conducted in eastern Tennessee by Kenneth F. Ferrigno, Kenneth R. Walker, and others of the University of Tennessee.

Important recent studies of Middle Ordovician bifoliate

cryptostomes are by: Phillips (1960), Ross (1960 a, b, c; 1961; 1963; 1964 a, b; 1966; and 1970) (Chazy and Black River Groups, New York); Farmer (1968), unpublished dissertation, (Simpson Group, Oklahoma); and Karklins (1969) (Decorah Shale, Minnesota). The studies of Ross provide descriptive morphology, information on stratigraphic distribution, and phylogenetic relations of various bifoliate cryptostomes. Farmer reported that trepostomes occur stratigraphically below cryptostomes in the Simpson Group, Oklahoma, which is partially Middle Ordovician in age. Trepostomes first appear near the base of the Oil Creek Formation of Whiterock age (Farmer, 1968, p. 1). The first cryptostomes are reported to occur near the base of the McLish Formation of Marmor age (Farmer, 1968, p. 6). Karklins (1969) discusses morphological characteristics of the informal taxonomic groups of bifoliata cryptostomes. Karklins (1969, p. 11) proposed that the pachydictyid group of Phillips (1960) and Ross (1964b) be divided into two groups: the astreptodictyid group with wall construction similar to Pachydictya acuta (Hall), and the athrophragmid group with zoecial wall construction similar to Pachydictya foliata Ulrich. He also discussed characteristics of the stictoporida and escharoporida groups and species of Stictoporella.

Blake (1973) published an extensive report on acanthopore morphology and function in the non-bifoliate cryptostome family, Rhabdomesidae.

METHODS OF STUDY

Most of the field work for this study was conducted during the summer of 1972. Some of the preliminary work was done during 1971 while completing undergraduate study at Madison College, Harrisonburg, Virginia (Suter, 1971).

In this study, rock samples containing bryozoans from the three stratigraphic sections were prepared for study. Approximately 800 cellulose acetate peels and 300 thin sections of material containing bryozoans were made.

After initial peels and thin sections were made from a specimen, an attempt was made to obtain additional views of the same specimen. This proved difficult since all specimens were an integral part of the limestone matrix. Only a few well oriented second and third views were obtained by this procedure. This did provide enough information about a desired view so that the same view could be recognized in other specimens of the same species.

Several large acetate peels and thin sections of 100 sq. cm. or more were made from samples showing a great number of bryozoans. This aided in studying orientation of specimens, taxonomic association and diversity, and intraspecific variation. The process for producing large peels and thin sections is described later.

Field Collection and Sample Selection.- Samples showing observable skeletal fragments of bryozoans on surface outcrop were collected where possible. Exposures with few bryozoans were sampled approximately every meter (three feet). Fewer samples were collected and prepared from the Edom section because of poor exposure of the

Lincolnshire. Spot samples from the New Market, Lincolnshire, and basal Edinburg of the Edom section were prepared and studied in conjunction with material from the other sections to develop an interpretation of the depositional environments represented by this sequence of rocks.

Initial Preparation. - Individual bryozoan colonies and other fossils are an integral part of the dense Lincolnshire Limestone and are not commonly freed from the matrix by weathering. This makes it very difficult to obtain isolated individual specimens for study. Therefore, an alternate method for preparation of rock material was employed to study the bryozoans of the Lincolnshire Limestone.

The following technique was used and is recommended for material of this type. Rough field samples are first cut into slabs approximately 25 mm. thick from which rectangular blocks 25 mm. x 25 mm. x 40 mm. are cut. These rough blocks are etched lightly in dilute hydrochloric acid to remove small particulate rock material and are then rinsed. After rinsing, the blocks are examined while wet under a dissecting microscope for presence of bryozoans. From two to four rectangular blocks from each sample are selected and the surface prepared for making cellulose acetate peels.

Rapid initial grinding to remove saw marks is best achieved by use of a flat revolving lapidary wheel and number 320 or 400 abrasive. Final grinding is achieved by using the finest abrasives, either well worn number 600 abrasive paper or five micron loose abrasive on a glass plate with water. After the final grinding, samples are thoroughly cleaned in an ultrasonic cleaner to remove any loose

abrasive grains from the surface and from small cracks. The surfaces are then polished on a flat polishing wheel fitted with a short napped polishing cloth and tin oxide. Polishing is essential in making high quality peels because it removes fine surficial rock particles. Polishing also results in better differential etching of the rock surface.

Preparation of Peels.- Peels are impressions of etched, polished surfaces of rock or fossils produced on a piece of transparent cellulose acetate. This impression is the replica of the micro-relief produced on the surface of the rock or fossil by the etching process. Mineral grains and fossil fragments are differentially affected by the acid etching which produces the micro-relief surface.

The ease and rapidity at which peels are produced makes them useful for initial study of skeletal morphology, taxonomic identification at the generic level, and for biometric studies. Detailed wall microstructure of bryozoans is not adequately replicated in acetate peels and it is necessary to make thin sections of specimens selected for detailed study.

The method used for preparing acetate peels is essentially that described by Boardman and Utgaard (1964, p. 79). Equipment includes: (1) grinding and polishing compounds for surface preparation; (2) 1:20 solution of formic or hydrochloric acid for etching; (3) acetone as the acetate solvent; and (4) clean, clear cellulose acetate. Clear, colorless cellulose acetate is available in 20 by 50 by 0.06 inch (60 mil) sheets which are cut to the desired size, commonly that of standard microslides. The acetate is easily cut on a large power or hand operated sheet-metal cutting shears.

After the initial surface preparation described above, the rock or fossil surface is etched in a 1:20 solution of formic or hydrochloric acid for two to ten seconds depending on the desired effect. The specimen is immediately rinsed in water to stop the etching process. An etching time of four to six seconds is most effective for etching material from the Lincolnshire.

After thorough drying, the specimen is submerged in acetone and immediately applied to a clean cellulose acetate microslide with a slight rolling action and little or no pressure. The weight of the specimen is generally sufficient to produce the impression. The peel and attached specimen is dried and cured for at least an hour after which the peel is removed from the specimen.

Preparation of Thin Sections.- From analysis of the acetate peels, properly oriented, well preserved specimens were selected for further study. Thin sections of these specimens were made. The procedure used for preparation of thin sections is essentially that used at the United States National Museum of Natural History as described by Nye, Dean, and Hinds (1972, p. 274).

Initial preparation of rock surfaces follows techniques described in the previous section. Surfaces from which peels were made were re-ground using well worn number 600 fixed grit paper and polished before cementing to 25 mm. x 75 mm. frosted-end glass microslides with epoxy. The epoxy used was "Epotuf" resin 37-128 and hardener 37-614, supplied by Reichhold Chemical Company, White Plains, New York. Resin and hardener are mixed at a ratio of four parts resin to one part hardener by weight.

Preparation of Large Peels.- Large acetate peels from 60 to 650 square centimeters in surface area were made to study taxonomic associations and orientation of bryozoan specimens within a large sample.

Materials needed for making large peels include: (1) grinding compounds for initial surface preparation; (2) acetone as a solvent for the acetate; (3) a 1:20 solution of formic or hydrochloric acid for etching; and (4) thin cellulose acetate. In making large peels, it is desirable to use a thinner cellulose acetate than is used in making the smaller microslide peels. The thinner acetate is more easily applied to larger rock surface. Clear, colorless cellulose acetate can be obtained in rolls or sheets of various dimensions. Four and six mil acetate can be used in making large peels. The use of cellulose acetate thinner than three mil is not recommended because it may be completely dissolved by the acetone. Thick acetate is not recommended because it is difficult to apply and tends to entrap air pockets when applied.

In producing a large peel, rock samples are first sawed into slabs. Saw marks are removed using a flat revolving lapidary wheel and number 320 or 400 abrasive. Final grinding is done on a large piece of plate glass with number 600 and five micron abrasives and water. After grinding, the surface is cleaned, dried, and etched in a 1:20 solution of formic or hydrochloric acid for four to six seconds. A final polishing step is not necessary in making peels of large slabs unless a high degree of clarity is desired. After etching, the slab is placed in a level position and flooded with

acetone. The thin, pre-cut cellulose acetate is applied to the surface from one edge, or the center, using a rolling motion to ensure removal of air bubbles and excess acetone. Excess acetone beneath the acetate may soften the acetate and cause the peel to wrinkle. After applying the acetate to the rock surface, it should be allowed to dry and cure for eight to twelve hours to assure minimal curling when removed.

Preparation of Large Thin Sections.- Thin sections up to 250 square centimeters in surface area were made from samples containing many bryozoans. This aided in studying detailed microstructure of very large explanate colonies. In a sample with many bryozoans, a large thin section was more efficiently made than many small ones.

Materials needed for making large thin sections include:

(1) grinding compounds for initial surface preparation; (2) clean, first quality, single-strength glass; and (3) a suitable bonding agent. The Epotuf epoxy referred to in the previous section was used in making large thin sections.

The following procedure was used and is recommended for making large thin sections.

- (1) Initial grinding and surface preparation is essentially the same as that described for production of large peels except that no etching step is included.
- (2) After grinding, the surface is cleaned and the sample dried in an oven at low heat. The sample is allowed to cool to near room temperature before applying the epoxy. If the sample is not sufficiently cooled before it is cemented to the glass, the

glass may crack from differential contraction.

- (3) Epoxy cement is then applied to the warm rock surface and allowed to heat for two or three minutes. This reduces the viscosity of the epoxy and drives off most small air bubbles.
- (4) Any remaining bubbles may be removed by the heat from the flame of a match held closely over the epoxy surface. A quick "brush" with a low flame from a bunsen burner over the epoxy surface is also effective in removing small air bubbles.
- (5) A piece of first quality, single-strength glass is cleaned with acetone and then applied to the freshly epoxied rock using a slow "rolling" motion so that air pockets are not entrapped. A slow circular motion of the glass over the rock surface removes excess epoxy or small air bubbles from under the glass. The epoxy should be allowed to cure for at least 10 hours before completing the following steps.
- (6) After curing, excess rock material is removed by use of a large oil lubricated slab saw. To hold the glass and rock combination in the saw, a small rectangular block of wood, approximately the size of the glass slide and about two inches thick, is secured to the open face of the glass and then placed in the saw vise. An effective method for securing the wood block to the glass, so that it is easily removed later, is to lightly glue a thin piece of cardboard between the glass and wood block. The cardboard is cut slightly smaller than the wood block and is secured between the glass and wood block with a small amount of water soluble glue such as "Elmer's Glue-All" applied only to the

edges of both sides of the cardboard. A small bead of glue may be placed around the perimeter of the block to seal out excess oil during the sawing process.

- (7) After the glue has hardened, the wood block with attached glass is secured in the saw vise and aligned parallel to the cutting blade. At least 2 millimeters of rock should be left attached to the glass to allow for irregularities from sawing.
- (8) After sawing, excess rock material is removed by grinding on a flat, revolving lapidary wheel and number 220 or 320 abrasive. During this initial grinding, the wood block remains attached to the glass.
- (9) When the section becomes thin enough so that light begins to pass through the rock material, the wood block is removed from the glass by soaking in warm water for a few minutes.
- (10) Final grinding is completed on a glass plate using number 600 and five micron abrasives. A circular or figure-eight motion is used to assure even grinding of the rock surface. Particular care must be given to grinding if the fringe of epoxy around the rock is not evenly distributed. The side of the thin section with a wide epoxy fringe will grind slower than the side with the narrow epoxy fringe. Greater pressure must be applied to the side with the wider epoxy fringe to prevent beveling and/or loss of a portion of the section.
- (11) After grinding to the desired thickness using five micron grit, a thin coat of acetone soluble "Alvar" resin may be applied to the surface to protect it from scratching. The resin coat is

polished using a soft cloth, water or mineral oil, and tin oxide.

Although thin sections with a surface area of over 250 square centimeters were made using this method, sections with a surface area of 50 to 150 square centimeters were most efficiently made.

STRUCTURAL SETTING

Rockingham County is in the Valley and Ridge Province of west central Virginia with the Blue Ridge Mountains to the east and ranges of the Appalachians to the west. The three measured stratigraphic sections of this study are within the Long Glade syncline (Lowry, 1971, p. 126) in Rockingham County near Harrisonburg, Virginia.

The Long Glade syncline is a broad northeast-southwest trending structure with dips from 25° to 35° on both the southeast and northwest limbs. The syncline extends from Long Glade, Augusta County, northeastward through central Rockingham County to near Broadway, Virginia. The southeast limb of the structure is bounded by the Staunton-Pulaski Thrust Fault, and the northwest limb is terminated by the North Mountain Thrust Fault. Just north of Harrisonburg, the syncline bifurcates into an eastern branch, the Harrisonburg syncline, and a western branch, the Broadway syncline (Lowry, 1971, p. 126).

Exposed within the Long Glade syncline are rocks that range from Middle Cambrian through Upper Ordovician in age.

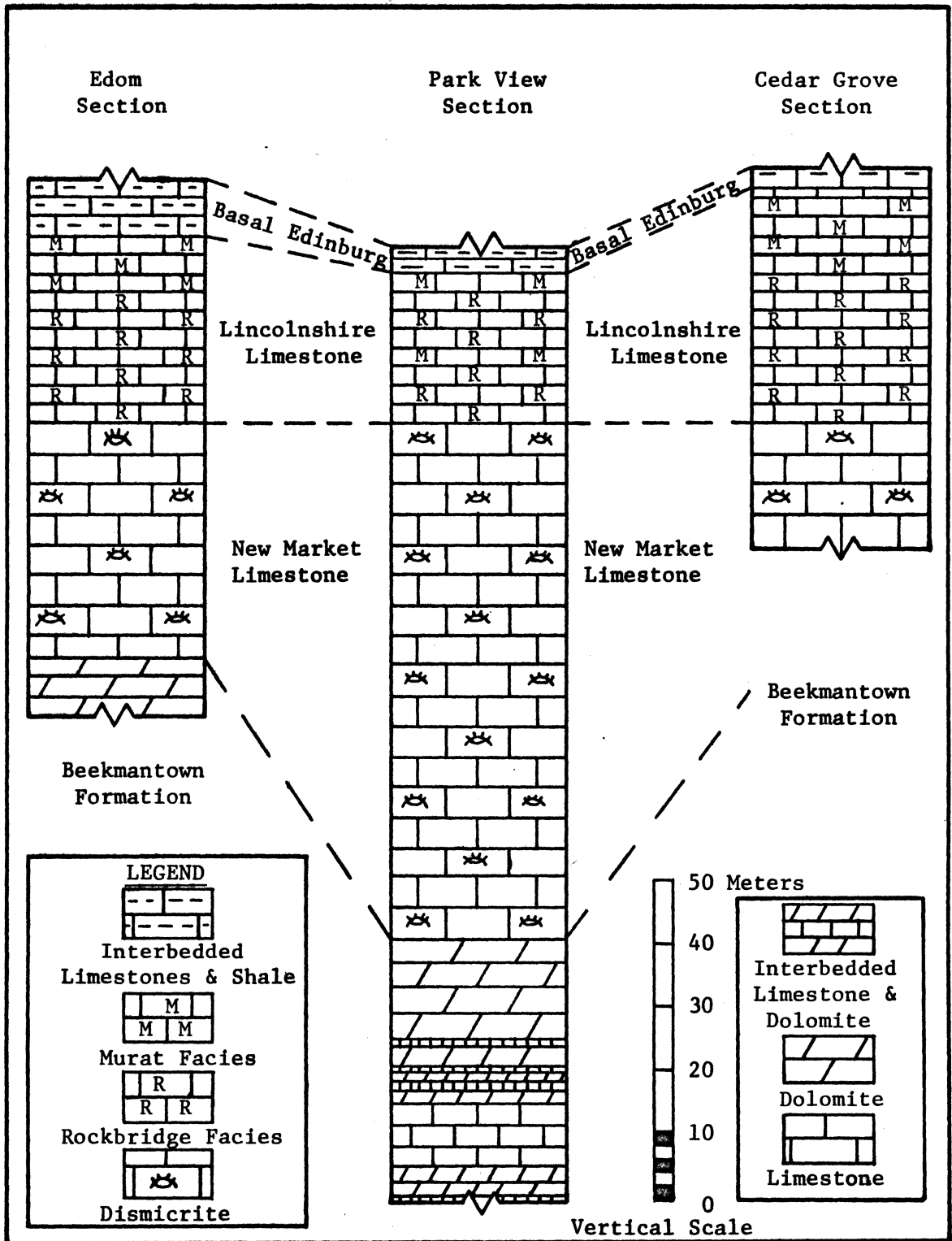
The Cedar Grove section (Section 2, Text-Fig. 1) is on the southeast limb of the Long Glade syncline about 4.8 km. (3 miles) southeast of the axis. The Edom section (Section 3, Text-Fig. 1) is on the northwest limb of the Broadway-Long Glade syncline about 2.4 km. (1.5 miles) northwest of the axis, and the Park View section (Section 1, Text-Fig. 1) is on the northwest limb of the small doubly plunging Park View anticline which is developed in the axial portion of the Long Glade syncline.

STRATIGRAPHY

Introductory Statement.- Lower Middle Ordovician formations in Rockingham County, Virginia, include the New Market and Lincolnshire Limestones and the Edinburg Formation. From this study, it was found that some beds in the upper Beekmantown Formation (considered Canadian in age) contain a conodont fauna that suggests that they are Whiterock age (lower Middle Ordovician).

Rocks studied for this report include: fine grained micrites, dismicrites, and dolomicrites of the upper Beekmantown; fine grained dismicrites of the New Market; fossiliferous biomicrites and biosparites of the Lincolnshire; and buff weathering shales and thin limestones of the lower Edinburg. (Petrographic terms used in this report are according to Folk, 1959.) Samples were collected from three measured stratigraphic sections. Columnar sections for the three sections are given in Text-Figure 2. Detailed descriptions of these sections are given in the Appendix of this report. Section descriptions include physical characteristics of individual units, field numbers and stratigraphic positions of samples, individual unit thicknesses, and cumulative thicknesses of formations.

Stages of the Champlainian Series.- The stage names used in this report are those defined by G. A. Cooper and B. N. Cooper (in Cooper, 1956, p. 6-8). The definition of these stages was based on studies of the brachiopod fauna. The boundaries of the stages were based on the first appearances and extinctions of brachiopod genera. Correlations of rock units included in the Cooper study were based on physical stratigraphic relationships and comparison of brachiopod



Text-Fig. 2 - Columnar section for the three stratigraphic sections showing lithologies and relative thicknesses of units.

faunules from different units. Cooper (1956, p. 7) realized that correlations based on a single taxonomic group do not give the accurate relationships and correlations of strata and suggested that study of additional groups was needed to refine the stages as originally defined.

Stages of the Champlainian Series included in this report are in ascending order: Whiterock, Marmor, Ashby, and Porterfield. These stage names have been used extensively in literature pertaining to Southern Appalachian stratigraphy and are generally accepted as the stage divisions of the Champlainian Series. The Whiterock Stage, however, has its type area in Nevada, and rocks of this age have heretofore not been recognized in the Southern Appalachians.

Recent work by Bergström (in Sweet and Bergström, 1971) with conodont faunas from rock units included in the above mentioned stages provide information that does not agree with the stage divisions originally defined by Cooper. Bergström (1971, p. 83-104) has defined conodont faunal zones which he based on conodont ranges. He has grouped these zones under the stages erected by Cooper but finds that the originally defined Ashby and Porterfield stages, in part, overlap the same time interval. He therefore concluded that additional information is needed from areas in the Appalachians to establish more useful time stratigraphic relationships of units.

In this report, the names Chazy and Black River are used as rock stratigraphic names rather than as stages or time stratigraphic names.

The Cryptostome bryozoan fauna of the Lincolnshire in Rockingham

County, is found to have many similarities to elements of the upper Chazy and lower Black River Limestone faunas of New York which were described by Phillips (1960; Ross, 1963, 1964a, 1964b). This suggests that the Lincolnshire in central Virginia is partially correlative to the upper Chazy and lower Black River units in New York although exact correlation with these rocks is difficult to define.

Whiterock Stage.- The type sections of the Whiterock Stage are in the Antelope Valley region, and the Toquima and Monitor Ranges of Nevada. The name "Whiterock" is taken from the Whiterock Canyon in the Monitor Range. Rocks of Whiterock age have also been reported from the Marathon Mountains of Texas, from the Arbuckle Mountains of Oklahoma, and from California, Newfoundland, and Alabama. They have not previously been reported from Virginia, but samples from the upper Beekmantown of the Park View Section contain a conodont fauna similar to that described from some of the areas mentioned above (Suter and Tillman, 1973, p. 441). This shows that rocks of Whiterock age are present in Rockingham County, Virginia, at least where a disconformity between the Knox-Beekmantown and New Market is not clearly developed.

Throughout much of the Valley and Ridge Province of the Southern Appalachians, a marked erosional disconformity is recognized between carbonates of the Lower Ordovician Knox Group and carbonates of Middle Ordovician age. At various localities, this erosional disconformity has developed relief of up to several hundred feet. In portions of Rockingham County of west-central Virginia, this disconformity is difficult to recognize. Where present on the southeast

limb of the Long Glade syncline, the disconformity exists between the Lower Ordovician Beekmantown Formation, which is largely dolomite, and the basal Middle Ordovician New Market Limestone, which is largely dismicrite. On the northwest limb of the same structure, the disconformity is more difficult to recognize.

The northwest limb of the small Park View anticline at the Park View section, lacks a marked disconformity between the Beekmantown and New Market. The boundary between them is difficult to place using lithologic criteria alone. The stratigraphic sequence at this location consists of interbedded buff weathering dolomites, dolomitic limestones, and bluish limestones in the upper Beekmantown, followed upward by dove-gray New Market Limestone. There is little indication of major interruption in sedimentation throughout this sequence.

Carbonates of the upper Beekmantown exhibit primary sedimentary features similar to the basal New Market, including mudcracks, algal laminations, scour surfaces, and carbonate pebble conglomerates. At this location, the upper Beekmantown is highly dolomitic, whereas the New Market is nearly pure limestone. The presence of dolomites, however, is not a certain criterion for distinguishing the Beekmantown from the New Market, as dolomite is known in the Tumblez and Blackford Formations in southwestern Virginia which occupy the same stratigraphic positions as the New Market Limestone.

The sedimentary structures of the upper Beekmantown suggest that their genesis has a close parallel in modern tidal flat sedimentation. Regions of the Bahamas and Florida Keys exhibit similar features and are interpreted as having formed during alternate periods of submer-

gence and wave scour and subaerial exposure and desiccation.

That these facies represent a harsh marine environment is suggested by the very low faunal abundance and diversity with gastropods and a few cephalopods making up the majority of the shelly fauna. When fossils do occur, they are present locally in abundance, and usually are restricted to rather thin beds.

Girvanella-like algal structures were observed in thin section, but no large stromatolite structures were observed in the field.

Ten samples of limestone and dolomite from the approximately 41 meters (135 feet) of exposed Beekmantown were processed for microfossils and all were found to contain conodonts.

Samples were also collected upward into the New Market Formation to provide comparative conodont material at the same site. Eleven samples were collected through the 80 meters (263-foot) of New Market limestone. Three of these samples, distributed more or less evenly through the formation, were fossiliferous. Distribution of conodonts in the Beekmantown and New Market interval of the Park View section is shown in Table 1. Data for Beekmantown and New Market samples are given in Table 2.

The conodont fauna of the Beekmantown formation proved to be strikingly different from that of the New Market. A number of form species and genera are present in the Beekmantown including many single-cusp forms. The compound forms include Cordylodus, Dichognathus or Prioniodus, Histiodela, Tetraprioniodus, Trichonodella and Roundya-like forms, and other unidentified compound forms. But the most distinctive forms belong to species of the form genus

Table 1 - Conodonts from the upper Beekmantown - New Market interval of the Park View section.

Conodonts from the New Market Limestone		
C2-4	C2-8	C2-17
<u>Erismodus</u>	<u>Falodus</u>	<u>Curtognathus</u>
<u>Cardiodella</u>	<u>Cyrtoniodus</u>	<u>Cardiodella</u>
<u>Polycaulodus</u>	<u>Ozarkodina</u>	<u>Trucherognathus</u>
<u>Trucherognathus</u>	<u>Erismodus</u>	<u>Erismodus</u>
<u>Zygognathus</u>	<u>Polycaulodus</u>	<u>Polycaulodus</u>
<u>Phragmodus</u>	<u>Microcoelodus</u>	<u>Ozarkodina</u>
<u>Rhipidognathus</u>	<u>Trucherognathus</u>	
	<u>Cardiodella</u>	
	<u>Zygognathus</u>	
	<u>Rhipidognathus</u>	
Conodonts From the Upper Beekmantown Formation		
C2-19	C2-19B	C2-23
<u>Ligonodina</u>	<u>Falodus</u>	<u>M. tridens</u>
<u>Dichognathus</u>	<u>Prionodus</u>	<u>M. lateralis</u>
<u>Cordylodus</u>	<u>Dichognathus</u>	<u>M. subdentatus</u>
<u>Roundya</u>	<u>Cardiodella</u>	<u>Drepanodus</u>
<u>Tetraprioniodus</u>	<u>Tetraprioniodus</u>	<u>Acodus</u>
<u>Drepanodus</u>		<u>Histioidella</u>
<u>Scandodus</u>	C2-19C	<u>Dichognathus</u>
	<u>M. subdentatus</u>	<u>Cordylodus</u>
C2-19A	<u>Drepanodus</u>	<u>Prionodus ?</u>
<u>Oistodus</u>		<u>Roundya ?</u>
<u>Prionodus</u>	C2-20	
<u>Gothodus</u>	<u>Multioistodus</u>	C2-24
<u>Acontiodus</u>		<u>Drepanodus</u>
<u>Cordylodus</u>	C2-21	<u>M. tridens</u>
<u>Scandodus</u>	<u>M. tridens</u>	<u>M. lateralis</u>
<u>Acodus</u>	<u>M. subdentatus</u>	
<u>Roundya</u>	<u>M. lateralis</u>	C2-25
<u>Tetraprioniodus</u>	<u>Cordylodus</u>	<u>Oistodus</u>
	<u>Drepanodus</u>	<u>Strachanognathus</u>
	<u>Tetraprioniodus</u>	<u>M. lateralis</u>
		<u>M. subdentatus</u>
	C2-22	<u>Multioistodus tridens</u>
	<u>Dichognathus</u>	
	<u>Hibbardella</u>	
	<u>M. subdentatus</u>	
	<u>M. lateralis</u>	
	<u>M. tridens</u>	

Table 2 - Sample interval data from the Beekmantown - New Market portion of the Park View section.

Sample Number	Dip, Degrees	Sample interval, Horizontal		Cumulative Elevation		Cumulative Strat. Thickness	
		Feet	Meters	Feet	Meters	Feet	Meters
Top of New Market							
C1-1	55	27.9	8.50	53.1	16.16	236.1	80.19
C2-1		26.9	8.20	47.2	14.36	236.7	72.15
C2-2		27.8	8.47	42.3	14.36	212.1	64.65
C2-3		30.5	9.30	39.4	11.99	185.6	56.57
C2-4		20.8	6.34	38.0	11.57	168.5	51.36
C2-5		30.6	9.36	37.1	11.30	143.8	43.86
C2-6	47	15.6	4.75	35.3	10.75	130.8	39.86
C2-7		79.2	24.14	33.4	10.17	88.8	27.07
C2-8	44	63.8	19.45	28.4	8.65	39.9	12.16
C2-9		34.3	10.45	25.3	8.65	14.1	4.30
C2-17		1.00	0.30	19.4	5.91	4.2	1.28
C2-18	41	2.8	0.85	18.5	5.64	2.8	0.85
Base of New Market		0.0	0.00	17.7	5.40	0.0	0.00
Top of Beekmantown							
C2-18A		14.6	4.45	17.7	5.40	135.1	41.18
C2-18B		45.6	13.90	13.5	4.12	122.6	36.36
C2-19		17.6	5.36	12.5	3.82	93.0	28.35
C2-19A		2.6	0.79	11.3	3.45	81.1	24.72
C2-19B		14.8	4.51	10.5	3.21	79.0	24.08
C2-19C		5.0	1.52	5.5	1.69	67.1	20.45
C2-20		3.4	1.04	6.1	1.87	63.1	19.23
C2-21	34	8.1	2.47	6.4	1.96	60.7	18.50
C2-22		10.9	3.32	4.4	1.35	55.2	16.83
C2-23		2.6	0.79	4.4	1.35	48.4	14.75
C2-23A		13.2	4.02	3.3	1.01	46.4	14.14
C2-23B		5.8	1.77	4.9	1.50	40.6	12.37
C2-23C		11.0	3.35	3.0	0.92	35.8	10.91
C2-23D	30	14.9	4.54	2.7	0.83	30.4	9.27
C2-24		2.9	0.88	3.3	1.01	23.4	7.16
C2-25		41.2	12.56	1.8	0.55	20.0	6.10
Base of measured section		0.0	0.00	0.0	0.00	0.0	0.00

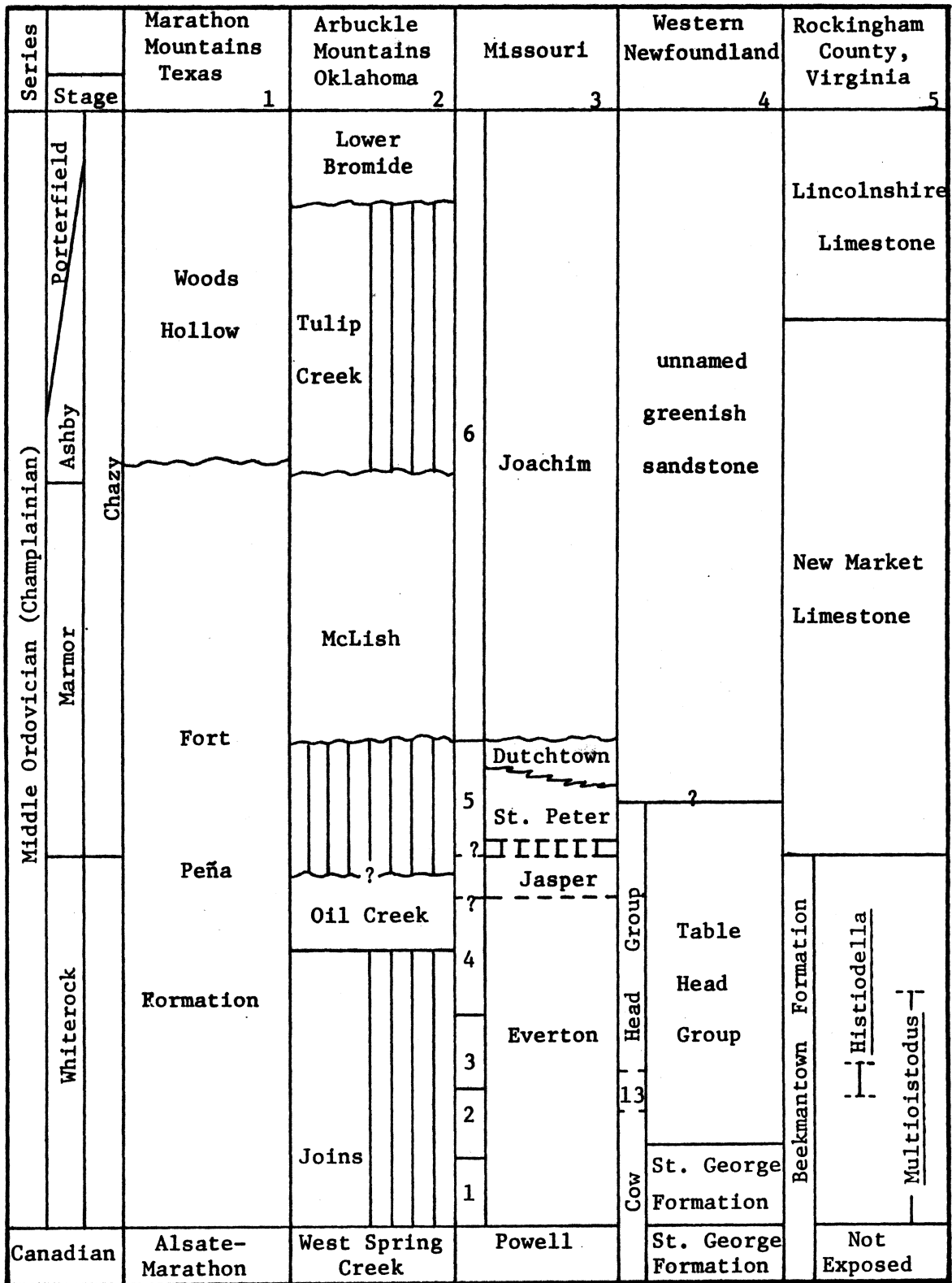
Multiostodus Cullison, 1938, here reported in abundance for the first time from the Appalachians.

Multiostodus is a conodont that consists of a large posteriorly curved cusp from whose base a denticle is developed at one or more of its anterior, lateral, or posterior basal slopes. This is a highly variable form genus which has been subdivided by various workers into four form species, M. subdentatus Cullison 1938, M. lateralis Cullison 1938, M. tridens Cullison 1938, and M. compressus Harris and Harris 1965.

In contrast to the Multiostodus-rich Beekmantown fauna on the Park View anticline, the overlying New Market contains a completely different conodont fauna in which first appear the form genera Curtognathus, Cardiodella, Erismodus, Polycaulodus, Trucherognathus, Zygnathus, and other forms including a striking unidentified palmate species. This fauna is completely devoid of Multiostodus and Histioidella.

Correlations for selected Middle Ordovician Formations from which Histioidella and Multiostodus are reported to occur, are given in Text-Figure 3. Column one of the Marathon Mountains, Texas is modified after Bradshaw (1969), Berry (1960), and Graves and Ellison (1941).

Column two of Oklahoma is modified after Mound (1965), Harris and Harris (1965) and Sweet, Ethington, and Barnes (1971). Column three of Missouri is after Sweet, Ethington, and Barnes (1971). Column four of western Newfoundland is after Fähræus (1970). Column five represents the section of this study. Ranges of the genera Histioidella and Multiostodus from the Park View section are given



Text-Fig. 3 - Correlation of Middle Ordovician Formations for sections from which conodonts are mentioned or illustrated. See text page 25 for sources of information.

in the left center of column five.

A review of the distribution of Multiostodus provides some insight as to the possible importance of its discovery in the Appalachians of Virginia.

Missouri. Multiostodus was first described by Cullison from the Lower Middle Ordovician Dutchtown Formation of Missouri (Text-Fig. 3, column 3). It has not been found in higher formations there, but the next overlying Joachim Formation contains a conodont fauna similar to that of the New Market.

Oklahoma. Multiostodus has been reported from several formations that span a considerable time interval, mainly in the Arbuckle Mountains (Text-Fig. 3, column 2). Mound (1965) reported M. subdentatus from the McKenzie Hill and Cool Creek formations of the Arbuckle Group and M. cf. M. tridens from the Cool Creek. Harris and Harris (1965) described the new species M. compressus from the West Spring Creek Limestone at the top of the Arbuckle Group (Canadian Age) on the south side of the Arbuckle Mountains. Mound (1965) described all four named species of Multiostodus from the Joins Formation (Whiterock age) in Oklahoma. And Harris (1964) also recorded all three of Cullison's species from the overlying Oil Creek Formation which is also of Whiterock Age. The next higher formations, the McLish, Tulip Creek and Bromide Formations, apparently lack Multiostodus. Elsewhere in Oklahoma, Harris (1964) reported the genus from the Burgren and Tyner Formations, correlatives of the Oil Creek Formation (Whiterock age). The genus Histiodelia Harris (1962) was first described from the Joins Formation (Whiterock age) and is

found only in that formation in Oklahoma.

Texas. The genus Multioistodus was reported by Bradshaw (1969) from the Fort Peña Formation of the Marathon Mountains but not from the underlying Marathon Formation (Canadian plus Whiterock age) nor the overlying Woods Hollow (Ashby-Porterfield age) and younger formations. The Fort Peña was dated by means of graptolites (Berry, 1960) as Whiterock and Marmor in age, with the top few feet Ashby age.

Nevada. Ettington and Schumacher (1969) reported that Multioistodus and Histiodelia are typical Antelope Valley conodonts. The Antelope Valley Formation, of the Monitor Range of eastern Nevada, is the type Whiterock Stage. The overlying Copenhagen Formation lacks these two genera.

Newfoundland. Fähræus (1970) reported the presence of Multioistodus in bed 13 of the Cow Head Group whose upper part correlates with the Table Head Formation. Multioistodus was also reported from the Table Head. Both the Table Head and the correlative part of the Cow Head are considered Whiterock age by Whittington and Kindle (1963) and Kindle and Whittington (1958).

With the accumulation of considerable data on the stratigraphic distribution of conodont species in North America, Sweet, Ettington and Barns (1971, p. 166) erected a succession of 12 conodont faunal assemblages based on ranges of stratigraphically important Middle and Upper Ordovician conodont species. These conodont faunas were placed within the stratigraphic framework defined by Cooper (1956). The successions begin at the base of the Whiterock Stage and continue through the top of the Richmond Stage. Faunal assemblages 1 through

6 of Sweet, Ethington, and Barnes (1971, p. 166) are shown in Text-Figure 3, column 3. Faunas 1 through 4 are Whiterock age. Fauna 5 contains the fauna of the Dutchtown of Missouri and Crystal Peak Limestones of Utah. Fauna 6 occurs in the Joachim Formation of Missouri (except top part) and in the Tulip Creek and McLish of Oklahoma.

Considering the above mentioned occurrences of Multiostodus and Histiodela, the occurrence of these form genera in rocks below the New Market at the Park View section indicates that Whiterock age rocks are present in this part of the Southern Appalachians. Since Multiostodus occurs in the lowest sample processed from this section, it is possible that not all of the Whiterock age rocks are exposed within this sequence.

The upper Beekmantown of the Park View Anticline contains a rich conodont fauna many of whose species have not been found in rocks of Canadian age. Multiostodus is abundant and represented by several species; Histiodela, and other new and distinctive species not found in younger rocks, are present. The overlying New Market Limestone contains a different fauna more like that of fauna 5 (Dutchtown of Missouri) and fauna 6 (Joachim of Missouri) as described by Sweet, Ethington, and Barnes (1971). Thus the upper Beekmantown of the Park View section appears to contain a Middle Ordovician conodont fauna of probable Whiterock age but it occurs below the position of the regional post-Knox unconformity. This distinctive fauna should permit recognition of this interval elsewhere in the Appalachians where continuous sedimentation occurred

across the Beekmantown - New Market boundary.

Marmor Stage.- The name for the Marmor Stage is taken from an area northeast of Friendsville, Tennessee. Cooper (1956, p. 8) states that "This stage includes the Chazy group of rocks and its correlatives." In the type area, the units included in this stage are the Tumblez and Lenoir Formations and the Mosheim facies of the Lenoir. In Rockingham County, the New Market Limestone is the only unit present that is included in the Marmor Stage.

New Market Limestone.- The name New Market Limestone was proposed by Cooper and Cooper (1946, p. 71) for exposures of dove gray calcilutites near Edinburg, Virginia that occur above the Beekmantown Formation and below the Lincolnshire Limestone.

The New Market Limestone throughout much of Rockingham County is nearly pure calcium carbonate which weathers light dove-gray. A distinct characteristic of the New Market is the birdseye fabric of clear calcite blebs. The blebs are quite prominent on weathered surfaces. The New Market contains a very restricted marine fauna of low abundance and diversity with gastropods and ostracodes making up the majority of the shelly fauna.

The thickness of the New Market at the Park View section is approximately 80 meters (263 feet). At the Edom section the unit is approximately 37 meters (120 feet) thick. No measurement was made of the New Market at the Cedar Grove section.

Ashby Stage.- The type area of the Ashby Stage is in northeastern Tennessee. It was named for a road intersection along Hogskin Creek in the northeast quarter of the center sub-quadrangle of the

Maynardville (30') Quadrangle, Tennessee. In the type area, units of the Ashby Stage are: the Elway, Lincolnshire, and a shaly unit, the Hogskin Member of the Lincolnshire. In Rockingham County, the Whistle Creek and Lincolnshire are assigned to the Ashby Stage but in areas studied, only the Lincolnshire is present.

Studies of conodont faunas from units of Middle Ordovician age in the Southern Appalachians by Bergström (1971) suggest a time overlap of the Ashby and Porterfield Stages. The top of the Lincolnshire, taken as the upper boundary of the Ashby Stage in Virginia, varies in age. Stratigraphic data from conodonts suggest that the Lincolnshire in the Southern Appalachians is older than in the Shenandoah Valley to the north. Rocks assigned to the Ashby Stage in regions considerably north of its type area in Tennessee are largely Porterfield in age according to Bergström (1971, p. 125).

From studies of the conodont fauna from the type Chazy sequence, Champlain Valley, New York, Bergström (1971, p. 127) concluded that the base of the Chazy corresponds to the top of the Marmor Stage and the top of the Chazy is but slightly younger than the base of the Porterfield. For these reasons, he proposed that where an overlap of the Ashby and Porterfield could not be established, the term Chazy should be used as a stage designation for rocks of the post-Marmor, pre-Porterfield interval. However, this name is also problematic because the type area of the Chazy is quite remote from the Marmor and Porterfield type areas. The stage name Chazy as used in this sense has not yet received wide recognition and is not used in this report.

Lincolnshire Limestone.- The name Lincolnshire Limestone was proposed by Cooper and Prouty (1943, p. 863) for an exposure of dark, cherty limestone between the Five Oaks and Ward Cove limestone members of the Clifffield Formation. The type area is along a tributary to the Clinch River about one mile west of Five Oaks in Tazewell County, Virginia. Cooper (1944, p. 58) elevated the Lincolnshire to the rank of formation but retained the name Lincolnshire Limestone. In 1946, Cooper and Cooper (p. 75) extended the use of the name Lincolnshire into the Shenandoah Valley to include the dark gray, cherty limestones above the New Market or Whistle Creek, and below the brownish weathering beds of the Botetourt Member of the Edinburg Formation.

In Rockingham County, the Lincolnshire contains dark gray, cherty biomicrite and light gray, non-cherty biosparite. In most localities the biosparite occurs at or near the top of the unit, but may be present lower in the unit. Cooper and Cooper (1946, p. 53-54, 76-77) realized that these are lithofacies and proposed the name Murat for the light gray, biosparite facies of the Lincolnshire. No specific name was given to the dark gray, cherty limestone and such names as "typical Lincolnshire," "cherty Lincolnshire," "non-Murat Lincolnshire" have been used in reference to this facies. Carson (1968, p. 48) proposed the name Rockbridge facies for the dark gray, cherty limestones of the Lincolnshire. The type section for this facies is at Murat, five and one-half miles southwest of Lexington, Virginia.

In 1946, Cooper and Cooper (p. 74) proposed the name Whistle Creek Limestone for the dark gray, irregularly bedded limestone

containing bedded black chert that occurs between the New Market and Lincolnshire Limestones northwest of Lexington, Virginia. The Whistle Creek and Lincolnshire are very similar in physical characteristics except for the nature of the chert. Carson suggests that the Whistle Creek contains platy chert whereas the Lincolnshire contains nodular chert. He indicated that at some localities these units are superimposed and the contact between them gradational so that it is difficult to recognize the formational boundary using physical characteristics alone. Cooper and Cooper (1946, p. 74) said that where this occurs, fossils are helpful in determining the boundary. The Whistle Creek contains a Hesperorthis fauna, whereas the Rockbridge facies of the Lincolnshire has a Dinorthis atavoides fauna. At locations where the Whistle Creek is overlain by the Murat facies of the Lincolnshire, the contact is easily recognized.

Because of physical similarities and stratigraphic relationship, Carson (1968, p. 49) proposed that the dark gray limestone containing platy chert which is overlain by the Rockbridge or Murat facies be renamed the Whistle Creek facies of the Lincolnshire Limestone.

In sections studied in Rockingham County for this report, chert occurs only as nodules oriented roughly parallel to bedding. No platy chert has been observed. It is concluded that the Whistle Creek facies is not present, but the dark gray, fine grained limestone containing nodular chert should be called the Rockbridge facies of the Lincolnshire Limestone.

At all sections studied, the lower part of the Lincolnshire is dark gray, and contains reddish-brown partings along irregular bedding

planes. Black chert nodules are commonly oriented roughly parallel to bedding. The lower Lincolnshire may have a "knobby" or "spongy" appearance on extensively weathered surfaces. This apparently results from differential weathering of the limestone matrix, fossil fragments, and chert. Fossils include bryozoans, brachiopods, echinoderms, mollusks, trilobites, and ostracodes which occur in a fine grained micrite matrix.

At the Cedar Grove section, the Lincolnshire coarsens upward through the unit. Light gray biosparite (Murat facies) becomes dominant over biomicrite (Rockbridge facies). This is a gradual transition and a definite boundary between the two facies is difficult to place. This change, however, is quite apparent when the unit is viewed as a whole. The upper 14 meters is coarse, contains little chert, and is considered the Murat facies of the Lincolnshire Limestone.

At the Park View section, the upper three or four meters are poorly exposed and the character of this interval is difficult to evaluate. The major part of the Lincolnshire exposed at the Park View section is Rockbridge facies. Exposures of Murat facies at this location are few, but several thin beds of coarse fossiliferous biosparite occur about midway through the unit. One bed, only 20 to 30 centimeters thick, occurs at the top of the sequence.

At the Edom section, much of the unit is poorly exposed. The lower part of the unit is a dark, gray biomicrite. It contains black chert nodules and is considered the Rockbridge facies of the Lincolnshire. Black chert is absent from the upper nine meters (20 feet) of light gray biosparite, which is considered Murat facies.

Porterfield Stage.- The type section of the Porterfield Stage is at the Porterfield Quarry just southeast of Saltville, Virginia. Units included in this stage at the type section are the Arlene, Effna, Rich Valley, and Chatham Hill Formations. The only rock unit included in the Porterfield Stage in Rockingham County is the lower part of the Edinburg Formation.

Basal Units of the Edinburg Formation.- At both the Park View and Edom Sections, the Lincolnshire Limestone is overlain by fine grained, buff to gray weathering shales and thin limestones forming the base of the Liberty Hall facies of the Edinburg Formation. The shales contain ampyxinid and cryptolithid trilobites, brachiopods, and graptolites. Some of the thin limestones contain small phosphatic inarticulate brachiopods and large platform conodonts.

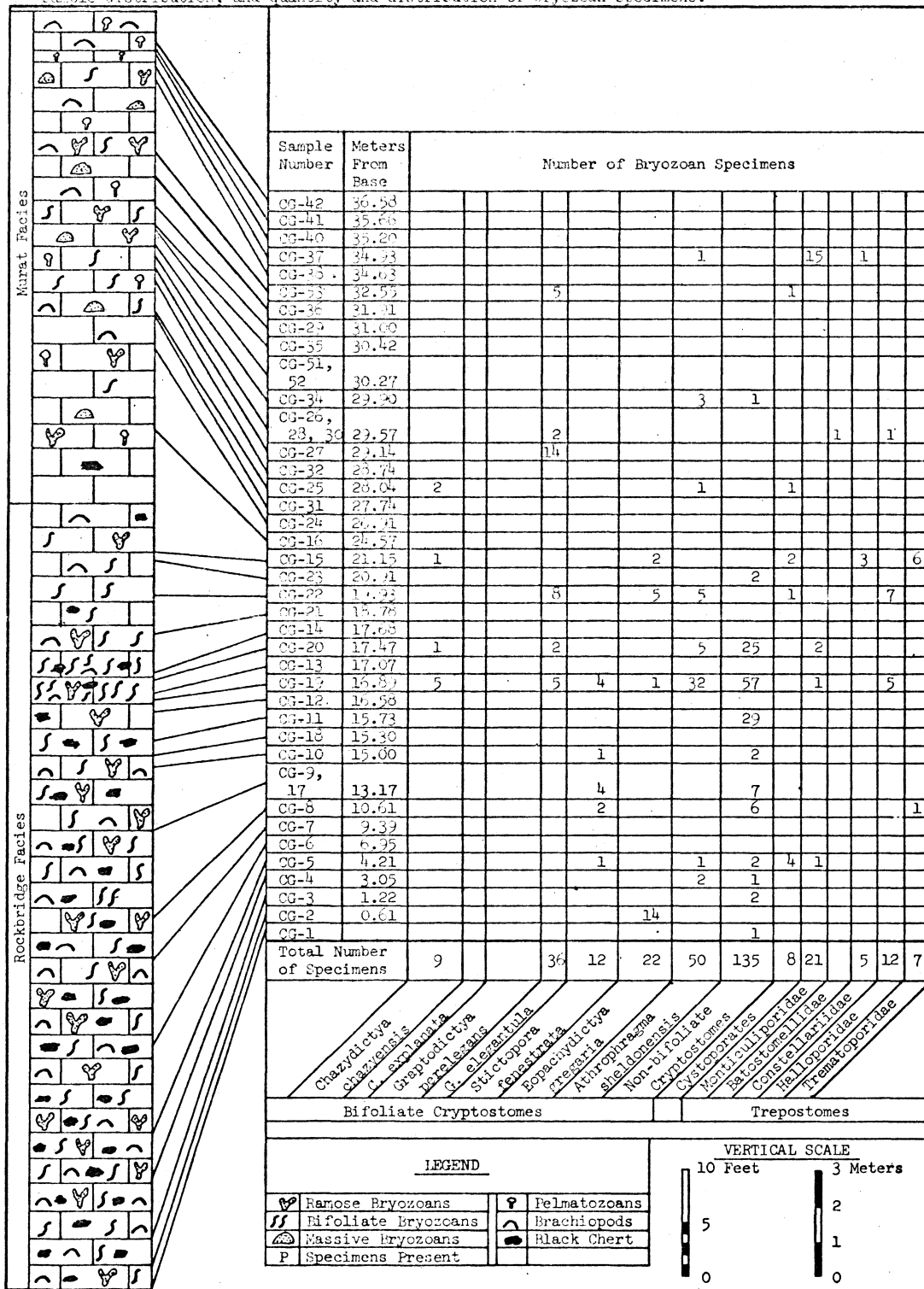
At the Cedar Grove Section, the upper three to four meters (10 feet) of exposed limestone is quite coarse, weathers a dark reddish-brown, and contains many large strophomenid brachiopods. This facies is the Botetourt Member of the Edinburg Formation of Cooper and Cooper (1946, p. 80).

At the Park View and Edom Sections, no units have been found that correspond to the Botetourt.

Stratigraphic Distribution of the Bryozoan Fauna.- The stratigraphic distribution of bryozoans throughout the Lincolnshire Limestone from the Park View and Cedar Grove sections is shown in Table 3 and Table 4.

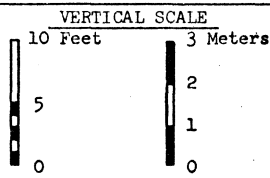
The tables record the frequency of occurrence of bryozoans of various taxa, but does not give information on relative size of

Table 4 - Columnar section for the Lincolnshire Limestone of the Cedar Grove section showing sample distribution, and quantity and distribution of bryozoan specimens.



LEGEND

	Ramose Bryozoans		Pelmatozoans
	Bifoliate Bryozoans		Brachiopods
	Massive Bryozoans		Black Chert
	Specimens Present		



colonies. All recognizable taxa in three 25 x 45 millimeter thin sections from each sample were counted and recorded. The bryozoan fauna is dominated by cryptostomes representing about 88% of the fauna. Trepostomes rank second representing about 11% of the fauna and in lesser numbers are bryozoans of the Order Cystoporata. Cryptostomes occur more frequently than do trepostomes or cystoporates, but cryptostomes are generally smaller and occupy less space than the larger trepostomes and cystoporates.

Stratigraphic Significance of the Bryozoan Fauna of the Lincolnshire Limestone.- From evidence previously stated, it is apparent that certain Middle Ordovician formations are not precisely the same age at all areas of occurrence. Bergström (1971), from studies of conodont faunas, suggested that the Lincolnshire and basal Edinburg Formations are younger in northern and central Virginia than in areas of southwestern Virginia and northeastern Tennessee. Ross (1970, p. 362) suggested that species of bryozoans described by Coryell (1921) in central and eastern Tennessee occur in older rocks than bryozoans of comparable morphology in north central and eastern New York State. Twenhofel, et al., (1954) and Cooper (1956) suggested that faunas, including bryozoan genera, occur earlier in units in Tennessee than do the same genera in New York. A comparison of bryozoan species of the Lincolnshire Limestone of Rockingham County with species of comparable morphological development in Ordovician rocks of east-central Tennessee (verbal communications, Kenneth R. Walker and Kenneth K. Ferrigno, University of Tennessee) suggests that these species occur considerable earlier in east-central

Tennessee than in Rockingham County, Virginia. This distribution of bryozoans could indicate a northeastward migration of species during the Middle Ordovician so that time ranges of bryozoans began and ended earlier in central Tennessee than in regions of central Virginia or north-central and eastern New York. This means that the complete stratigraphic ranges of these species are not observed in any single region or section.

Until there is more information on the distribution of bryozoan taxa, and until relationships of physical stratigraphy, associated fossil communities, and their evolution through time, are better understood, it will be difficult to accurately determine age correlations for rock units that contain similar faunas.

Correlations with Other Areas.- Of the eight species of cryptostomes that occur in the Lincolnshire Limestone of Rockingham County, four were described by Ross from Chazy rocks of north central and eastern New York State. Stratigraphic ranges for four cryptostome species from New York, given by Ross (1963b, and 1964) are shown on the left side of Text-Figure 4. Stratigraphic ranges for the same four species plus three additional species from the Lincolnshire Limestone, this study, are shown on the right side of Text-Figure 4. Chazydictya chazyensis, Athrophragma sheldonensis, Eopachydictya gregaria, and Stictopora fenestrata occur both in the Chazy of New York and the Lincolnshire of Rockingham County. Ross does not report Graptodictya perelegans and G. elegantula from Chazy rocks of New York, but does report them from younger rocks of the same general area. Ross (1960) does not give specific ranges for G. perelegans

Text-Fig. 4 - Stratigraphic range chart for bifoliate cryptostome species.

CHAZY FORMATION			NEW YORK STATE (ROSS, 1963)
Member A Day Point	Member B Crown Point	Member C Valcour	
	<hr/> Chazydictya Chazyensis <hr/> Athrophragma sheldonensis <hr/> Eopachydictya gregaria <hr/> Stictopora fenestrata		
NEW MARKET LS.	LINCOLNSHIRE LS.		ROCKINGHAM COUNTY, VIRGINIA (THIS STUDY)
	<hr/> Chazydictya chazyensis <hr/> C. explanata (n. sp.) <hr/> Athrophragma sheldonensis <hr/> Eopachydictya gregaria <hr/> Stictopora fenestrata <hr/> Graptodictya elegantula <hr/> G. perelegans		

and G. elegantula, but in 1964 reported that Graptodictya ranges from upper Middle through Upper Ordovician age. The association of species of Graptodictya in Rockingham County with C. chazyensis, S. fenestrata, A. sheldonensis and E. gregaria indicates that their stratigraphic ranges do overlap to some extent.

Since some of the same faunal elements occur in units of both areas, either the Lincolnshire of Rockingham County is partly correlative with rocks of upper Middle Ordovician age in New York, or, the ranges of G. perelegans and G. elegantula should be extended to the Middle Ordovician. Comparing the cryptostome bryozoan fauna with stratigraphic information based on conodonts, suggests that the Lincolnshire Limestone in west-central Virginia is post-Marmor/pre-Porterfield in age (Chazyan age of Bergström, 1971) and may slightly overlap both of these time intervals. The distinctive bryozoan fauna of the Lincolnshire Limestone in Rockingham County, should permit recognition of this interval elsewhere in the central and southern Appalachians. For example: comparison should be possible with Middle Ordovician limestones of Tennessee, Alabama, and Oklahoma where abundant bryozoan faunas also occur.

ENVIRONMENTAL INTERPRETATION

Middle Ordovician rocks in Rockingham County, represent part of a transgressive carbonate sequence. Lithologic units of the sequence are: dense, fine grained New Market dismicrite; gray-black, bryozoan-brachiopod biomicrite of the Rockbridge facies of the Lincolnshire; light gray bryozoan-pelmatozoan biosparite of the Murat facies of the Lincolnshire; interbedded buff shales and thin limestones of the basal Edinburg; and dark, relatively unfossiliferous micrites of the Liberty Hall Member of the Edinburg Formation.

New Market Limestone.- Characteristics of the New Market correspond to criteria suggested by Shinn (1968, p. 215), Laporte (1967, p. 73), and Walker and Laporte (1970, p. 930-933) for a supratidal or high-intertidal carbonate facies. A distinct characteristic of the New Market Limestone is the birdseye fabric that is evident on many weathered outcrops. The "birdseyes" are intergrown crystals of clear, sparry calcite that form dark blebs on the outcrop surface as a result of differential weathering. Shinn (1968, p. 215), in working with recent carbonate sediments, suggested that birdseye fabric results from void fillings that were formed by either gas bubbles or shrinkage resulting from dessication. He established that both types are common in supratidal sediments, only sometimes present in intertidal sediments and absent in subtidal sediments. Another indication that the New Market was a very harsh marine environment is the low diversity and abundance of marine fossil organisms. Gastropods, ostracodes, and a few trepostome bryozoan fragments make up the total shelly fauna of the New Market. Algal structures were observed in thin section and

conodonts have been recovered from beds containing many gastropods. When present, fossils often are abundant, and are usually restricted to rather thin beds. These thin, fossiliferous beds may represent storm deposits or "wash-ins" during high tides.

New Market-Lincolnshire Disconformity.- At all three study sections, and at other areas in Rockingham County that were observed, there is a distinct disconformity between light gray New Market dismicrite and dark, fossiliferous Lincolnshire biomicrite (Pl. 1, figs. 1, 2). The depositional environments and associated organic communities of these two units are different across the lithologic boundary. The contact between these two units is abrupt. Very few irregularities were noted on the surface. This disconformity could represent a time of subaerial erosion, but the lack of surface relief, basal conglomerates, and indication of weathering makes this doubtful. Another possibility is that this represents a time of non-deposition, but there is no evidence to support this idea. There are no surface borings by organisms or algae, no shell hash layers, no phosphatic pebbles or nodules, or no pyritized zones which frequently occur on nondepositional surfaces, and there is no evidence of extensive solution along the contact. Therefore, the nondeposition hypothesis for the formation of this disconformity is also doubtful. Another possibility is that during transgression, the more seaward, shallow, protected subtidal environment migrated across the semi-lithified tidal flat surface which resulted in a change in sedimentation and the subsequent disconformity. The significance of such a disconformity was first noted by Stamp (1922) in Tertiary deposits of Burma. He referred to the

development of this type of disconformity as "revinement." Stamp's model was further developed by Swift (1967) in which he suggested that during revinement, the sea may destroy part or all of its marginal record. The shift from deposition of supratidal or high intertidal dismicrite to protected subtidal biomicritic and bioclastic sediments corresponds to the revinement hypothesis. Such a sequence could result during a carbonate transgression.

It is difficult to determine how much of a time gap the disconformity represents, because of its character. A few ramose trepostome bryozoan fragments were found in the New Market, but are quite primitive appearing in comparison to trepostomes in the Lincolnshire. This may suggest a hiatus, but the depositional environment of the Lincolnshire was so different from the New Market, as indicated by the difference in lithologies, that the diminutive bryozoan fauna of the New Market may simply reflect the difference in depositional environment.

Lincolnshire Limestone.- The dark, cherty biomicrite of the Rockbridge facies of the Lincolnshire (Pl. 2, figs. 3a, 3b) directly overlies the New Market Limestone and has a rather high faunal abundance and diversity. The presence of large relatively unabraded fragments of bryozoans and brachiopods, some of which appear to be in life position, indicates little transportation of faunal elements into or away from their habitat in the lower part of the unit. High abundance and diversity of untransported fossils in a micritic to sparry matrix are criteria suggested by Walker (1972, p. 2507) for a shallow "protected subtidal" environment. Bioturbation of sediment is also

characteristic of this environment. In such an environment, distribution of nutrients is adequate, but current action is not strong enough to discourage the growth of delicate bryozoan colonies. At the Cedar Grove section, patchy areas with high concentrations of bryozoans give the suggestion of poorly developed reef structures. Well structured bryozoan reefs with a definite framework of reef core and flank material apparently did not develop, but large populations of bryozoans did form small mounds or bioherms. These populations of bryozoans may have baffled currents just above the sediment water interface thereby aiding in trapping the fine micritic sediment.

Upward through the section, sediment becomes coarser. Chert and unabraded fossil fragments decrease in abundance. At the Cedar Grove section, where the middle portion of the Lincolnshire is well exposed, several unusual bedding surfaces separate beds of slightly different color and texture (Pl. 2, figs. 1-6). On weathered outcrop, the lower surfaces are quite planar, but higher in the unit contacts become more irregular. From surface observation alone, one can not determine whether these are bored or burrowed surfaces, stylolitic surfaces, or "micro-karst" solution or erosion surfaces. In thin section, a thin zone of hematite-stained sediment is concentrated at the contact along the upper surface of the lower bed, and extends over highs and lows of the irregular surfaces. This may result from oxidization of iron minerals during subaerial exposure. Along some extensively developed surfaces, fragments of brachiopods and bryozoans protrude into depressions, but on positively exposed surfaces, fossil fragments are

truncated nearly even with the sediment surface (Pl. 2, figs. 4, 6). This suggests that current action may have plucked fine sediment away from resistant skeletal fragments in the depressions, while on positively exposed surfaces, fossil fragments were abraded as the surface was scoured.

If these were all burrows or borings of organisms, the oxidized, hematite stained zone should occur only along depressions occupied by organisms, but they extend over most of each surface (Pl. 2, figs. 1-3). Also, organisms that burrow would have been deflected by obstructions such as a brachiopod or bryozoan fragment. Organisms that bored would have truncated such fragments. Neither would have left the fragment protruding into its burrow (Pl. 2, figs. 4, 6).

These surfaces are not all stylolitic because truncation of fossil fragments and chemical alteration of sediment is almost always confined to a thin zone immediately below a surface and very seldom occurs above a surface. One fossil fragment actually extends across a surface (P. 2, fig. 2). A thin section cut perpendicular to one of these surfaces shows a small hemispherical bryozoan colony, apparently in life position, which grew on one of these surfaces (Pl. 2, fig. 5). Some fossil fragments are resting on a surface and are not truncated or abraded on their lower sides. Figure 3 of Plate 2 shows sediment from the overlying bed filling a laterally branching cavity in the underlying bed.

These conditions are not typical of normal stylolites, but sediment on both sides of a stylolitic surface is usually affected in the same manner. Stylolites are quite numerous throughout the

unit but are easily distinguished from these unusual surfaces.

These surfaces seem to be "micro-karst" erosion or solution surfaces that formed either during subaerial exposure or following shallow marine lithification. Normal carbonate build-up through time may have periodically allowed for subaerial exposure of the sediments. This permitted oxidization of iron minerals and lithification to take place a few centimeters below a surface. The relief features of these surfaces may have developed by erosion during tidal fluctuations, from fresh water run-off over the semi-lithified surface, or from solution.

These surfaces may also have developed in a way similar to that described by Allen, et al. (1969, p. 143) for the conversion of some modern beach sediments into beach-rock. The mechanism of conversion is not fully understood, but Allen suggested that aragonite cemented quartz and carbonate sediments do form in the shallow intertidal zone along tropical and subtropical coasts. It is possible that under very shoal conditions, some sediments now making up the Lincolnshire Limestone were partially lithified in a similar manner. The semi-lithified surfaces would have been subject to surf scour and subaerial erosion during tidal fluctuations which could have developed the micro-relief features. Algal borings may have also produced some of the surface irregularities. Later inundation, under more normal marine conditions, may have begun another cycle of sediment buildup, partial lithification, and scour.

Another explanation for the development of these surfaces is that they represent submarine carbonate lithification. Taft (1968,

p. 551), in a study of marine carbonate lithification at Yellow Bank, Bahamas, found that submarine lithification occurs, but is restricted to water nine to sixteen feet deep, and does not occur in water deeper than nineteen feet. This surely would be in the zone of wave and tidal action and could have produced the micro-relief features.

Near the top of the Lincolnshire, bryozoan-pelmatozoan biosparite becomes dominant over bryozoan-brachiopod biomicrite. This coarse biosparite is considered the Murat facies of the Lincolnshire. Fragments of brachiopods, bryozoans, and pelmatozoans compose much of the biosparite sediment but are greatly abraded. Some beds of the Murat facies are lenticular and cross-stratified. These sedimentary features indicate that conditions became more shoal and the energy level increased during the time of deposition of the Lincolnshire.

Environmental Implications of Bryozoan Colony Forms.- There are many different bryozoan colony forms present in the Lincolnshire Limestone. Colony form reflects both the genetic characteristics of individual taxa and effects of the environment. Therefore, only the properly adapted forms can live in particular environments. Some taxa can assume different colony forms, depending on the environment, while others exhibit a more constant form and are quite environmentally restricted.

Schopf (1969), in studies of modern bryozoans, said that maximum species diversity occurs in water between 50 and 125 meters deep. This depth range would be below normal wave base, but within the range of sunlight penetration. Ross (1970, Text-Fig. 7), however, suggested that maximum species diversity in Middle Ordovician time may have

occurred in water from five to fifteen meters deep. Schopf (1969) also noted that the percentage of erect colony forms increases relative to encrusting forms as depth increases. This suggests that distribution of bryozoan species, and associated colony forms, is dependent on the energy level of the environment. The distribution of bryozoan colony forms, therefore, is useful in evaluating the environmental parameters of the Lincolnshire Limestone.

Cryptostome bryozoans generally formed upright, ribbon-like or explanate colonies which were small and quite fragile. In the Lincolnshire Limestone, explanate and ribbon-like colonies of Athrophragma sheldonensis, Stictopora fenestrata, Eopachydictya gregaria, and Chazydictya chazyensis are abundant in the biomicrites of the Rockbridge facies. Explanate forms of A. sheldonensis are particularly abundant in biohermal beds (Pl. 3, fig. 1; Pl. 4, fig. 1) of samples CG-13, 14, and 19 of the Cedar Grove section. These beds occur from 55 to 60 feet above the base of the Lincolnshire. In the Murat facies, these species mostly occur as small fragments in coarse sparry matrix. A. sheldonensis is the most abundant bifoliate in the Murat facies, but is robust, and more heavily calcified than in the Rockbridge facies. One encrusting form of A. sheldonensis (Pl. 17, fig. 2) was observed in sample CG-22 of the upper Rockbridge facies.

Ross (1963) noted that in Chazyan strata of the Champlain Valley, New York, A. sheldonensis, C. chazyensis, and E. gregaria occur with varying abundance in both reef and inter-reef lithologies. Ross (1963) also noted that the most persistent occurrence of S. fenestrata was in biosparites which represented high wave-energy environments.

The distribution of cryptostome species in facies of the Lincolnshire is consistent with that described by Ross (1963) except that in the Lincolnshire, S. fenestrata commonly occurs with the other cryptostome species, and is not restricted only to biosparite facies. The greater degree of integration or mixing of species in the Lincolnshire may indicate more gradual environmental changes, laterally, and through time, than occurred in Chazyan strata of New York.

Trepostomes built ramose, massive, hemispherical and encrusting colonies and are found in all sediment types of the Lincolnshire. In the bryozoan-brachiopod biosparites of the Rockbridge facies, large, unabraded ramose colonies are common. Some appear to be in life position, as indicated by their orientation to bedding. In the bryozoan-pelmatozoan biosparite of the Murat facies, the dominant colony forms are encrusting and massive forms. Many small abraded fragments of ramose colonies are present in the Murat facies, but few large unabraded fragments were observed.

Cystoporate bryozoans had a wide variety of colony forms. Zoaria were encrusting, ramose, hollow ramose, or other forms. Few cystoporate bryozoans were found in the Lincolnshire and were observed only in the biomicritic sediments in the Rockbridge facies.

In conjunction with sedimentary textures and features, the change in bryozoan colony forms suggests that conditions became more shoal and the energy level increased during the time of deposition of the Lincolnshire.

Facies Relations.- The vertical sequence of Middle Ordovician carbonates in the area of study represents the shoreward migration of

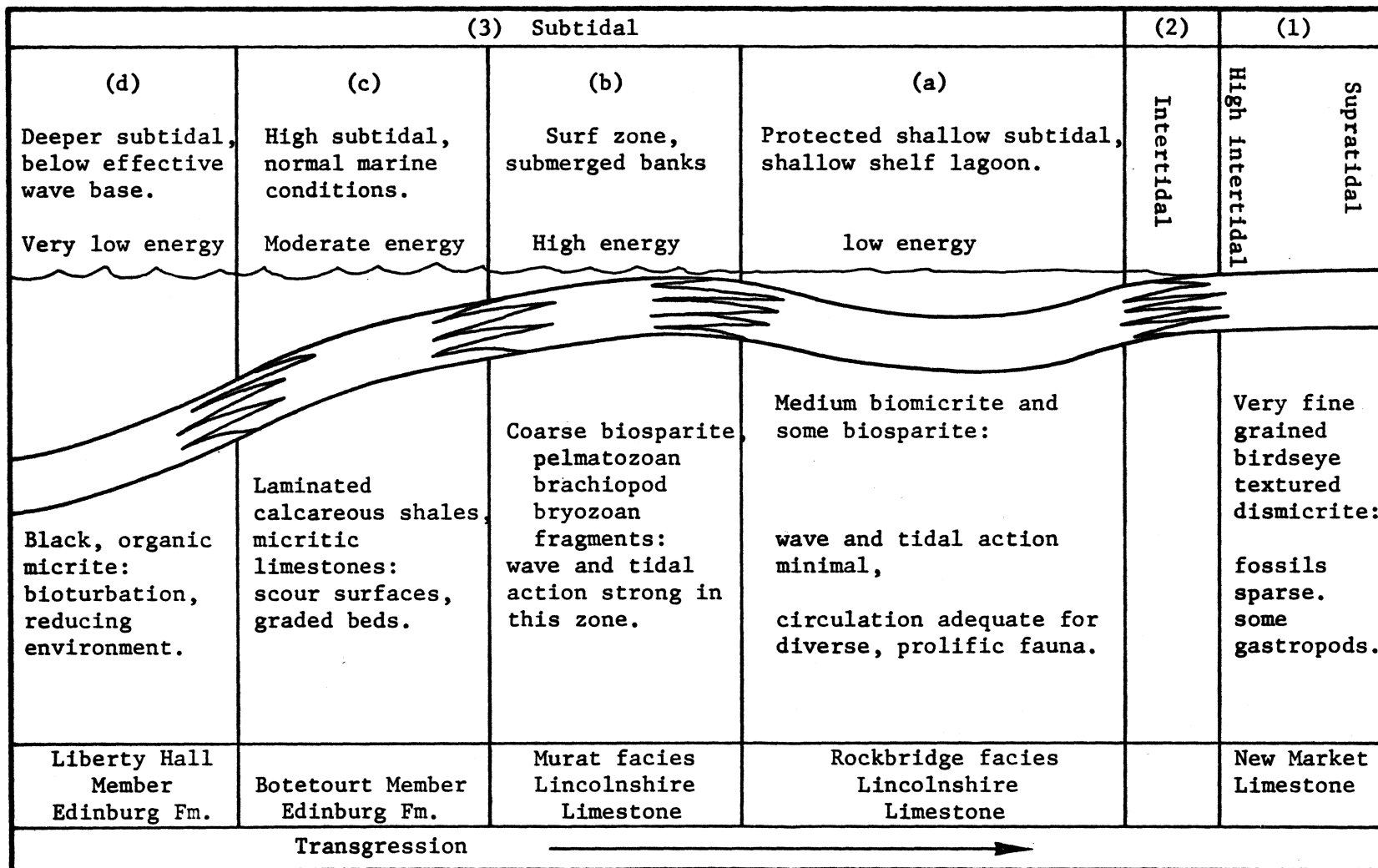
sedimentary facies during transgression of the sea over a rather flat shallow shelf. The New Market dismicrite, at the base of the sequence, is interpreted as sediment deposited in a supratidal or high intertidal environment. The bryozoan, brachiopod biomicrite of the lower Lincolnshire is interpreted as sediment deposited in a shallow protected subtidal environment within a broad shelf lagoon. The bryozoan-brachiopod biomicrite grades upward into bryozoan-pelmatozoan biosparite which shows evidence of current reworking of bryozoan pelmatozoan, and brachiopod fragments. These coarse sediments are interpreted as representing mounds or banks of bioclastic sediment which, for the most part, were submerged, but occasionally may have been exposed to subaerial erosion. These banks or mounds were seaward from the shallow, protected subtidal environment in which the biomicrites were deposited. The shaly sequence above the Lincolnshire suggests an influx of fine grained terrigenous material into the basin and the overlying dark micritic Liberty Hall facies may suggest progressive deepening of the basin.

A similar transgressive carbonate sequence has been described in the Manlius and Coeymans Formations of the Lower Devonian Helderberg Group of New York by Laporte (1969). Irwin (1965) proposed a general model for such sedimentary sequences in epeiric seas. While this model does not apply in detail to the Middle Ordovician sequence in Rockingham County, Virginia, the concept of gradational energy zones across a broad shallow shelf does seem applicable.

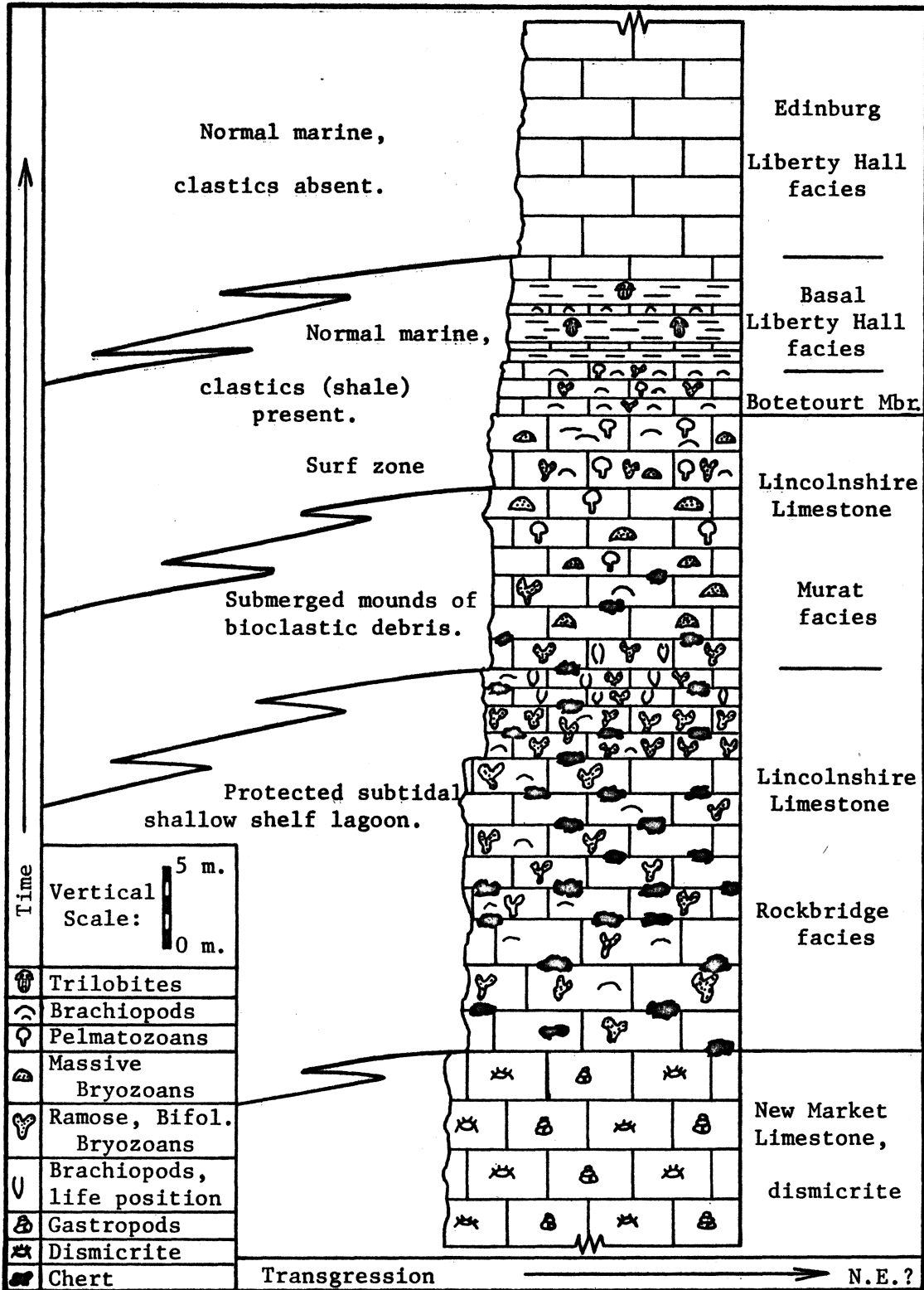
As in these cases, since transgression was occurring over a rather broad shallow shelf, at any two locations the same strati-

graphic sequence may be present, but similar lithologic units are not necessarily the same age.

A cross-section model for a possible depositional platform existing during the Middle Ordovician in west central Virginia is shown in Text-Figure 5. Although the figure suggests transgression occurring from west to east, this is only intended to illustrate the model. Additional work is needed to determine the actual direction of transgression. The stratigraphic sequence produced by such a transgression is shown in Text-Figure 6. Three recognizable divisions are shown in this sequence and are referred to as follows: (1) supratidal, (2) intertidal, and (3) subtidal. The supratidal is represented by the birdseye structured micritic New Market Limestone. The subtidal is subdivided into four zones. Zone (a) (Text-Fig. 5) is a low energy, protected, shallow subtidal, marine environment similar to a lagoon, but possibly lacking the unique barrier system of typical lagoons. Nonetheless, it was a protected environment landward from the high energy surf zone. The bryozoan-brachiopod biomicrite of the lower Lincolnshire may have formed in this zone. Subdivision (b) (Text-Fig. 5), represents the zone over which most of the surf and tidal energy was dissipated. No prominent barrier or bar system necessarily formed here, but probably some buildup of clastic material occurred within this zone. The biosparites of the Murat facies may have formed in this zone. Subdivisions (c) and (d) are open marine environments with (c) representing subtidal moderate energy conditions and (d) representing lower energy, deeper subtidal conditions.



Text-Fig. 5 - Cross-section diagram of the sedimentary environments of the depositional platform along the Appalachian shelf as it may have been during Middle Ordovician time.



Text-Fig. 6 - Columnar section for the Cedar Grove section showing possible relation between sediment types produced during the transgression through time.

SYSTEMATIC PALEONTOLOGY

PHYLUM BRYOZOA

Because of a superficial resemblance to certain plants, bryozoans were once considered "zoophytes," a group of organisms supposedly intermediate between plants and animals. In 1830, the name Polyzoa was given to this group of organisms by J. V. Thompson who realized that each individual element of a colony possessed a complete alimentary tract with mouth, gut, and anus. The name Polyzoa, which brings to mind many organisms living together in close proximity, has not had wide acceptance. This may be because being colonial is not a unique characteristic of bryozoans. In 1831, Ehrenberg, who worked independently of Thompson, proposed the name Bryozoa for this group of organisms, because of the superficial resemblance of certain bryozoan colonies to tufts of moss. In 1869, Nitsche realized that the phylum Polyzoa, as used in terms of its original designation, incorporated organisms with two distinct morphologic organizations. Nitsche distinguished two groups: Bryozoa Entoprocta which have a circlet of tentacles enclosing both mouth and anus, and Bryozoa Ectoprocta, in which only the mouth is enclosed by a ring of tentacles or lophophore. Bassler (1953, p. G30), cited important differences between ectoprocts and entoprocts, as they have been informally called. Ectoprocts form calcareous zoaria, have a true body cavity, and have a ring of ciliated tentacles called a lophophore surrounding the mouth. The lophophore is the feeding mechanism and can be retracted into a fleshy sheath when not in use. Except for bryozoans of the class Phylactolaemata, all

known ectoprocts are marine organisms. Entoprocts, however, are soft bodied organisms that do not build calcareous skeletons, and lack a true body cavity. The cirlet of tentacles surrounds both mouth and anus and is not morphologically comparable to the lophophore of the ectoprocts. The apparent resemblance of these two groups is entirely superficial as Ryland (1970, p. 25) points out. In 1888, Hatschek realized the fundamental differences between ectoprocts and entoprocts, and proposed that these subdivisions be raised to the phylum level. There is, however, a reluctance to completely separate these two groups partly because of their many years of association under the familiar names Bryozoa and Polyzoa. Hyman (1959, p. 277) proposed that the names Polyzoa and Bryozoa be replaced by Ectoprocta as the name for this phylum. Ryland (1970, p 16) says that "substitution of the older names Polyzoa and Bryozoa by Ectoprocta, as Hyman proposed, violates widely accepted principles of zoological nomenclature (though not the mandatory rules, which do not cover the naming of higher taxa). There is also the disadvantage that such closely similar words as Ectoprocta and Entoprocta can easily be confused, whether written, read, or spoken. The original names are therefore to be preferred. Although Polyzoa undoubtedly has priority, it seems on balance desirable to follow majority usage and adopt Ehrenberg's term Bryozoa."

The term for Bryozoa is being used in this report as the phylum name for this group of organisms. It is also realized that the terms Polyzoa and Ectoprocta are used by some authors as synonyms for this group. The Entoprocta which were formerly classified with the Bryozoa

are considered a separate phylum.

Class GYMNO LAEMATA Allman, 1856

The phylum Bryozoa is divided into two classes. Bryozoans of the class Gymnolaemata are all marine organisms whereas those of the class Phylactolaemata are fresh water organisms. Species in three orders in the class Gymnolaemata occur in the Lincolnshire Limestone. These orders are Cryptostomata, Trepostomata, and Cystoporata. Further discussion of geologic occurrence of bryozoans in this report deals only with these three orders. In the section which follows, trepostomes, cystoporates, and non-bifoliate cryptostome bryozoans are listed and illustrated, but systematic descriptions are not given for them. Bifoliate cryptostomes are described, illustrated, and classified to the species level.

Order TREPOSTOMATA Ulrich, 1882

Family MONTICULIPORODAE Nicholson, 1881

Genus MONTICULIPORA d'Orbigny, 1849

Monticulipora cf. M. mammulata, d'Orbigny, 1850

Pl. 23, figs. 2-3

References for Comparison: Bassler, 1953, p. G95, fig. 55, 1a-1d;
Boardman and Utgaard, 1966, p. 1093-1096, Pl. 133, figs. 1-3, Pl. 134
figs. 1-3.

Family BATOSTOMELLIDAE Miller, 1889

Genus ERIDOTRYPA Ulrich, 1893

Eridotrypa cf. E. crownensis Ross, 1967

Pl. 23, figs. 2, 3

Reference for Comparison: Ross, 1967, p. 638, pl. 69, figs. 8, 10;
pl. 70, figs. 1-10.

Family HALLOPORIDAE Bassler, 1911

Genus HALLOPORA Bassler, 1911

Hallopora cf. H. ovata (McKinney), 1971

Pl. 24, figs. 1-4

Reference for Comparison: McKinney, 1971, p. 282, pl. 63, figs. 3-8.

Family TREMATOPORIDAE Miller, 1889

Genus HEMIPHRAGMA Ulrich, 1893

Hemiphragma cf. H. pulcra Loeblich, 1942

Pl. 25, figs. 1-2c

References for Comparison: Loeblich, 1942, p. 434, pl. 64, figs. 17-20;
Merida and Boardman, 1967, pl. 100, fig. 1a-1c; Ross, 1970, p. 371, pl. 69,
figs. 2, 4, 7.

Hemiphragma cf. H. irrasum Ulrich, 1886

Pl. 26, figs. 1-4

References for Comparison: Loeblich, 1942, p. 443, pl. 63, fig. 1p;
Bassler, 1953, p. G114, fig. 77, 4a-4d; Bork and Perry, 1968, p. 242,
pl. 44, figs. 1-3, 5; McKinney, 1971, p. 276, pl. 61, figs. 7, 8;
pl. 62, figs. 1-6.

Order CYSTOPORATA Astrova, 1964

Family CONSTELLARIIDAE Ulrich, 1890

Genus CONSTELLARIA Dana, 1846

Constellaria sp. A

Pl. 21, figs. 1-3

References for Comparison: Bassler, 1911, p. 218, 219; Coryell, 1921, p. 288, 289; Ross, 1963a, p. 51-54; Utgaard and Perry, 1964, p. 88, pl. 17, figs. 8, 9; pl. 18, fig. 1.

Constellaria cf. C. islensis Ross, 1963

Pl. 21, figs. 3-6

Reference for Comparison: Ross, 1963a, p. 54; pl. 5, figs. 2, 7, 9, 10; pl. 6, figs. 4, 6-8.

Family CERAMOPOROIDAE Ulrich, 1895

Genus CERAMOPHYLLA Ulrich, 1895

Ceramophylla cf. C. vaupeli (Ulrich) 1890

Pl. 22, figs. 1a-1d

Reference for Comparison: Utgaard, 1968, p. 1453, pl. 184, fig. 4; 184, figs. 3, 4.

Family DIANULITIDAE Vinassa de Regny, 1920

Genus DIANULITES Eichwald, 1829

Dianulites? sp.

Pl. 23, fig. 1

References for Comparison: Bassler, 1911, p. 229-232; pl. 2, figs. 1-3, text-figs. 127, 128; Bassler, 1953, p. G106, fig. 71, 3a-3d; Hinds, 1970, p. 32, pl. 5, figs. 1-4.

Order CRYPTOSTOMATA Vine, 1883

Non-bifoliate

Family RHABDOMESIDAE Vine, 1883

Genus OTTOSEETAXIS Bassler, 1952

Ottoseetaxis cf. O. bipartitus Bassler, 1952

Pl. 19, figs. 1-3

References for Comparison: Bassler, 1952, p. 384; p. 383, fig. 23;

Bassler, 1953, p. G134, fig. 94, 3a-3c.

Family ATHROSTYLIDAE Ulrich, 1888

Genus ULRICHOSTYLUS Bassler, 1952

Ulrichostylus sp.

Pl. 19, fig. 4; Pl. 20, figs. 1-6

References for Comparison: Bassler, 1952, p. 384; 1953, p. G130,
fig. 90, 4a-4c.

Bifoliate

Bifoliate cryptostomes of the Lincolnshire Limestone are represented by six genera. They are assigned to two families in the classification set forth by Bassler (1953): (1) Chazydictya, Graptodictya and Stictoporellina to the Ptilodictyidae Zittel (1880), and (2) Eopachydictya, Pachydictya and Stictopora to the Rhinidictyidae Ulrich, 1895. The fundamental criterion for establishing these family groupings was external zoarial variations, although, considerable detail was known about internal structures at the time of their definition.

Phillips (1960) recognized that a revision of generic and suprageneric classification of some bryozoans was needed and began a series of studies and publications dealing with some of the bifoliate cryptostome genera (Phillips, 1960; Ross, 1960a, b, c; 1961; 1963; 1964a, b). As a result of her studies, Phillips (1960, p. 1) established three informal taxonomic categories: escharoporida group, stictoporida group, and pachydictyid group. These categories are distinguished by the character of laminate

zooecial walls, mode of growth of the zooecia from the median lamina, the occurrence and structure of mesopores, and transverse structures in the zooecial cavities. Ross (1963, p. 586) gave possible phylogenetic relationships of genera within these groups, and (1964, p. 940) established phylogenetic lineages for the escharoporid, stictoporid and pachydictyid groups.

Karklins, (1969, p. 10-29) elaborated on morphological characteristics of these taxonomic groups based on studies of cryptostome bifoliate from the Decorah Shale of Minnesota. He retained the stictoporid and escharoporid groups of Phillips (1960) but re-evaluated the pachydictyid group. Karklins erected two new genera based on morphologic characteristics of zooecial walls. The name Astreptodictya Karklins (1969) was introduced for pachydictyid forms having zoarial structures observed in Pachydictya acuta (Hall), the type species. The name Athropragma Karklins (1969) was introduced for forms having zoarial characteristics of Pachydictya foliata Ulrich, the type species. The characteristics of these new genera were employed to define two new informal taxonomic groups: athropragmid group and astreptodictyid group (Karklins, 1969, p. 24-35).

In an attempt to conform to the most recent taxonomic classification schemes for bifoliate cryptostomes set forth by Ross and Karklins, genera of this study are placed under the five informal taxonomic groups rather than families.

Bifoliate cryptostomes of the Lincolnshire belong to four of these informal structural groups. These structural groups are distinguished according to construction and characteristics of the

median laminae (mesotheca of some writers) and in the zooecial microstructure. The four groups represented are: (1) escharoporida, which includes species of Graptodictya and Chazydictya, (2) stictoporida, which is represented by Stictopora fenestrata, (3) athrophragmid, which is represented by Athrophragma sheldonensis, and (4) astrepto-dictyid, which is represented by Eopachydictya gregaria. Morphological details of these groups are given by Phillips (1960, p. 6-24) and Karklins (1969, p. 10-29).

ESCHAROPORID Group

Diagnosis.- In the escharoporida group, zooecia bud from the median lamina at a low angle but extend outward only a short distance before abruptly turning toward the zoarial exterior. Zooecial walls are thinly laminate in the endozone but become greatly thickened and sinuous in the exozone.

Longitudinal views of the escharoporida colonies show that the zooecial walls are constructed of continuous layers of calcite between adjacent zooecia (Pl. 5, fig. 6; Pl. 9, fig. 3a). In the exozone of transverse and longitudinal views, zooecial wall laminae are dark, sinuous, and nearly parallel the zoarial exterior.

The median lamina has a thin bilaminate structure along the central part of the zoarium which becomes less distinct near the lateral margins of the zoarium. Along the midline of the median lamina in well preserved specimens, a dark, thin, intermittent boundary of closely spaced laminae is present which defines the midline of a zoarium. The median lamina lacks small rod-like median tubulae which are prominent features of the stictoporida

athrophragmid, and astreptodictyid groups.

Genus CHAZYDICTYA Ross, 1963

Type species.- Chazydictya chazyensis Ross, 1963, p. 587.

Diagnosis.- Zooecia are aligned in longitudinal ranges and diagonal rows but no distinct boundaries are present between ranges of zooecia. Zooecia bud from the mediana lamina at a low angle (Pl. 5, fig. 6) and may gently curve outward toward the exterior of the colony, or they may be nearly straight and approach the exterior of the colony at an angle (Pl. 7, figs. 1a-2).

Zooecial walls are laminate, but laminae are not arranged in extensive, even layers as in species of Graptodictya. Zooecial walls are thin in the endozone. A thickening of zooecial walls marks the beginning of the exozone. Zooecial boundaries are indistinct with laminae extending across walls of adjacent zooecia (Pl. 5, figs. 2, 9; Pl. 9, figs. 3a, 3b).

Large laminate acanthopores penetrate the zooecial walls. They originate in the early exozone and are arranged in circlets about zooecial openings (Pl. 13, figs. 4-5). Mesopores are absent.

Diaphragms are thinly laminate, and may be straight to slightly curved. They are emplaced at various positions in the zooecial cavities.

In longitudinal view, the median lamina is flexuous (Pl. 5, fig. 6).

Chazydictya chazyensis Ross, 1963

Pl. 5, figs. 1-6

Chazydictya chazyensis Ross, 1963, p. 587, Pl. 2, figs. 1-10, Pl. 7,

figs. 3, 9, 10, table 2; Ross, 1964, p. 941, 942, fig. 8a.

Description.- Zoaria are ribbon-like (Pl. 5, fig. 5) or explanate (Pl. 5, fig. 4). Zooecia are oval and are aligned in diagonal rows and longitudinal ranges, but no definite boundaries separate ranges of zooecia as in the stictoporida group.

Zooecia leave the median lamina at an angle of 20-30 degrees curving gently outward through the exozone. They approach the exterior of the zoarium at 70 to 80 degrees (Pl. 5, figs. 2, 6). In the endozone, zooecial walls are thinly laminate but become thicker and sinuous in the exozone (Pl. 5, fig. 2, 5, 6). The boundary between the endozone and exozone is not distinct, but the base of the exozone is marked by a thickening of zooecial walls (Pl. 5, figs. 2, 6). In the endozone, boundaries between adjacent zooecia are marked by dark, closely spaced laminae. In the exozone, laminae of the zooecial boundary merge with the zooecial wall laminae. Distinct laminate acanthopores penetrate the zooecial wall structure beginning in the exozone and are arranged in one or more circles about a zooecial opening, as seen in tangential view (Pl. 5, fig. 5).

Two or three diaphragms generally cross a zooecial cavity and are flat to gently curved. Laminae that form the diaphragms appear to be continuous with laminae that form the lining of zooecial cavities.

The median lamina, as seen in transverse view (Pl. 5, fig. 4), lacks median tubulae. A very thin, intermittent, dark line defines the midline of the zoarium.

Occurrence.- Ross (1963, p. 587) reports that C. chazyensis occurs throughout the entire Chazy group at Chazy, New York. It also occurs at Jordan Point, New York and at Isle La Motte and South Hero Island, Vermont.

In this study, C. chazyensis was found to occur in the basal 12 meters of the Lincolnshire at the Park View section. At the Cedar Grove section, it was found to occur in the lower 28 meters.

Chazydictya explanata n. sp.

Pls. 6-8, all figures

Description.- Zoaria are extensively explanate. No ribbon-like colonies were observed. Zoaria lack fenestrule areas, but scattered maculate areas are present in tangential view (Pl. 7, fig. 3).

Zooecia are arranged in distinct diagonal rows and longitudinal ranges as seen in tangential view (Pl. 7, fig. 3; Pl. 8, fig. 2). Boundaries between ranges of zooecia are absent. Zooecia bud from the median lamina at 40-50 degrees (Pl. 7, figs. 1, 1a, 2) and continue nearly straight to the exterior of the zoarium. Zooecial walls are distinctly laminate and quite thick but intrazooecial areas are not as extensive as in C. chazyensis. Wall laminae are continuous with laminae of the median lamina (Pl. 6, fig. 2), so that the junction of the wall structure with the median lamina is thickened. Zooecial walls abruptly thicken and become very sinuous after leaving the median lamina so that there is no distinct endozone (Pl. 7, figs. 1a, 2). A distinct dark line of closely spaced laminae forms the exterior lining of each zooecial cavity (Pl. 7, fig. 1b; Pl. 8, fig. 1c). These laminae are continuous with laminae of the diaphragms

that cross the zooecial cavities (Pl. 7, fig. 1b; Pl. 8, fig. 1c). Laminae abruptly turn away from the zooecial lining toward adjacent cavities forming the thickened wall structure of the exozone (Pl. 7, fig. 1b).

In tangential views, zooecia are ovate (Pl. 7, fig. 3; Pl. 8, fig. 2). Wall laminae are seen as concentric bands surrounding zooecial openings. Surrounding the laminate zooecial wall is a circlet of dark, laminate acanthopores (Pl. 7, figs. 1a-3; Pl. 8, fig. 2), the laminae of which appear to be continuous with adjacent zooecia. In longitudinal and transverse views, acanthopores are broad, dark structures that occur between adjacent zooecia (Pl. 7, figs. 1a-2; Pl. 8, fig. 2).

Lateral margins of zoaria (Pl. 6, fig. 1) are rounded to slightly angular, lack zooecial cavities, and are thickly laminate. They are penetrated by acanthopores that extend from the median lamina to the zoarial margin where they form small crests (Pl. 6, fig. 1).

This species normally has six to twelve well defined diaphragms (Pl. 7, figs. 1a-2) crossing zooecial cavities. One or two diaphragms are commonly emplaced in the narrow endozone with four to ten closely spaced diaphragms present in the exozone.

The width of the median lamina ranges from 0.02 mm - 0.03 mm. Laminae of the median lamina appear to be continuous with zooecial wall laminae (Pl. 6, fig. 2). An intermittent dark line of closely spaced laminae forms the midline of the median lamina (Pl. 6, figs. 1, 2; Pl. 7, figs. 1a-2).

Remarks.- In several zooecia (Pl. 7, figs. 1a-1c) distinct funnel-cystiphragms extend into zooecial cavities from the zooecial lining. This, however, is not a specific characteristic of this species because they are also found in other taxa. For a discussion of funnel-cystiphragms, see Boardman (1971, p. 22-27). This species takes its name from the extensively explanate nature of zoaria.

C. explanata is very similar to C. chazyensis in the budding pattern of zooecia along the median lamina, in the arrangement of zooecia in longitudinal ranges and diagonal rows, and in the presence of acanthopores. The major differences between C. explanata and C. chazyensis is in the number of diaphragms that cross a zooecium and in the extensively explanate zoaria. In the original generic diagnosis of Chazydictya, Ross (1963, p. 587) says that from two to three diaphragms cross a zooecial cavity. This diagnosis was based on the number of diaphragms present in C. chazyensis, the type species, which is described in the same article. Characteristics other than the number of diaphragms present in a zooecium closely compare with those of the generic description for C. chazyensis. It does not appear that the greater number of diaphragms alone constitutes a sufficient criterion for establishing a new genus. This species is therefore placed in the genus Chazydictya.

Table 3 gives quantitative data for Chazydictya explanata n. sp. All measurements are in millimeters except for zooecial angles. Taxonomic characters were selected from those used for measurements of Chazydictya chazyensis by Ross (1963, p. 588), by Karklins (1969, p. 37) for measurements of Stictopora exigua (Ulrich), and from

Table 5 - Quantitative data for seven specimens of *Chazydictya chazyensis*. Measurements in millimeters

	1	2	3	4	5	6	7
No. of whole zooecia per 1 mm. square					19 - 20		19 - 21
Zooecial void dimension Maximum							.13 - .15
Minimum							.09 - .11
No. whole zooecia per 2 mm. laterally							9
NO. whole zooecia per 2 mm. longitudinally							4 - 5
Zooecial angle			40 - 48	36 - 46	35 - 42		
Branch depth	1.15-1.25	1.10-1.30	1.15-1.20	1.23-1.50	1.10-1.15	1.20	
Width of exozone		.45			.45 - 46		
Width of endozone	.11	.10	.11 - .12		.11 - .13		
Length of zooecia			.80 - .85	.95-1.05	.75 - .81		
Width of median laminae		.03 - .04	.03 - .04	.03 - .04	.02 - .03	.03 - .04	
No. diaphragms per zooecia				10 - 17		8 - 14	
Interzooecial space laterally							.13 - .14
longitudinally							.22 - .26

biometric parameters suggested by Anstey and Perry (1970) for studies of Paleozoic bryozoans.

Occurrence.- C. explanata occurs between 2.5 meters and 6.0 meters from the base of the Lincolnshire at the Park View section. It was not observed in thin sections from the Cedar Grove section and is not reported from any other locations.

Genus GRAPTODICTYA Ulrich, 1882

Graptodictya Ulrich, 1882.

Athropora Ulrich, 1882, p. 162; Ross, 1960b, p. 859.

Type Species.- Ptylodictya perelegans Ulrich, 1878, p. 94, Pl. 4, figs. 16, 16a; designated by Ulrich, 1882, p. 165; redescribed by Phillips, (1960, p. 19); Karklins, (1969, p. 71).

Diagnosis.- Zoaria are small, bifoliate, and ribbon-shaped with straight to curved bifurcating branches. Lateral margins are angular to rounded.

In tangential views, zooecia are arranged in distinct diagonal rows. Ranges of zooecia are not distinct. Zooecia arise from the median lamina at a low angle and gently curve outward toward the exterior of the colony. Zoecial walls are thinly laminate in the endozone. The beginning of the exozone is marked by a thickening of the zoecial walls. Wall laminae of the exozone as seen in transverse views have a distinct M-shape which forms distinct outward pointing crests. Crests of laminae may form acanthopore-like structures in the very shallow exozone.

Diaphragms are rare to absent. When present, they are thinly laminate and planar. Superior hemisepta, if present, are formed from

extensions of wall laminae toward the median lamina at the base of the exozone.

The median lamina is thin, slightly zigzag in shape, and lacks median tubulae. The laminae of the median lamina are poorly defined but are continuous with, or merge with, wall laminae in the endozone region. Median lamina extend to the lateral margins of zoaria but is not well defined near the margins.

Graptodictya perelegans Ulrich, 1878

Pl. 9

Ptilodictya perelegans Ulrich 1878, p. 94, Pl. 4, figs. 16, 16a.

Graptodictya perelegans (Ulrich) Ulrich, 1882, p. 165; Phillips, 1960, p. 19, Pl. 7, figs. 1-3, 6, 7; Pl. 8, figs. 4.

Description.- Zoaria are slender and ribbon-shaped with rounded lateral margins (Pl. 9, fig. 1). Zooecia bud from the median lamina at 20 to 25 degrees and approach the exterior of the zoarium at nearly 90 degrees (Pl. 8, figs. 3a-3b). The endozone is marked by very thin laminate walls and is only one-third to one-quarter the width of the exozone (Pl. 9, figs. 1a, 3a, 3b). The base of the exozone is marked by an abrupt change in growth direction of zooecia toward the exterior of the colony and a conspicuous thickening of the zooecial walls. Zooecial walls are thickly laminate in the exozone (Pl. 9, figs. 1a-3b). Superior hemisepta and diaphragms were observed in zooecia. The median lamina is thin and slightly flexuous (Pl. 9, figs. 1a, 3a).

Remarks.- Graptodictya perelegans is similar to G. elegantula (Pl. 10, figs. 1-3; Pl. 11, figs. 1a-2) in zooecial wall structure,

character of the median lamina, and mode of growth of zoaria.

G. elegantula has distinct concentric laminae that are penetrated by small pustules (Pl. 10, fig. 3). In G. perelegans laminae are continuous around zooecial openings (Pl. 9, fig. 2) and are not interrupted by pustules. Zooecial cavities in G. perelegans are more restricted than in G. elegantula and are not as closely spaced in either the diagonal or longitudinal rows as in G. elegantula. The exozone of G. perelegans is approximately three times as wide as the endozone. In G. elegantula, however, the exozone and endozone are approximately the same width.

Graptodictya elegantula (Hall), 1847

Pl. 10, figs. 1-3; Pl. 11, figs. 1a-2

Stictopora elegantula Hall, 1847, p. 75, Pl. 26, figs. 4a and 4c.

Graptodictya elegantula Hall, 1847; Phillips, 1960, p. 21, Pl. 8, figs. 1-3, 5; Pl. 9, figs. 1-7.

Description.- Zoaria are small and ribbon-shaped with angular lateral margins (Pl. 11, fig. 1a). Zooecia are arranged in distinct diagonal rows (Pl. 10, fig. 3) but longitudinal ranges of zooecia are not distinct.

Zooecial walls are thinly laminate and not well defined in the endozone (Pl. 10, figs. 1, 2; Pl. 11, figs. 1a, 1b) but become very dense and "M" shaped in the exozone (Pl. 10, figs. 1, 2; Pl. 11, figs. 1a, 1b). Zooecia leave the median lamina at 20 to 30 degrees and gently curve toward the zoarial exterior with a slight ogee pattern. The beginning of the exozone is marked by a thickening of the laminate zooecial walls (Pl. 10, figs. 1, 2; Pl. 11, figs.

1a-2). The endozone and exozone are about equal in width. Zooecial wall laminae become very dark and dense in the exozone, and are seen as concentric bands around zooecial openings in tangential views (Pl. 10, fig. 3). Laminate pustules (small structures that appear as laminate acanthopores in shallow tangential views) may penetrate the laminate wall structure forming circlets about zooecial openings (Pl. 10, fig. 3). No diaphragms have been observed in zooecia. The median lamina is thin, nearly straight to slightly zigzag in shape (Pl. 10, figs. 1, 2).

Remarks.- G. elegantula has been compared to G. perelegans in remarks about the latter species.

Occurrence.- G. elegantula was described by Hall from the Trenton Limestone (Trenton), Watertown, New York. Additional material was reported from Trenton Limestone from Black Creek, Trenton Falls, and Rathbone, New York. Dr. J. R. P. Ross (Phillips, 1960), in a re-study of G. elegantula, did not give additional information on occurrence of the species. Ross (1964b, fig. 7, p. 735) suggested that Graptodictya first appears in the Middle Black River Group.

G. elegantula was collected at 0.6 meters, 12.3 meters, and 12.5 meters from the base of the Lincolnshire at the Park View section. At the Cedar Grove section it was collected from the upper 19 meters of the Lincolnshire and it was very abundant in the Botetourt Member of the Edinburg Formation.

Genus STICTOPORELLINA? Nekhoroshev, 1956

Pl. 10, figs. 4a, 4b, 5

Stictoporellina? Nekhoroshev, 1956, p. 48 (Karklins, 1970, p. 143)

Type Species. - Stictoporellina cribrosa, (Ulrich) 1895, by original designation, Nekhoroshev, 1956, p. 48.

Remarks. - This bifoliate cryptostome has a definite escharoporid wall structure (Pl. 10, figs. 4a-5), but different characteristics from either Chazydictya or Graptodictya. A transverse and longitudinal view of this specimen is present in sample CG-14 (Pl. 10, figs. 4a-5), but a tangential view was not available for study. The generic assignment of this form is uncertain, therefore.

Zoaria appear to be explanate and may be cribose, as suggested by the configuration of zooecia and wall structures in a transverse view (Pl. 10, fig. 4a). Zooecial walls are distinctly laminate in the exozone. Zooecia bud from the median laminae with an ovate to bulb-shaped pattern (Pl. 10, fig. 4a). The median laminae is nearly straight in transverse views (Pl. 10, figs. 4a, 5), but flexuous in longitudinal views, (Pl. 10, fig. 4b). In longitudinal views, zooecial budding occurs alternately across the median laminae (Pl. 10, fig. 4b). Zooecia leave the median laminae at a low angle but curve abruptly toward the exterior of the colony at the base of the exozone, which is marked by a greatly thickened, laminate wall structure (Pl. 10, fig. 4b).

The transverse and longitudinal views of this specimen have characteristics very similar to that described for Stictoporellina by Karklins, (1970, p. 135). Of the species in Stictoporellina described and illustrated by Karklins (1970, p. 134-138), this specimen is most similar to S. cribrosa (Ulrich), 1886, which has a very similar budding pattern of zooecia along the median laminae. The

shape of the zooecia, characteristics of the zooecial walls, and the flexuous nature of the median lamina with the intermittent dark mid-line (Pl. 10, fig. 4b) are also similar to S. cribrosa.

In transverse view, the zoarium of this specimen is somewhat broader than that of Graptodictya and lacks the very distinct "M" shape of the laminate wall structure in the exozone. The median lamina of this specimen is nearly straight in transverse view (Pl. 10, fig. 4a), but flexuous in longitudinal view (Pl. 10, fig. 4b). In Graptodictya the median lamina is somewhat zigzag in shape in transverse views. The budding pattern of the zooecia from the median lamina in Graptodictya is sub-rectangular, whereas in Stictoporellina the budding pattern is more bulb-shaped.

Occurrence.— Karklins reported the genus Stictoporellina from the Decorah Shale (Middle Ordovician) from Minnesota.

In this study, Stictoporellina? has been observed in sample CG-14, 17.5 meters from the base of the Lincolnshire at the Cedar Grove section, and from sample C1-38, 0.6 meters from the base of the Lincolnshire at the Park View section.

STICTOPORID Group

In the stictoporid structure, the zooecial wall laminae leave the median lamina at a low angle but soon curve away from the median lamina. Wall laminae of stictoporids are continuous from one zooecial cavity to the next as in the escharoporids and pachydictyids. Two types of boundaries are associated with an individual zoecium. One boundary is located between longitudinally adjacent zooecia, which Karklins (1969, p. 12, p. 13, fig. 3) called the zooecial boundary.

This boundary is most distinct in transverse views. The second boundary separates the laterally adjacent zooecia and usually extend through the entire length of a colony. It begins at the median lamina and extends to the exterior of the colony (Pl. 13, fig. 6). Karklins calls this the range boundary.

In most stictoporids, the budding pattern of zooecia along the median lamina has a distinctly rectangular pattern (Pl. 11, fig. 5). This pattern is apparently due to the shape of the newly formed zooecia adjacent to the median lamina. In the stictoporids, the median lamina is well defined (Pl. 12, figs. 1, 3). Enclosed within the median lamina are small rod like structures called median tubulae. They have distinct cores of translucent calcite. When seen in transverse view, these median tubulae appear as small beads incorporated within the median lamina (Pl. 11, fig. 5; Pl. 13, fig. 3). In the stictoporids, median tubulae do not cause bulges in the median lamina as in the pachydictyid structure. The median tubulae appear to be structureless and boundaries around the tubulae are not distinct.

Genus STICTOPORA Hall, 1847

Stictopora Hall, 1847, p. 73.

Sulcopora d'Orbigny, 1849, p. 499-501.

Rhinidictya Ulrich, 1882, p. 152.

Type Species.- Stictopora fenestrata Hall (1847, p. 16), designated by Ulrich (1886, p. 67), redescribed by Phillips (1960, p. 7).

Diagnosis.- Zoaria are bifoliate with relatively straight, slender, ribbon-shaped bifurcating branches. Zoaria occasionally may be subramose, encrusting, or explanate.

Zooecia are arranged in longitudinal ranges with distinct boundaries between ranges of zooecia (Pl. 13, fig. 5). Zooecia bud from the median lamina at a low angle and curve outward to the margin of the colony. Zooecial walls are laminate, arising from the median lamina (Pl. 12, fig. 3). Zooecial walls thicken gradually in some species, abruptly in others; the change in zooecial growth direction marks the base of the exozone. Zooecia, adjacent to the median lamina, are rectangular in cross-sectional outline as seen in transverse view (Pl. 12, fig. 1). In the more distal exozone region, zooecia are ovate as seen in tangential view (Pl. 12, fig. 5).

The median lamina is narrow with small ovate median tubulae enclosed within the median lamina.

Diaphragms are scarce and their laminae are continuous with zooecial wall laminae (Pl. 11, fig. 7).

Stictopora fenestrata Hall, 1847

Stictopora fenestrata Hall 1847, p. 16, Pl. 4, figs. 4a, b, c, d;

Ross, 1960, p. 7, Pl. 1, figs. 3, 5, 9, 11; Karklins, 1969, p. 35.

Rhinidictya fenestrata (Hall); Clarke, 1903, p. 159.

Description.- Zoaria are bifoliate with relatively straight, slender, ribbon-shaped bifurcating branches. Zoaria may be ribbon-like (Pl. 12, fig. 1) or explanate. Zoarial margins are angular to rounded (Pl. 12, fig. 5; Pl. 13, fig. 5). Surface ornamentation such as monticules and maculae are apparently lacking.

Zooecia are arranged in linear ranges with distinct boundaries between ranges of zooecia (Pl. 12, fig. 5; Pl. 13, fig. 6). Zooecia bud from the median lamina at an inclination of 15 to 25 degrees

(Pl. 11, fig. 7; Pl. 13, figs. 2-4). Zooecia may follow along the median lamina for a short distance before curving away toward the zoarial exterior (Pl. 11, fig. 7; Pl. 12, fig. 3). This gives an ogee shape to zooecia from their budding point on the median lamina to the exterior of the zoaria. Budding of zooecia alternate across the median lamina as seen in longitudinal view (Pl. 11, fig. 7; Pl. 17, fig. 1). Zooecia also may be offset across the median lamina as seen in transverse view (Pl. 11, fig. 5, Pl. 12, fig. 1). In shallow tangential view, zooecia are ovate (Pl. 12, figs. 1, 5; Pl. 13, fig. 5).

Zooecial walls are thinly laminate in the endozone with laminae parallel to the longitudinal growth direction of the zooecia (Pl. 12, figs. 4, 5). Boundaries between individual zooecia are difficult to define (Pl. 12, fig. 3). In the exozone, laminae are inclined to the zooecial lining. This greatly thickens the zooecial walls (Pl. 11, fig. 7; Pl. 12, fig. 3). A gradual curving and thickening of zooecial walls marks the beginning of the exozone.

Acanthopores, if present, originate in the early exozone. They extend to the exterior of a colony along range or zooecial boundaries (Pl. 12, fig. 1). Acanthopores in S. fenestrata are small, laminate structures without definite cores. They appear to be formed by outward flexures of the zooecial walls so that their laminae intertwine with zooecial wall laminae (Pl. 12, fig. 1).

Diaphragms, if present, are thinly laminate and may be straight to slightly curved (Pl. 11, fig. 7). A single diaphragm usually crosses a zooecial cavity and may be emplaced near the proximal or

distal end of the zooecium. Laminae of diaphragms are continuous with laminae of adjacent zooecia.

The median lamina is narrow and slightly flexuous in longitudinal views (Pl. 11, fig. 7; Pl. 12, fig. 2). The median lamina is continuous throughout the zoarium extending to the lateral margins. Ovate to sub-circular median tubulae penetrate the dark median laminae as seen in transverse view.

Mesopores, tabulate zooecial interspaces, and cystiphragms are not present in this species.

Remarks.- Stictopora fenestrata is similar in transverse view to S. nicholsoni (Phillips, 1960, p. 9). Both have a thin, laminate median laminae with enclosed median tubulae, a rectangular budding pattern, and laminate acanthopores. In longitudinal view, S. fenestrata is distinctly different from S. nicholsoni. S. nicholsoni has well developed superior hemisepta whereas S. fenestrata lacks hemisepta (Phillips, 1960, Pls. 1, 2). In longitudinal view, range boundaries are not as distinct in S. fenestrata as in S. nicholsoni.

Occurrence.- Hall (1847, p. 73, 74) described S. fenestrata from rocks of the Chazy group, New York. Ross (1963, p. 581) reported the occurrence of S. fenestrata from the upper two-thirds of the Chazy Group at Chazy, Jordan Point, and at Sheldon Lane, New York.

S. fenestrata was collected from the lower 12 meters at the Park View section. At the Cedar Grove section S. fenestrata was collected from the lower 16 meters.

ASTREPTODICTYID Group

The astreptodictyid zoarial structure is seen in Eopachydictya

gregaria Ross, 1963. A detailed morphological description of this structure is given by Karklins (1969, p. 26-29).

Zooecial boundaries in the astreptodictyids are very similar in construction to that of the pachydictyid and stictoporid groups of Phillips (1960) and to the athrophragmid structure of Karklins (1969). The structure of the median laminae and median tubulae in the astreptodictyids is very similar to that of the pachydictyid and athrophragmid structures. The zooecial boundary forms a cylindrical band around zooecial cavities so that it encloses the cavity and the adjacent part of the laminate wall structure. This also occurs in the athrophragmids.

Unlike the athrophragmids, however, zooecia are aligned on approximately longitudinal ranges in the direction of zoarial growth. These linear rows of zooecia are marked by distinct to indistinct range boundaries, depending on the species. Zooecia also are arranged in diagonal rows. Range boundaries usually are best seen in the exozone of shallow tangential views, but in some species these boundaries are best seen in the exozone of transverse views (Pl. 14, fig. 3). Range boundaries usually are not shared by adjacent zooecia as in the stictoporids, but a narrow laminated area separates adjacent range boundaries (Pl. 14, fig. 3). This condition is also seen in a transverse view (Pl. 14, fig. 1). Range boundaries in the exozone are formed by thin bands of closely spaced laminae which are continuous with zooecial boundaries in the endozone. The base of the exozone occurs where the single distinct zooecial wall bifurcates forming separate walls of adjacent zooecia. This also marks the beginning

of range boundaries.

Diaphragms are present in zooecial cavities but are usually few in number. Diaphragms are thin and straight to slightly curved. They are laminate and abut or adjoin laminae of the zooecial lining.

A major difference that distinguishes the athrophragmid structure from the astreptodictyid structure is the extent of development of tabulated zooecial interspaces. In the athrophragmids, tabulated interspaces are extensively developed (Pl. 16, figs. 1-6), but in the astreptodictyids, tabulated interspace areas are not as common (Pl. 14, fig. 1; Pl. 15, figs. 1-5). Tabulae, or diaphragms, of these interspace areas are scarce and usually are restricted to the inner exozone. Toward the outer part of the exozone, tabulated interspace areas may become obscured by the greatly thickened zooecial wall laminae.

Genus *EOPACHYDICTYA* Ross, 1963

Type Species.- *Eopachdictya gregaria* Ross, 1963, p. 591.

Diagnosis.- Zoaria are small, bifoliate, ribbon-shaped to robust (Pl. 14, fig. 1). Zooecial walls have the astreptodictyid structure. Small acanthopores may form circlets about individual zooecial openings as seen in tangential views.

Zooecia bud from the median lamina at a low angle in an alternate pattern across the median lamina (Pl. 15, fig. 4). Zooecial walls are laminate with a dark line of closely spaced laminae forming zooecial boundaries. Range boundaries are seen as single dark lines occurring between zooecial boundaries (Pl. 14, fig. 1). Tabulate zooecial interspace areas are poorly developed in *Eopachydictya*. The inter-

zoecial spaces are usually laminate (Pl. 5, fig. 2). Few diaphragms are present in zooecia. The median lamina is bilaminate with a dark line of closely spaced laminae forming the midline (Pl. 14, fig. 2). Distinct, nearly circular closely spaced median tubulae, penetrate the zoarial midline (Pl. 15, figs. 3-5).

Remarks.- Eopachydictya Ross, 1963 was proposed for a primitive pachydictyid form having small, robust zoaria. Zooecial walls are thinly laminate and zooecia generally are smaller than species of Pachydictya. Karklins (1969, p. 29) assigned Eopachydictya to the astreptodictyid group because of its structural characteristics.

Eopachydictya is similar to Pachydictya and Athrophragma in having a bilaminate median lamina with median tubulae, and in having distinct zoecial boundaries in the exozone. A major distinguishing characteristic of Eopachydictya is that tabulate interspaces between zooecia are not as well developed as they are in Pachydictya and Athrophragma. Eopachydictya differs from Astreptodictya in having only one distinct range boundary between zoecial boundaries rather than two.

Eopachydictya gregaria Ross, 1963

Eopachydictya gregaria Ross, 1963, p. 591, Pl. 4, figs. 1-5, 7-9, table 5.

Description.- Zoaria are ribbon-like (Pl. 15, fig. 4) or robust (Pl. 14, fig. 1) with rounded lateral margins.

Ranges of zooecia are marked by intermittent boundaries that are seen as thin lines between adjacent zooecia. In transverse views, range boundaries are thin lines of closely spaced laminae between well

defined zoecial boundaries (Pl. 14, fig. 1). Range boundaries do not extend to the median lamina but are confined to the exozone. Laminae of the range boundaries become mixed with laminae of the zoecial walls in the outer exozone so that they are not distinct in shallow tangential views. The base of the exozone occurs where zoecial boundaries bifurcate. This also marks the beginning of range boundaries.

Zoecial cavities are small and bud from the median lamina at an angle of 40 to 50 degrees (Pl. 15, figs. 2, 5). Zooecia curve outward the exterior of a zoarium with a slight ogee shape (Pl. 14, fig. 2). A zoecial lining is formed by closely spaced laminae that parallel the growth direction of the zooecia (Pl. 1, figs. 1, 2). Laminae bend abruptly away from the zoecial lining and are distally convex forming the thickened wall structure of the exozone. Laminae are present between zoecial and range boundaries and form a chevron shaped pattern in the exozone as seen in transverse view.

From one to three diaphragms may cross a zoecial cavity and are emplaced in the exozone (Pl. 15, fig. 2). Laminae of the diaphragms are continuous with laminae that form the zoecial lining.

Tabulate interspace areas are not well developed in E. gregaria. Those that do occur contain few tabulae and are "walled-over" in the outer exozone so that they are not open to the exterior of the colony.

From 12 to 18 small acanthopores surround a single zoecial opening and approximate the zoecial boundary. They are easily recognized in tangential views, but are difficult to recognize in longitudinal and transverse views.

Occurrence.- Ross (1963, p. 591, 583) reported the occurrence of E. gregaria only from the upper one-third of the Chazy Group from Isle La Motte, Vermont, and from Jordan Point, New York.

In this study, E. gregaria was found to occur in the lower 12.3 meters of the Lincolnshire at the Park View section. At the Cedar Grove section, E. gregaria occurs in the lower 21 meters of the Lincolnshire.

ATHROPHRAGMID Group

A fourth type of zoarial structure occurs in the genus Athropragma of which Pachydictya foliata Ulrich is the type species. A complete description of this structural group is given by Karklins (1969, p. 24-26).

Zoecial boundaries of the athropragmids are similar in construction to the pachydictyids (Phillips, 1960) and the stictoporids (Phillips, 1960; and Karklins, 1969). The arrangement of zooecia, however, is quite different.

In the athropragmids, the zoecial cavities and part of the zoecial walls are enclosed by a cylindrical zoecial boundary (Pl. 17, fig. 14). Zooecia are arranged in longitudinal ranges and diagonal rows (Pl. 17, fig. 6), but no range boundaries separate adjacent ranges of zooecia. Zoecial boundaries begin at the median lamina but abruptly bifurcate after leaving the median lamina (Pl. 16, figs. 1-6). The endozone is very narrow, with the base of the exozone beginning where the zoecial boundary bifurcates. In the exozone, laminae of the zoecial walls are inclined to the zoecial cavity so that they gradually thicken and are slightly convex in a distal direction.

Diaphragms occur in the zooecia in varying numbers depending on the species.

A distinct characteristic of the athrophragmids is the extensive development of tabulated interspace areas between adjacent zooecia (Pl. 16, figs. 1-6). Tabulated interspace areas commonly begin at or near the median laminae. They extend to the outer part of the exozone where they become "walled-over" so that they are not open to the exterior of the colony. Interspace areas may be quite narrow with tabulae extending continuously across the interspace, or, they may be quite wide with tabulae arranged in an adjacent overlapping fashion which gives the interspace areas a very cystose appearance. Interspace tabulae are more closely spaced and more curved than zooecial diaphragms. Tabulae of the interspace areas abut or adjoin laminae of the zooecial boundaries but do not cross them. Tabulate interspace areas commonly alternate with zooecial cavities as seen in transverse and longitudinal views.

The median lamina of the athrophragmids is bilaminate with a dark line of closely spaced laminae forming the midline of a zoarium (Pl. 18, fig. 2). Large, nearly circular median tubulae penetrate the midline of the zoarium (Pl. 18, fig. 36). Construction of the median lamina in the athrophragmids is very similar to that of the stictoporids but median tubulae are larger and more rounded than in the stictoporids.

Genus *ATHROPHRAGMA* Karklins, 1969

Type Species.- *Pachydictya foliata* Ulrich, 1886, p. 73; 1895, p. 149, Pl. 9, figs. 1-5; Pl. 10, figs. 5-10.

Diagnosis.- Colonies are bifoliate, ribbon-like or explanate.

Zooecia are aligned in longitudinal ranges and diagonal rows and are ovate to sub-circular in cross-section. Acanthopores and/or pustules are commonly present but are restricted to the exozone. They are most distinct in shallow tangential section (Pl. 17, fig. 6).

Zooecia bud from the median lamina at a high angle. They may be straight to slightly curved from the median lamina to the zoarial surface. Zooecial walls are thinly laminate in the endozone. The exozone begins at the base of the tabulated interspace areas. This also marks the point of bifurcation of zooecial walls.

Diaphragms are planar to slightly curved and about evenly spaced in zooecia. In the tabulate interspace areas, tabulae are closely spaced and commonly are arranged in overlapping series.

Remarks.- Athropragma differs from Astreptodictya and Pachydictya in having a more explanate colony growth form (Pl. 4, fig. 1). As in Pachydictya, zooecia are arranged in longitudinal ranges and diagonal rows, but no boundaries separate ranges of zooecia. Pachydictya differs from Athropragma in having the pachydictyid wall structures, as described by Phillips (1960, p. 13-16). Zooecial cavities are considerably more constricted in Pachydictya than in Athropragma. In Athropragma, zooecial cavities are nearly parallel from the median lamina to the exterior with relatively little thickening of the outer wall. In Pachydictya, however, the outer zooecial wall becomes distally thickened so that the size of zooecial cavities is restricted. Configuration of the wall laminae of Athropragma differs from that of Astreptodictya by being more U-shaped. Tabulate interspaces in

Athrophragma are more extensively developed than in Astreptodictya or Pachydictya and diaphragms within these areas are better developed.

Athrophragma sheldonensis (Ross), 1963

Pachydictya sheldonensis Ross, 1963, p. 590, Pl. 3, fig. 4; Pl. 4, figs. 6, 8; Pl. 5, figs. 1-8; Pl. 6, figs. 1-9; Pl. 9, fig. 5; Pl. 10, figs. 7, 8; table 4.

Description.- Zoaria are slender with an explanate growth plan (Pl. 4, fig. 1; Pl. 16, figs. 1, 2, 4, 5). One encrusting form has been observed (Pl. 17, fig. 2). Zooecia are slightly curved from the budding point at the median lamina to the zoarial surface. Zooecia leave the median lamina at 60 to 80 degrees and approach the zoarial exterior at 70-85 degrees (Pl. 16, fig. 3). In shallow tangential views, zooecia are ovate to sub-circular in cross section. Zooecial walls are dark and thinly laminate in the endozone. Wall laminae parallel the zooecial cavities in the endozone, but in the exozone, they curve slightly away from the zooecial boundaries (Pl. 18, fig 3b).

Tabulate interspace areas begin near the median lamina, and mark the beginning of the exozone (Pl. 16, figs. 1-6). They commonly alternate with zooecia, as seen in both longitudinal and transverse views (Pl. 16, figs. 1-6). In some colonies, tabulate interspace areas are quite narrow and tabulae commonly extend across the entire space (Pl. 18, fig. 32). In more robust zoaria, tabulate interspaces may be quite wide with tabulae arranged in an overlapping cystose pattern (Pl. 16, fig. 3).

From one to five diaphragms commonly cross a zooecial cavity and are usually emplaced in the exozone (Pl. 16, fig. 3; Pl. 16, fig. 3).

Laminae of the diaphragms adjoin laminae that form the zoecial lining and walls, but are not continuous with interspace tabulae.

Zoecial boundaries are very distinct, especially in tangential views. They appear as dark lines surrounding zoecial cavities and enclose part of the zoecial wall structure (Pl. 17, fig. 4). Boundaries occur between both zoecia and tabulate interspace areas.

Remarks.- A. sheldonensis (Ross) 1963 is here removed from the genus Pachydictya Ulrich, 1882 and is placed in the genus Athrophragma Karklins (1969) because: it has an extensively explanate colony growth form; zoecial cavities are considerably less restricted in diameter in the exozone; zoecial walls are thinner and have a different construction; and the zoecial cavities are not as constricted distally so that outer zoecial cavity walls are more nearly parallel from the median lamina to the zoarial exterior. A. sheldonensis has a very extensive tabulate zoecial interspace area as does Athrophragma foliata (Ulrich). In species of Pachydictya, tabulate zoecial interspace areas are not as extensively developed and are differently constructed.

A. sheldonensis (Ross) 1963 is similar to A. foliata (Ulrich) 1886 in the construction of zoecial walls and tabulate interspace areas. It differs from A. foliata: in having less extensive interspace areas, in the budding pattern of zoecia from the median lamina, and in the shape of the zoecia from the median lamina to the zoarial exterior.

Occurrence.- Ross (1953, p. 590), reported the occurrence of A. sheldonensis only from the Chazy Group of New York. It occurs

in the upper one-half of the Chazy Group at Jordan Point and Sheldon Lane, New York, and Isle La Motte, Vermont.

A. sheldonensis was collected from the lower 12.5 meters of the Lincolnshire at the Park View section. At the Cedar Grove section

A. sheldonensis was collected throughout the Lincolnshire and the Botetourt Member of the Edinburg Formation.

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APPENDIX

Location and Description of Stratigraphic Sections

Introduction. - All field measurements were taken to the nearest tenth of a foot and have been converted to the metric system. Some figures are of direct stratigraphic measurements and others are calculated from structural reconstructions. Conversion to the metric system was taken to two decimal places. Further rounding would increase the conversion factor error.

For convenience, both the original calculations in feet, and the converted metric figures are given in the section descriptions.

Access and Description. - The Park View section is reached by taking Chicago Avenue (County Road 763) northwest from Harrisonburg through Park View. The Coffman residence is north of County Road 763 about 0.3 km. (1/5 mile) west of Park View. The measured section is on the eastward facing slope of a low hill northwest of the Coffman residence, about 140 meters (450 feet) north of County Road 763.

The base of the section is 80 meters (262 feet) N. 40° E. from the northeast corner of the steel cattle shed directly behind the Coffman residence. The section begins in the upper Beekmantown formation and continues through the New Market and Lincolnshire Limestones. The basal unit of the section is a bluish limestone (sample C2-25) of the upper Beekmantown. From this point, the section was measured and samples collected along a line perpendicular to strike (N. 65° W.) to the crest of the hill. Sample collection locations were marked with black letters on a white background in the summer of 1972.

Three to eight pound samples were collected through the Beekmantown and New Market and processed for microfossils. Samples are given in the measured section at the footage from which they were collected. The prefix (C2-) of a number designates samples taken from the Beekmantown-New Market interval and (C1-) numbers designate samples from the Lincolnshire Limestone. Samples taken from the Lincolnshire were taken from outcrops along the crest of the hill. Where necessary, collection sites were measured independently from the New Market-Lincolnshire contact. Samples C1-A through C1-L were collected along the north side of the small stream, several hundred meters north of the crest of the hill, where samples C1-1 through C1-38 were collected (Text-Fig. 1). Samples HB-1

through HB-4 were collected on property owned by H. A. Brunk approximately 200 meters north of the small stream (Text-Fig. 1)

Sample locations are given in the measured section at the footage from which they were collected.

Sample
Description

Sample Number	Unit Thickness		Cumulative Thickness	
	<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>

ridge. The property is owned by H. A. Brunk; samples collected were marked (HB-); no samples were precessed for bryozoans; spot samples were collected for conodont analysis.

Covered interval

	3.51	11.5	19.05	62.5
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24. Limestone, dark gray biomicrite with black chert; reddish-purple iron stains common; few bryozoans and other fossil fragments present; matrix mostly fine grained micrite showing some recrystallization.

	2.44	8.0	15.54	51.0
C1-B			15.54	51.0
C1-24			14.94	49.00
C1-25			14.87	48.8
C1-23			14.56	47.8
C1-22			14.33	47.0
C1-33			13.35	43;8

23. Limestone, dark gray, fine biosparite; bryozoan fragments quite large, some appear to be in life position; fragments show little evidence of abrasion; black chert and silicified ramose bryozoans present and are locally abundant (C1-12 & 13).

	2.59	8.5	15.54	43.0
C1-19			12.50	41.0
C1-32			12.44	40.8
C1-12,13			12.28	40.3
C1-31			11.92	39.1
C1-11,H			11.40	37.4
C1-C			11.28	37.0
C1-14,34			11.22	36.8
C1-15			10.97	36.0

22. Limestone, gray, coarse biosparite composed mainly of fragments of bryozoans, pelmatozoans, mollusks, and

	1.98	6.5	10.52	34.5
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Sample Description	Sample Number	Unit Thickness		Cumulative Thickness		
		<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>	
trilobites; fossils randomly oriented, some are quite abraded; matrix mostly sparry calcite, some micrite; black chert absent.	C1-18			10.21	33.5	
	C1-26			10.00	32.8	
	C1-20,21			9.75	32.0	
	C1-8			9.45	31.0	
	C1-10,G			8.96	29.4	
	C1-17			8.84	29.0	
	21. Limestone, dark gray, medium grained micrite; bryozoan		3.39	14.5	8.53	28.0
	fragments quite large but show evidence of some	C1-35			7.92	26.0
	recrystallization; matrix mostly biomicrite, some	C1-28			7.80	25.0
	sparry calcite void fillings; black chert abundant.	C1-9			7.44	24.4
20. Limestone, dark gray, medium biomicrite; some sparry and some micritic matrix; large bryozoan and other fossil fragments present; black chert scarce; some scour surfaces present.	C1-6			6.89	22.6	
	C1-5			5.97	19.6	
	C1-29			5.79	19.0	
	C1-D			5.18	17.0	
	C1-E			4.57	15.0	
	C1-30			4.27	14.0	
			3.50	11.5	4.11	13.5
	C1-4			3.90	12.8	
	C1-36			3.81	12.5	
	C1-K			3.05	10.0	
C1-3			2.44	8.0		
C1-F			2.13	7.0		
C1-L			0.91	3.0		
19. Base of Lincolnshire Limestone; dark gray, massive, medium grained biomicrite; bedding poorly defined; reddish-brown iron stains present along partings;		0.62	2.0	0.61	2.0	

Sample
Description

Sample
Number

Unit
Thickness
Meters Feet

Cumulative
Thickness
Meters Feet

fossils include fragments of bryozoans, brachiopods,
pelmatozoans, mollusks, and trilobites; fossil content
quite variable along strike; black chert absent; several
scour surfaces present. (Strike - N. 25° E., Dip - 55°
Northwest).

C1-2	0.61	2.0
C1-38	0.46	1.5
C1-I	0.30	1.0
C1-1	0.00	0.0

New Market Limestone (80.19 m.; 263.1 ft.)

18. Limestone, dense, dove gray dismicrite; contains
some fragments of gastropods; birdseye fabric prominent
on weathered and fresh surfaces; bedding poorly defined,
stylolitic surfaces present.

28.59	93.8	80.19	263.1
C2-1	71.96	236.1	
C2-2	64.65	212.1	
C2-3	56.57	185.6	

17. Limestone, dense, dove gray dismicrite; contains many
fragments of gastropods, some ostracodes and trilobite
fragments, and large, well preserved palmate conodonts.;
some algal structures seen in thin section.

0.24	0.8	51.48	168.9
C2-4	51.36	168.5	

16. Limestone, bluish to dove gray, dense, smooth weathering
dismicrite; birdseye fabric prominent; bedding obscure,

38.77	127.2	51.24	168.1
C2-5	43.86	143.9	

Sample Description	Sample Number	Unit Thickness		Cumulative Thickness	
		<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
some cream-colored stringers and stylolites present. (At C2-6, Strike N. 25° E., Dip 47° Northwest).	C2-6 C2-7			39.87 27.07	130.8 88.8
15. Limestone, thin bed of bluish-gray dismicrite, contains many small gastropods, large palmate conodonts, some ostracodes, algal structures, and small fragments of trepostome bryozoans; all shelly fossils partially recrystallized.	C2-8	0.30	1.0	12.48 12.31	40.9 40.4
14. Limestone, light gray, very fine grained micrite with cream-colored stringers paralleling bedding; no fossils present.	C2-9	10.03	32.9	12.16 4.28	39.9 14.1
13. Limestone, bluish-gray micrite; contains algally laminated limestone, several thin carbonate pebble conglomerates, and mud-cracked surfaces; birdseye fabric present but not prominent; no fossils present.	C2-17 C2-18	2.13	7.9	2.13 1.28 0.85	7.0 4.2 2.8

Sample Description	Sample Number	Unit Thickness		Cumulative Thickness	
		<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
Beekmantown Formation (41.18 m., 135.1 ft.)					
12. Dolomitic limestone, dense, thick bedded, mottled dark and light on fresh surface; thin section of C2-18B shows alternating dark patches of partially dolomitized micrite occurring in a lighter more completely dolomitized matrix; some sparry calcite and dolomite suggests remnant birdseye fabric; C2-18A shows complete dolomitization of matrix.		16.46	54.0	41.18	135.1
	C2-18A			37.37	122.6
	C2-18B			28.35	93.0
11. Limestone, bluish-gray, smooth weathering, some birdseye fabric present; lower contact with dolomite sharp; upper part of unit locally contains large, weathered clasts of dolomite; unit can be traced north along strike approximately 200 meters; contains conodonts, no macro fossils seen on surface outcrop.		0.91	3.0	24.72	81.1
	C2-19			24.72	81.1
	C2-19A			24.08	79.0
10. Dolomite, dense, buff to light gray, smooth weathering; fret-work on weathered surfaces common; no samples collected.		2.77	9.1	23.80	78.1

Sample Description	Sample Number	Unit Thickness		Cumulative Thickness	
		Meters	Feet	Meters	Feet
9. Limestone, blue-gray, thin bedded; fossil fragments include gastropods, ostracodes, and trilobites; most fossil fragments are oriented convex up, and are confined to thin beds; conodonts present; stylolitic surfaces common.	C2-19B	1.10	3.6	21.03	69.0
				20.45	67.1
8. Dolomitic limestone, dark gray, rough weathering; lower contact with limestone sharp; unit grades upward to more limy beds; no samples collected.		0.70	2.3	19.93	65.4
7. Limestone, bluish-gray, smooth weathering, very fine grained; small doubly terminated quartz crystals occur in the micrite matrix; conodonts present.	C2-19C C2-20	0.98	3.2	19.23	63.1
				19.23	63.1
				18.15	60.7
6. Dolomitic limestone, dark gray, sugary textured; grades upward through impure, thin-bedded limestones, to nearly pure limestone; no samples collected.		1.16	3.8	18.26	59.9
5. Dolomitic limestone, blue-gray, rough weathering; grades upward into dense, sugary textured dolomite; dolomite rhombs seen along stylolitic partings in thin		0.61	2.0	17.10	56.1

Sample
Description

Sample
Number

Unit
Thickness
Meters Feet

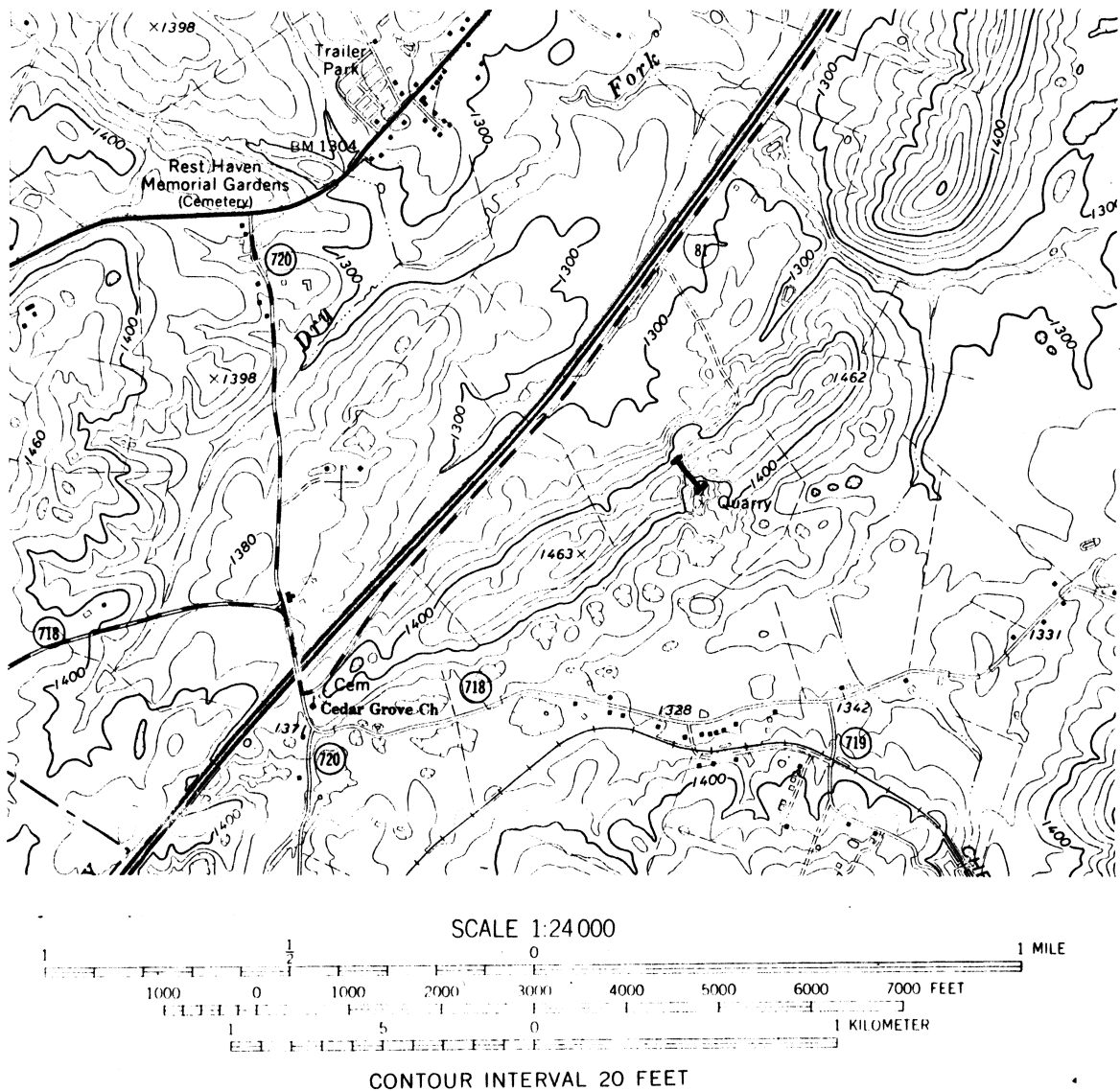
Cumulative
Thickness
Meters Feet

<p>section; recrystallized fragments of gastropods, and other fossils present; conodonts present. (At C2-21, Strike N. 25° E., Dip 34° Northwest).</p> <p>4. Dolomitic limestone, dark gray, sugary textured; lower contact with limestone abrupt and slightly irregular; grades upward into more limy beds.</p> <p>3. Limestone, dense, thick bedded, blue-gray; birdseye fabric on some outcrops; gastropods (some silicified), and straight and coiled cephalopods abundant; conodonts present. (At C2-23C, Strike N. 25° E., Dip 30° Northwest).</p> <p>2. Dolomite, dense, thick bedded; weathers buff to light gray; fret-work pattern common on weathered outcrop; no samples collected.</p> <p>1. Limestone, dense, blue-gray; shows partially recrystallized micrite matrix; conodonts and other fossils present.</p>	<p>C2-22</p> <p>C2-23</p> <p>C2-23A</p> <p>C2-23B</p> <p>C2-23C</p> <p>C2-23D</p> <p>C2-24</p> <p>C2-25</p>	<p>2.04</p> <p>6.7</p> <p>9.27</p> <p>30.4</p> <p>4.88</p> <p>0.30</p> <p>1.0</p>	<p>16.49</p> <p>54.1</p> <p>14.45</p> <p>47.4</p> <p>14.14</p> <p>46.4</p> <p>12.37</p> <p>40.6</p> <p>10.91</p> <p>35.8</p> <p>9.27</p> <p>30.4</p> <p>7.13</p> <p>23.4</p> <p>6.10</p> <p>20.0</p> <p>5.18</p> <p>17.0</p> <p>0.30</p> <p>1.0</p>	<p>14.75</p> <p>48.4</p> <p>14.45</p> <p>47.4</p> <p>14.14</p> <p>46.4</p> <p>12.37</p> <p>40.6</p> <p>10.91</p> <p>35.8</p> <p>9.27</p> <p>30.4</p> <p>7.13</p> <p>23.4</p> <p>6.10</p> <p>20.0</p> <p>5.18</p> <p>17.0</p> <p>0.30</p> <p>1.0</p>
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Beekmantown Dolomite

Geologic Section 2 - Cedar Grove Section

Location. - Geologic section 2 is about 4.02 km. (2.5 miles) east of the Harrisonburg City limits, in a quarry owned by the C. & W. Railway. The section is approximately one mile north of Cedar Grove Church, east of I-81.



Text-Fig. 8 - Portion of the Harrisonburg, Virginia 7½ minute topographic map showing the location of the Cedar Grove section.

Access and Description. - Permission for access to this property must be obtained from the C. & W. Railway office in Harrisonburg, Virginia.

This location is reached by taking Old Furnace Road, County Road 718, east from Harrisonburg City limits. Proceed onto County road 720 and cross I-81. Turn left immediately after crossing I-81 at Cedar Grove Church onto a paved access road that parallels I-81. Continue north approximately 1.8 km. (1.2 mi.) to a locked gate on the east side of the road that leads to a gravel access road to the quarry.

The Lincolnshire Limestone is exposed to the left of the pit access road, west of the quarry pit. The base of the section is at the lithologic contact between the light blue-gray New Market dismicrite and the darker gray biomicrite of the Lincolnshire just to the left of the pit access road on the west quarry face. The base of the section and collection locations were marked with black letters on a white background in the summer of 1972.

The prefix (CG-) designates samples from the Cedar Grove section. Samples were collected throughout the section and are given in the section description at the footage from which they were collected.

Sample Description	Sample Number	Unit Thickness		Cumulative Thickness	
		<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
Botetourt Member of Edinburg Formation (3.05 m., 10.0 ft.)					
14. Limestone, brownish-gray, thin bedded, knobbly weathering, medium grained biosparite; composed of fragments of bryozoans, brachiopods, pelmatozoans, and trilobites; contains many large strophomenid brachiopod shells oriented convex up.		3.05	10.0	3.05	10.0
	CG-50			3.05	10.0
	CG-49			2.44	8.0
	CG-46-48			1.83	6.0
	CG-43c-45			0.91	3.0
	CG-43b			0.73	2.4
	CG-43a			0.43	1.4
Lincolnshire Limestone (36.58 m., 120.0 ft.)					
13. Limestone, same type as 10.		1.00	3.3	36.58	120.0
	CG-42			36.58	120.0
	CG-41			35.66	117.0
12. Limestone, same type as 11; contains few bryozoans.		0.30	1.0	35.57	116.7
11. Limestone, light gray, thin bed of coarse biosparite, contains large fragments of ramose bryozoans.		0.09	0.3	35.27	115.7
	CG-40			35.20	115.5
10. Limestone, light gray, massive bedded, cross-strati- fication evident; unit thins to the northeast along strike; sediment composed mostly of abraded fragments of		0.55	1.8	35.17	115.4
	CG-37			34.93	114.6

Sample
Description

Sample
Number

Unit
Thickness
Meters Feet

Cumulative
Thickness
Meters Feet

<p>bryozoans, brachiopods, and pelmatozoans in sparry matrix; massive and encrusting bryozoan colony forms more common than ramose or bifoliate forms.</p> <p>9. Limestone, same type as 8; wavy or ribbon-like, reddish-brown partings occur throughout the interval; partings may be as wide as one centimeter and usually stand out in relief on weathered surfaces; partings contain hematite and-or limonite.</p> <p>8. Limestone, medium gray, massive bedded, coarse biosparite composed mostly of fragments of brachiopods, bryozoans, pelmatozoans, mollusks, and trilobites; some massive monticuliporoid bryozoan colonies present, ramose and bifoliate colonies fragmental; black chert sparse.</p> <p>7. Murat facies of Lincolnshire Limestone; light blue-gray</p>	<p>CG-38 CG-53</p> <p>CG-36 CG-29 CG-35 CG-51,52 CG-34 CG-26,28, 30 CG-27 CG-32 CG-25</p>	<p>2.74 9.0</p> <p>3.96 13.0</p> <p>5.06 16.6</p>	<p>34.63 113.6</p> <p>34.63 113.6 32.55 106.8</p> <p>31.91 104.6 31.91 104.6 31.00 101.7 30.42 99.8 30.27 99.3 29.90 98.1 29.57 97.0 29.14 95.6 28.74 94.3 27.92 91.6</p> <p>27.92 91.6</p>
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Sample
Description

- massive bedded, coarse biosparite; contains several closely spaced scour or "microkarst" surfaces; black chert and fossil fragments sparse; bryozoan colonies more robust and massive than in finer sediment of unit.
6. Limestone, light gray, massive bedded, coarse biomicrite; bryozoans present but not forming biostromal beds as in unit 5; large strophomenid brachiopods present at CG-15 oriented perpendicular to bedding; several minor scour surfaces occur throughout the interval; black chert nodules oriented roughly parallel to bedding.
5. Limestone, dark gray, knobbly weathering, massive bedded; large fragments of bryozoans and brachiopods present in dark biomicrite matrix; ramose and bifoliate bryozoan colonies present, many appear to be in life position; black chert nodules present.

Sample Number	Unit Thickness		Cumulative Thickness	
	<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
CG-D8			27.92	91.6
CG-31			27.74	91.0
CG-D7			27.34	89.7
CG-D6			27.04	88.7
CG-24			26.91	88.3
CG-D5			26.15	85.8
CG-16			24.57	80.6
	4.27	14.0	22.56	74.0
CG-15			21.15	69.4
CG-23			20.93	68.7
CG-22			19.93	65.4
CG-21			18.78	61.6
	1.52	5.0	18.29	60.0
CG-14			17.68	58.0
CG-20			17.47	57.3
CG-13			17.07	56.0
CG-19			16.89	55.4

Sample
Description

4. Limestone, dark gray, massive bedded, cherty; closely spaced black chert nodules occur roughly parallel to bedding, results in very irregular, nodular weathering surface; fragments of bryozoans and brachiopods common, some silicified; biomicrite matrix shows evidence of some recrystallization; at 16.77 m. (55.0 ft.) an abrupt change occurs from a sparsely fossiliferous biomicrite to a bryozoan biolithite.
3. Limestone, more fossiliferous than unit 2; fragments of bryozoans and brachiopods common.
2. Limestone, dark, bluish-gray biomicrite, black chert nodules oriented roughly parallel to bedding; scour surfaces evident, fragments of bryozoans and brachiopods truncated at scour surfaces; matrix mostly biomicrite.

Sample Number	Unit Thickness		Cumulative Thickness	
	Meters	Feet	Meters	Feet
	10.12	33.2	16.77	55.0
CG-12			16.57	54.4
CG-11			15.73	51.6
CG-18			15.30	50.2
CG-10			15.00	49.2
CG-9,17			13.17	43.2
CG-8			10.61	34.8
CG-7			9.39	30.8
CG-6			6.95	22.8
	3.60	11.8	6.64	21.8
CG-5			4.21	13.8
	2.26	7.4	3.05	10.0
CG-4			3.05	10.0
CG-3			1.22	4.0

Sample
Description

Sample
Number

Unit
Thickness
Meters Feet

Cumulative
Thickness
Meters Feet

1. Limestone, blue gray, massive bedded, biomicrite;
black chert nodules sparse; fragments of bryozoans,
brachiopods, mollusks, and trilobites distributed
throughout biomicrite matrix as observed in this
section. Base of Lincolnshire Limestone.

0.79 2.6 0.79 2.6

CG-2

0.61 2.0

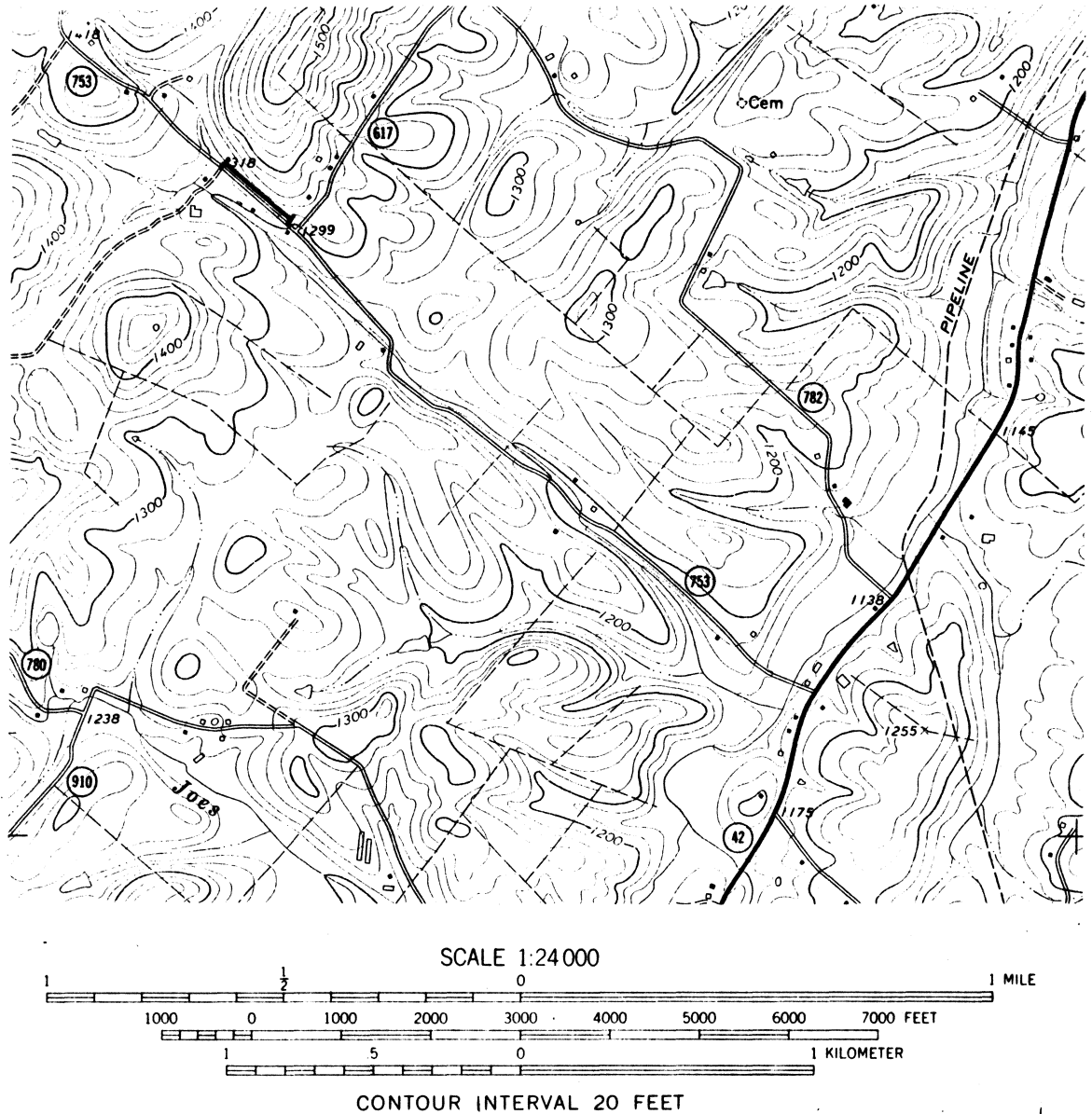
CG-1

0.00 0.0

New Market Limestone (not measured)

Geologic Section 3 - Edom Section

Location. - Geologic section 3 is about 4.02 km. (2.5 miles) north of Edom, Virginia, along County Road 753, just west of its junction with County Road 617.



Text-Fig. 9 - Portion of the Broadway, Virginia 7½ minute topographic map showing the location of the Edom section.

Access and Description. - The Edom section is reached by taking Virginia Rt. 42 north from Harrisonburg, Virginia. Proceed through Edom, Virginia approximately 2.8 km. (1.75 mi.). Turn left onto County Road 753 and continue westward 2.09 km. (1.3 mi.) to its junction with County Road 617. The base of the section is along the west side of County Road 753, 0.32 km. (0.2 mi.) west from its junction with County Road 617. Measurement began at the lithologic change from buff-weathering Beekmantown dolomite to light gray New Market dismicrite. The base of the section and sample locations were marked with black letters on a white background in the summer of 1972. Sample locations are given in the measured section description at the footage from which they were collected.

Sample
Description

Sample
Number

Unit
Thickness
Meters Feet

Cumulative
Thickness
Meters Feet

Liberty Hall Member of Edinburg Formation (8.83 m., 29.0 ft.; +)

10. Interbedded calcareous shales and thin bedded limestones; shale weathers buff to gray-black; small ampyxinid trilobites, brachiopods, and some graptolites occur in the calcareous shales; limestone is dark, dense, thinly laminate, coarse and fine grained; limestone sample E-26A contains small phosphatic inarticulate brachiopod shells similar to those observed in HB-4 of the Park View section.

E-26A

8.83 29.6

0.85 2.8

Lincolnshire Limestone (29.57 m., 97.0 ft.)

9. Limestone, light gray, massive beds of very coarse biosparite; cross-stratification evident; sediment composed mostly of fragments of pelmatozoans, bryozoans, and brachiopods; some ostracodes and small inarticulate brachiopods present.

E-26

0.91 3.0 29.57 97.0

29.41 96.5

Sample Description	Sample Number	Unit Thickness		Cumulative Thickness	
		<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
8. Limestone, light gray, massive bedded, coarse biosparite composed mostly of abraded fragments of pelmatozoans and bryozoans; sparry matrix; bedding obscure, reddish-brown partings common.	E-25 E-24	3.35	11.0	28.65	94.0
7. Murat facies of Lincolnshire Limestone; medium gray coarse biosparite, massive bedded; reddish-purple partings common; fragments of ramose bryozoans and other fossils present; soil cover a deep reddish- brown.	E-23	1.22	4.0	21.64	71.0
Covered interval.		1.98	6.5	21.00	68.9
6. Limestone, dark gray, medium biosparite; bedding obscure; few fossils present; black chert common.	E-22	0.76	2.5	20.42	67.0
Covered interval.		3.20	10.5	18.44	60.5
5. Limestone, dark gray, massive bedded, medium biosparite; fragments of bryozoans, brachiopods, trilobites, and pelmatozoans present; black chert sparse.	E-20,21	0.76	2.5	17.68	58.0
				14.78	48.5
				14.45	47.4

Sample Description	Sample Number	Unit Thickness		Cumulative Thickness	
		<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
Covered interval.		0.64	2.1	14.02	46.0
4. Limestone, dark gray, cobbly weathering medium biomicrite; fragments of bryozoans and brachiopods (some silicified) present; bedding obscure; reddish- purple partings present; black chert present. (At E-15, Strike N. 22° E, Dip 30° Southeast).	E-19 E-18 E-17 E-16 E-15	5.18	17.0	13.38 13.26 11.61 9.78 9.20 8.32	43.9 43.5 38.1 32.1 30.2 27.3
Covered interval.		0.61	2.0	8.20	26.9
3. Limestone, same type as 2.	E-14	0.30	1.0	7.59 7.28	24.9 23.9
Covered interval.		6.70	22.0	7.16	23.5
2. Limestone, dark gray, medium grained biomicrite; black chert and fossils sparse.	E-13	0.46	1.5	0.46 0.34	1.5 1.1
New Market Limestone (36.58 m., 120.0 ft.)					
1. Limestone, light dove-gray, dense; birdseye fabric prominent; fossil fragments sparse, mostly small gastropods; stylolites and cream-colored laminae occur locally parallel to bedding.		36.58	120.0	36.58	120.0

Sample
Description

(At E11; Strike N. 23° E., Dip 28° Southeast)
 (At E-7; Strike N. 21° E., Dip 25° Southeast)
 (At E-5; Strike N. 22° E., Dip 24° Southeast)
 (At E-2; Strike N. 20° E., Dip 21° Southeast)

Sample Number	Unit Thickness		Cumulative Thickness	
	<u>Meters</u>	<u>Feet</u>	<u>Meters</u>	<u>Feet</u>
E-12			36.58	120.0
E-11			33.52	110.0
E-10			31.09	102.0
E-9			27.97	91.8
E-8			25.00	82.0
E-7			20.02	65.7
E-6			16.37	53.7
E-5			15.84	52.0
E-4			12.20	40.0
E-3			5.58	18.3
E-2			1.01	3.3
E-1			0.18	0.6

Beekmantown Dolomite (not measured)

Explanation of Plate 1

Figs. 1, 2. Lithologic contact between the New Market and Lincolnshire Limestones. 1, Contact between light gray New Market dismicrite and darker, cherty Rockbridge facies of the Lincolnshire limestone at the Cedar Grove section; 2, photomicrograph of contact from the Park View section, sample C1-1.

Figs. 3a, 3b. Cherty bryozoan biolithite of lower Lincolnshire at the Cedar Grove section. 3a, Outcrop showing rough, "spongy" weathering, cherty limestone; 3b, close-up view of same outcrop showing large chert nodule and "spongy" weathering texture.

PLATE I



1



x25

2



3a



3b

Explanation of Plate 2

Figs. 1-6. "Micro-karst" surfaces within Lincolnshire of the Cedar Grove section. 1, Outcrop showing microkarst surface CG-D6, note slight change in texture and color of sediment across the surface; Figures 2-6 are negative prints of cellulose acetate peels. 2, magnified portion of surface CG-D6 showing color and textural difference across surface, light band along the vertical tube is the hematite-rich weathering zone; 3, section showing configuration of surface CG-D4.5; 4, surface CG-D7 showing a portion of a brachiopod shell extending across the surface; 5, surface CG-D6 showing development of a small monticuliporoid bryozoan colony on a "micro-karst" surface; 6, surface CG-D4.5 showing a large bifoliate bryozoan protruding into cavity (lower right) while being truncated at the upper surface (upper right).

PLATE 2



1



x3.5

2



x3.8

3



x2.2

4



x2.8

5



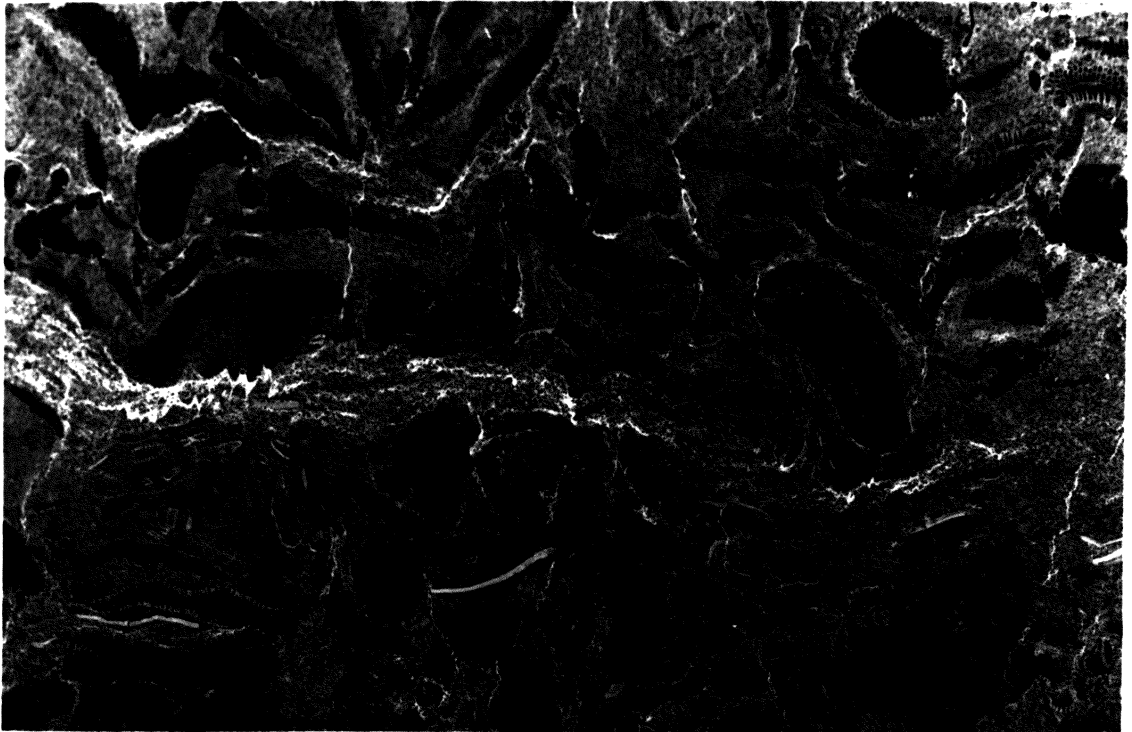
x2.75

6

Explanation of Plate 3

Fig. 1, 2. Negative prints of cellulose acetate peels. 1, Sample CG-14 showing large explanate and ribbon-shaped bifoliate cryptostome colonies oriented nearly parallel to bedding, a stylolitic zone is present in left center of the photo; 2, sediment of CG-23 composed mostly of large fragments of ramose and massive bryozoan colonies in a biomicrite matrix.

PLATE 3



x 1.82

1



x 2.5

2

Explanation of Plate 4

Fig. 1, 2. Negative prints of cellulose acetate peels. 1, Sample CG-19 containing very large unabraded fragments of explanate, bifoliate cryptostome colonies, ramose trepostome colonies and trilobite fragments, large explanate colony is Athrophragma sheldonensis (Ross) 1963; 2, oblique section through a large explanate colony of Chazydictya explanata n. sp. showing extensive explanate nature of colony, sample Cl-36.

PLATE 4



x4.75

1



x4.8

2

Explanation of Plate 5

Figs. 1-6. Chazydictya chazyensis Ross, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view of "old" colony showing very heavy wall structure and presence of few zooecial cavities, sample C1-10a; 2, longitudinal view showing very dark laminate zooecial wall structures in exozone, sample C1-10c; 3, oblique transverse view, sample C1-15b; 4, transverse view of explanate colony showing budding pattern of zooecia, zooecial boundaries, rows of acanthopores in the exozone, and median laminae, sample C1-5c; 5, oblique transverse view showing nature of zooecial boundaries, rings of acanthopores surrounding individual zooecial openings, and shape of zooecial cavities with few diaphragms, sample C1-16a; 6, longitudinal view showing laminate wall structure between adjacent zooecia, sample CG-13.

PLATE 5



x 63

1



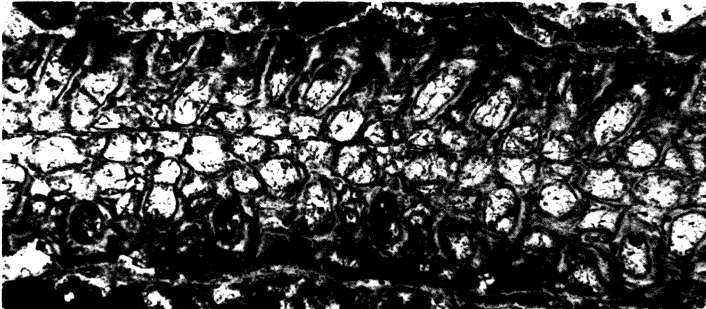
x 63

2



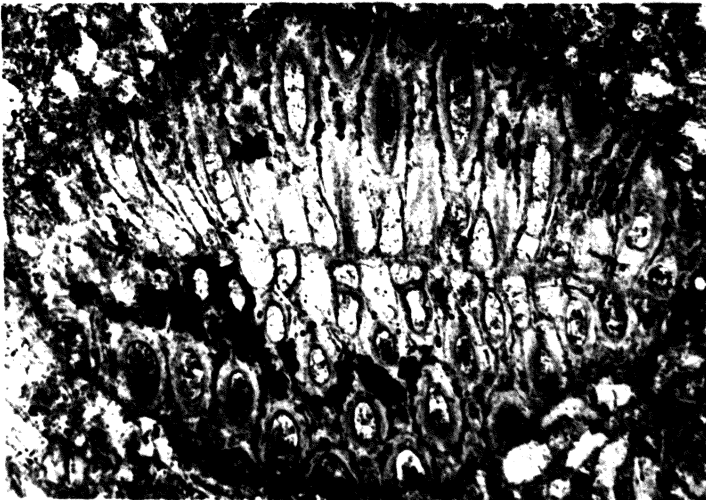
x 25

3



x 63

4



x 63

5



x 63

6

Explanation of Plate 6

Figs. 1-3. Chazydictya explanata n. sp., Lincolnshire Limestone, Harrisonburg, Virginia. 1, Oblique view of lateral margin of colony showing few zooecial cavities, heavily laminate wall structure penetrated by dark laminate acanthopores that extend from near the median lamina to the exterior surface; 2, transverse view showing alternate budding pattern of zooecia along laminate median lamina, character of zooecial walls, and shape of zooecia with numerous diaphragms; 3, transverse view showing arrangement of zooecia along median lamina, numerous diaphragms crossing zooecial cavities and well defined rings of acanthopores surrounding zooecial cavities.

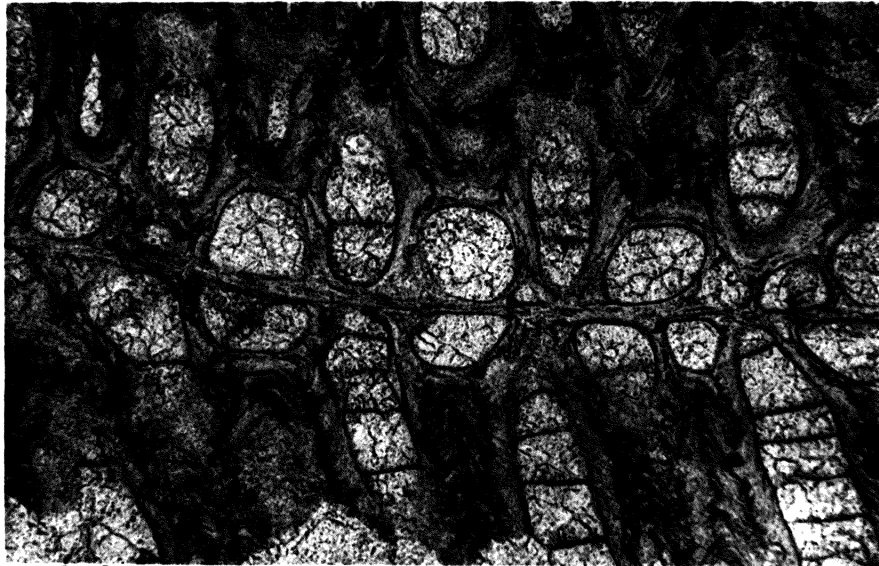
All specimens are from sample C1-36.

PLATE 6



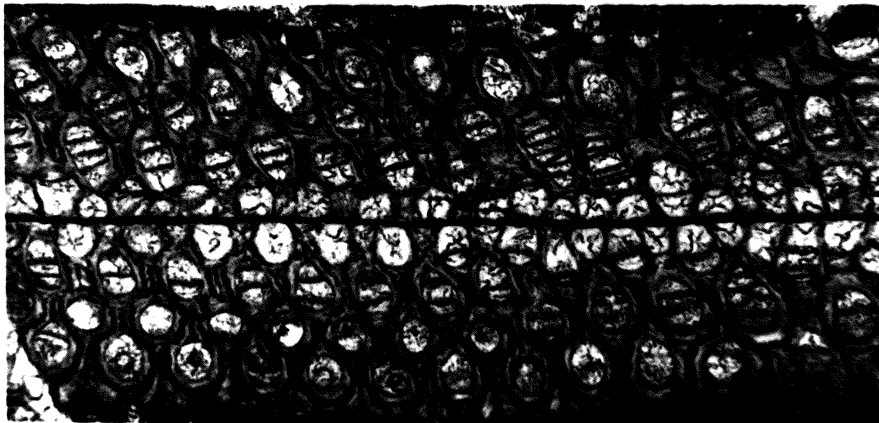
x63

1



x160

2



x63

3

Explanation of Plate 7

Figs. 1-3. Chazydictya explanata n. sp., Lincolnshire Limestone, Harrisonburg, Virginia. 1, Slightly oblique longitudinal view showing zooecial wall structure, shape of zooecial cavities, rings of acanthopores around zooecial openings, and numerous diaphragms in zooecial cavities; 1b, enlarged view of 1a showing distinct outer zooecial wall lining, diaphragms in zooecial cavities, and laminate zooecial walls; 2, oblique longitudinal view showing shape of zooecial cavities, numerous diaphragms, and very dark laminate acanthopores; 3, tangential view through a maculate area with poorly developed zooecia, rings of acanthopores are distinct about individual zooecial openings.

All specimens are from sample C1-36.

PLATE 7



x63

1a



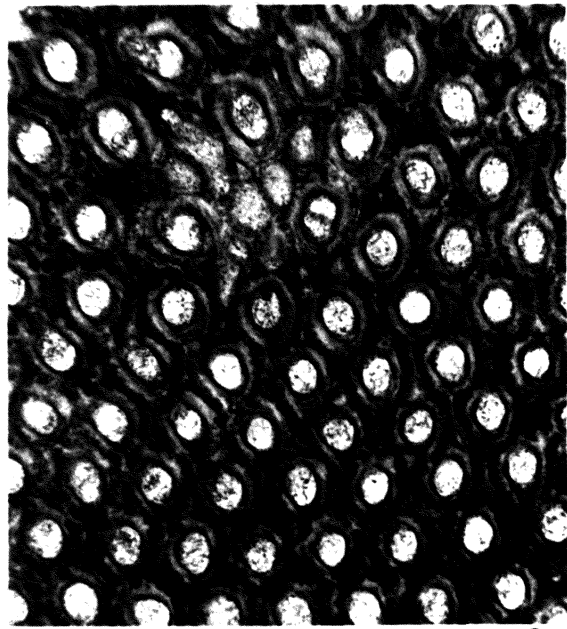
x160

1b



x63

2



x63

3

Explanation of Plate 8

Figs. 1-2. Chazydictya explanata n. sp., Lincolnshire Limestone, Harrisonburg, Virginia. 1a, longitudinal view showing well defined funnel cystiphragm structures within zooecial cavities; 1b, enlarged view of 1a showing distinct laminate wall structure and partially developed funnel cystiphragm structure; 1c, enlarged view of 1a showing distinct, well developed funnel cystiphragm structure within zooecial cavity; 2, transverse view showing rings of acanthopores about zooecial openings.

All specimens are from sample C1-36.

PLATE 8



x 160

1a



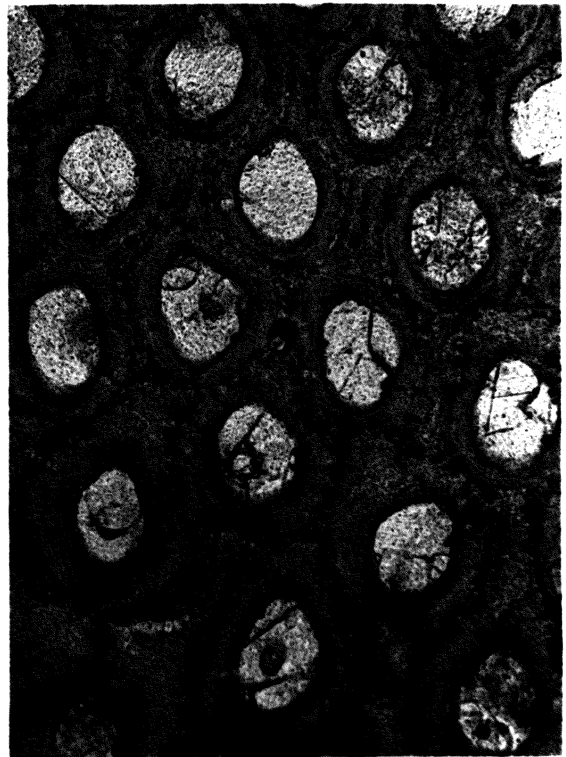
x 400

1b



x 400

1c



x 160

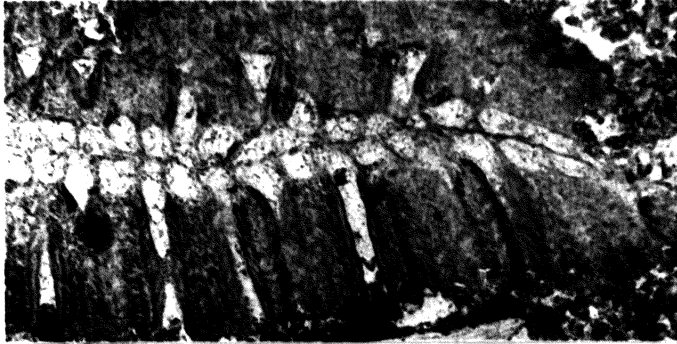
2

Explanation of Plate 9

Figs. 1a-3b. Graptodictya perelegans (Ulrich), Lincolnshire Limestone, Harrisonburg, Virginia. 1a, Transverse view showing narrow endozone, wide exozone with distinctly laminate, "M" shaped zooecial wall structure, and slight zigzag-shape of median lamina; 1b, enlarged view showing shape of zooecial cavities, and laminate zooecial walls; 2, oblique tangential view showing concentrically laminate zooecial walls (small black dots are air bubbles); 3a, longitudinal view showing continuous laminae between zooecial cavities, very narrow endozone, wide exozone, and abrupt curve of the zooecia toward exterior of the colony; 3b, enlarged view of 3a showing shape of zooecial cavity and laminate zooecial walls.

All specimens are from sample C1-38.

PLATE 9



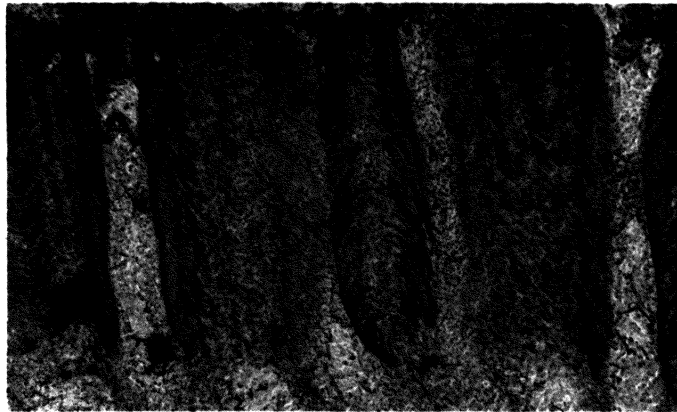
x63

1a



x160

2



x160

1b



x63

3a



x160

3b

Explanation of Plate 10

Figs. 1-3. Graptodictya elegantula (Hall). Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing shape of zoarium, zigzag-shape of median lamina, narrow endozone and exozone, and the distinct "M" shape of the laminate zooecial walls, sample Cl-38b; 2, transverse view showing zigzag-shape of median lamina, shape of zooecial cavities adjacent to the median lamina, and dark laminate exozone with distinct "M" shape, sample Cl-38; 3, tangential section showing ovate zooecial openings, concentric laminae, and small pustules surrounding zooecial openings, sample Cl-38b.

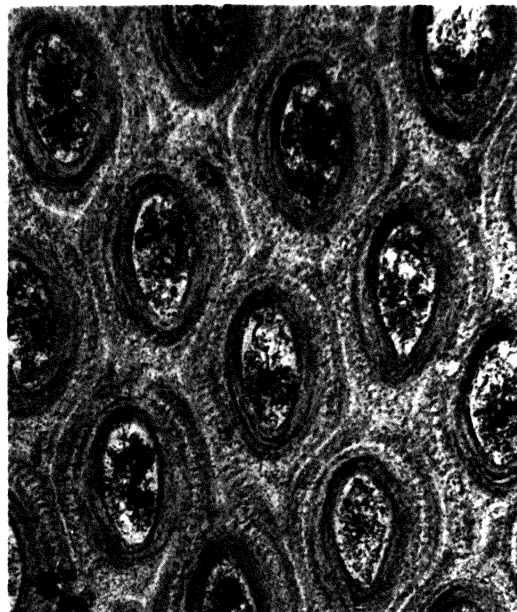
Figs 4a-5. Stictoporellina? Nekhoroshev, Lincolnshire Limestone, Harrisonburg, Virginia. 4a, transverse view showing budding pattern of zooecia along nearly straight median lamina, well defined laminae of zooecial walls, and zooecial boundaries in exozone, sample CG-14; 4b, longitudinal view showing flexuous median lamina, shape of zooecial cavities, and laminate character of zooecial walls, sample CG-14; 5, oblique transverse view showing an occasional diaphragm, sample Cl-38.

PLATE 10



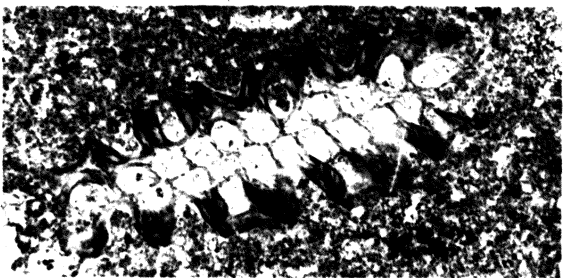
x63

1



x160

3



x63

2



x63

4 b



x63

4 a



x63

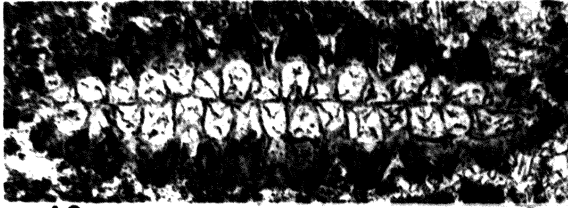
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Explanation of Plate 11

Figs. 1a-2. Graptodictya elegantula (Hall), Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing zigzag-shape of median lamina, zooecial budding pattern along the median lamina, and the well defined "M"-shaped zooecial wall laminae, sample C1-38; 1b, enlarged view of 1a showing distinct "M"-shaped wall laminae, sample C1-38; 2, transverse view showing pattern of zooecial wall laminae in exozone, sample C1-38.

Figs. 3-7. Stictopora fenestrata Hall, Lincolnshire Limestone, Harrisonburg, Virginia. 3, oblique transverse view; 4, oblique transverse view showing laminate zooecial walls and zooecial boundaries in exozone, sample C1-H; 5, transverse view showing well defined median lamina, rectangular budding pattern of zooecia along the median lamina, and rounded lateral margins of the colony, sample C1-4a; 6, transverse view of basal portion of colony showing very heavy laminate wall structure, few zooecial cavities along lateral margins, and well defined median tubulae, sample CG-14; 7, longitudinal view showing laminate zooecial walls in exozone and occasional diaphragms present in zooecial cavities, sample C1-H.

PLATE II



x63

1a



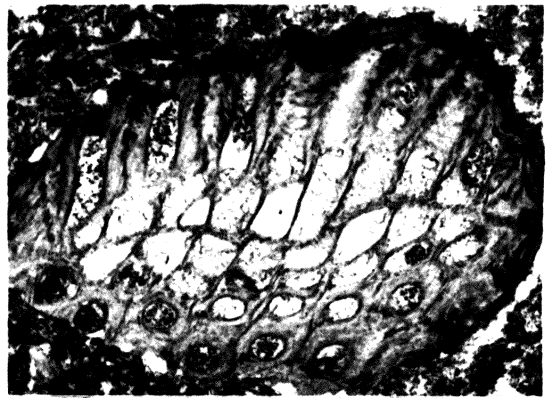
x160

2



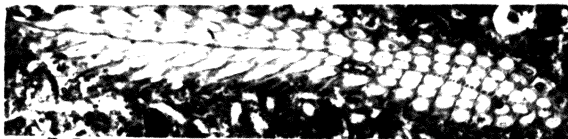
x250

1b



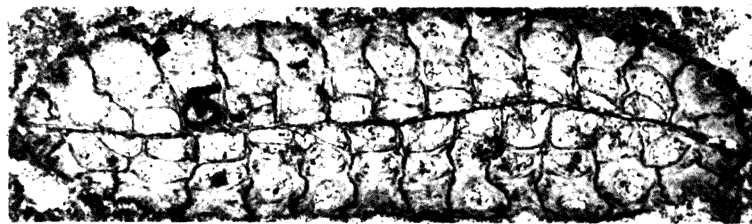
x63

4



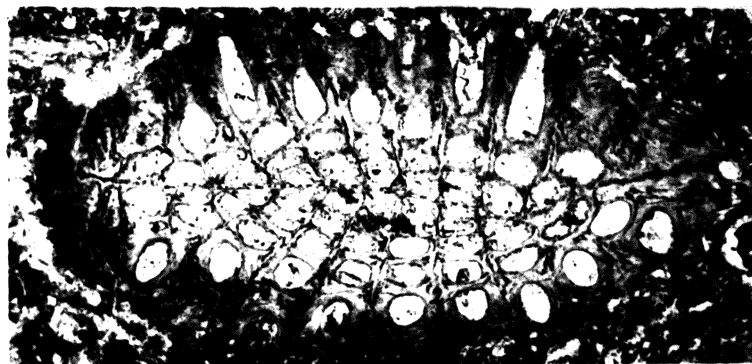
x25

3



x63

5



x63

6



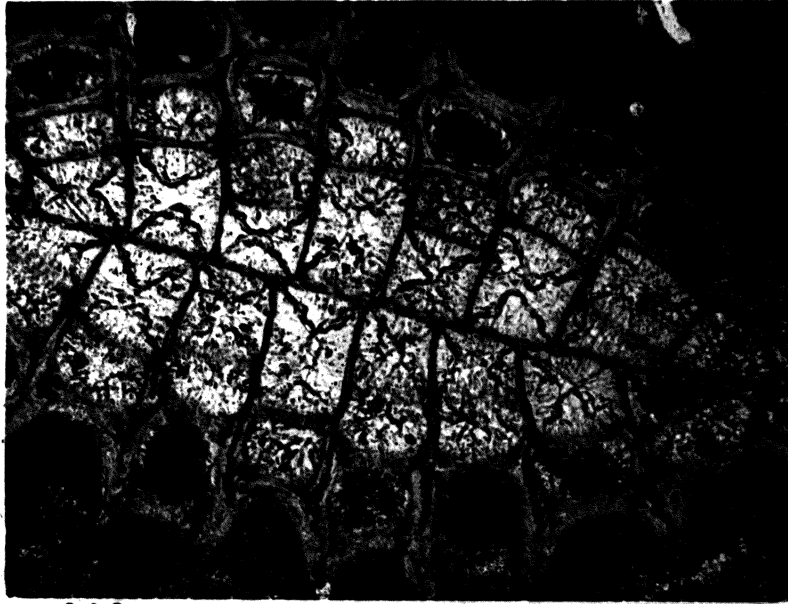
x63

7

Explanation of Plate 12

Figs. 1-5. Stictopora fenestrata Hall, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing rectangular budding pattern of zooecia along the median lamina, median tubulae, distinct zooecial boundaries, and thickening of zooecial walls in the exozone, sample C1-14a; 2, longitudinal view showing laminate zooecial walls, and flexuous median lamina, sample C1-38; 3, longitudinal view showing character of median lamina and laminate zooecial walls, sample C1-14a; 4, longitudinal view showing flexuous median lamina, sample C1-H; 5, tangential view showing zooecia aligned in longitudinal ranges with rings of acanthopores surrounding zooecial openings, sample C1-38.

PLATE 12



x160

1



x63

2



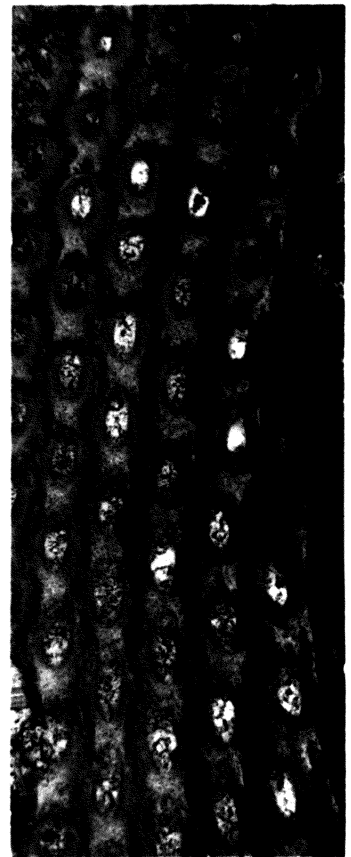
x160

3



x25

4



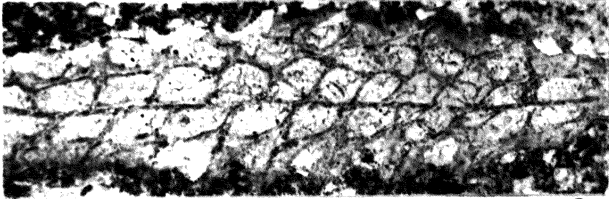
x63

5

Explanation of Plate 13

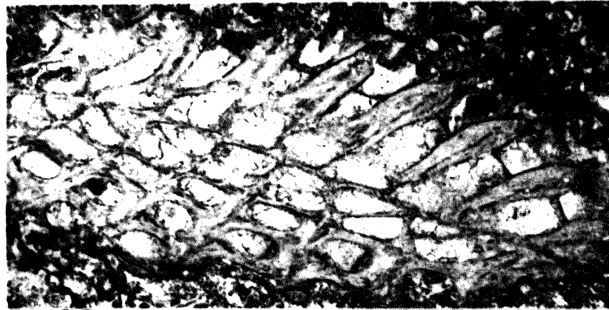
Figs. 1-6. Stictopora fenestrata Hall, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing median lamina with tubulae, sample Cl-E; 2, oblique view showing laminate zoecial walls, very thin diaphragms that abut or adjoin zoecial cavity lining, and median lamina, sample Cl-H; 3, oblique cut through median lamina showing distinct median tubulae, sample Cl-K; 4, oblique section showing laminate zoecial walls and median lamina, sample Cl-L; 5, transverse view showing median lamina with tubulae, distinct zoecial boundaries, and thickly laminate zoecial walls in the exozone, sample Cl-E; 6, oblique section through median lamina showing zooecia arranged in distinct longitudinal ranges, sample Cl-H.

PLATE 13



x 63

1



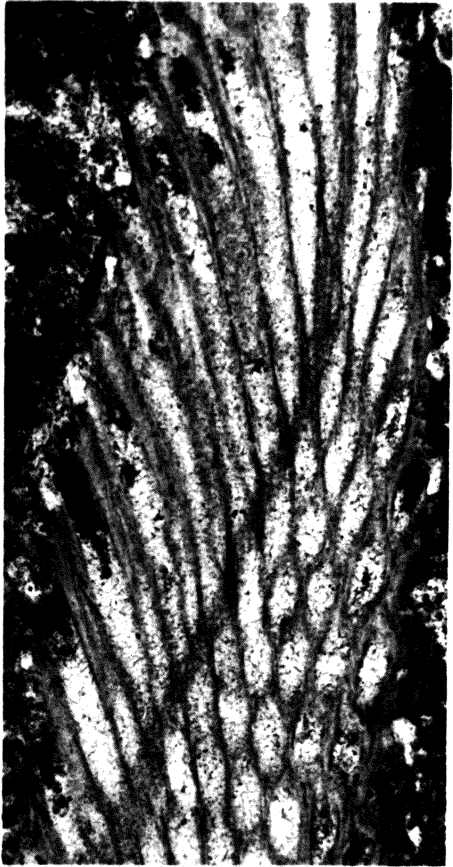
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2



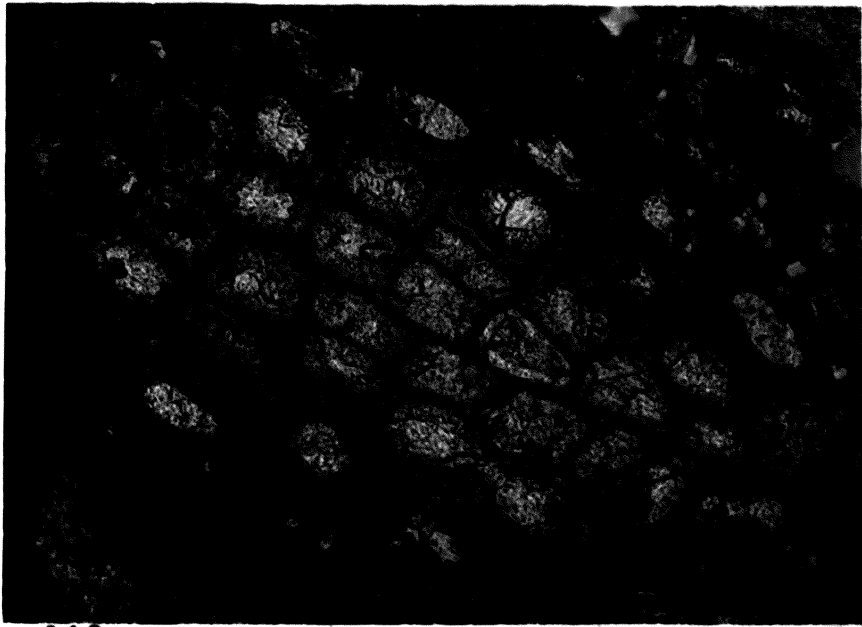
x 63

3



x 63

4



x 160

5



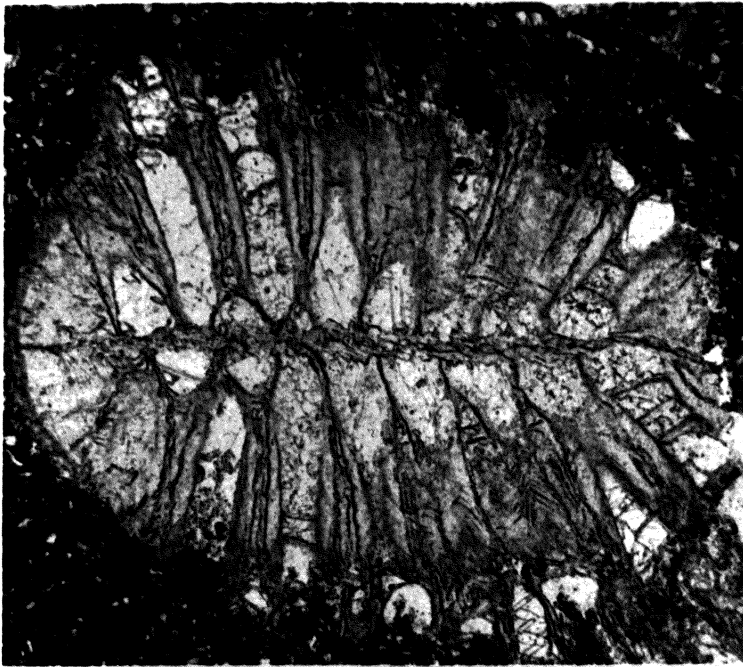
x 25

6

Explanation of Plate 14

Figs. 1-4. Eopachydictya gregaria Ross, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view of ovate zoarium showing zooecia with few disphragms, very limited tabulate interspace areas, distinct zooecial boundaries in exozone, distinct range partitions between adjacent zooecial cavities, and median lamina with tubulae, sample CG-22b; 2, longitudinal view showing zooecia, their boundaries, limited tabulate interspace areas, some poorly developed diaphragms in zooecial cavities, and flexuous nature of the median lamina, sample CG-3a; 3, oblique tangential view showing ovate zooecial openings and zooecial boundaries, sample CG-22b; 4, enlarged tangential view showing circlates of acanthopores about zooecial cavities, sample CG-22b.

PLATE 14



x63

1



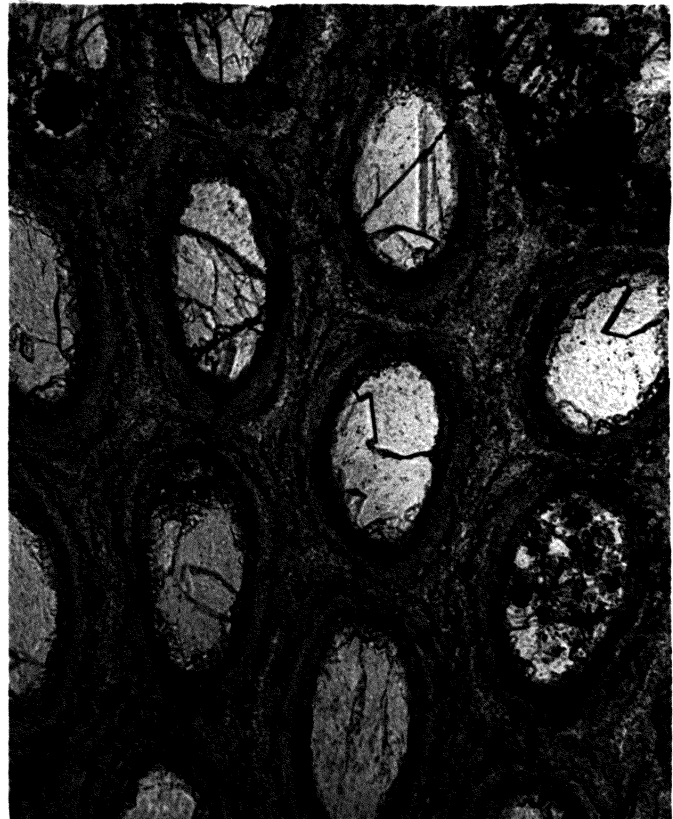
x63

2



x63

3



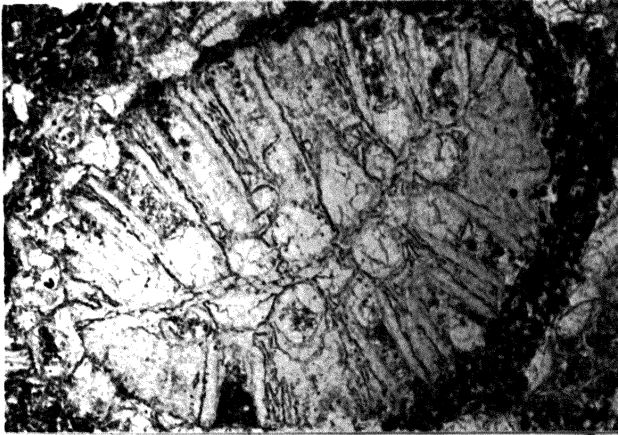
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4

Explanation of Plate 15

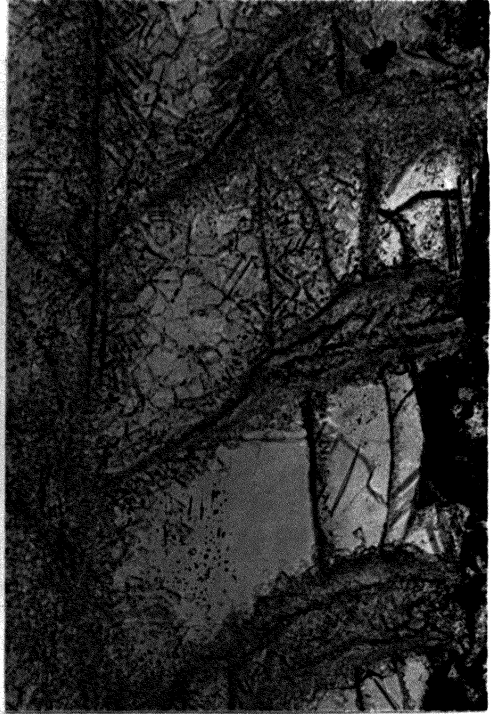
Figs. 1-5. Eopachydictya gregaria Ross, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing median lamina with tubulae, shape of zooecial cavities, zooecial boundaries, and laminate zooecial walls in exozone, sample C1-H; 2, longitudinal view showing shape of zooecial cavities with diaphragms, and zooecial and range boundaries, sample CG-22b; 3, transverse view showing median lamina with distinct tubulae, sample C1-H; 4, transverse view showing alternate budding pattern of zooecia along median lamina, distinct range and zooecial boundaries in some zooecia, and few diaphragms, sample C1-14; 5, slightly oblique longitudinal view showing shape of zooecia, zooecial wall structure, and median lamina, sample CG-22.

PLATE 15



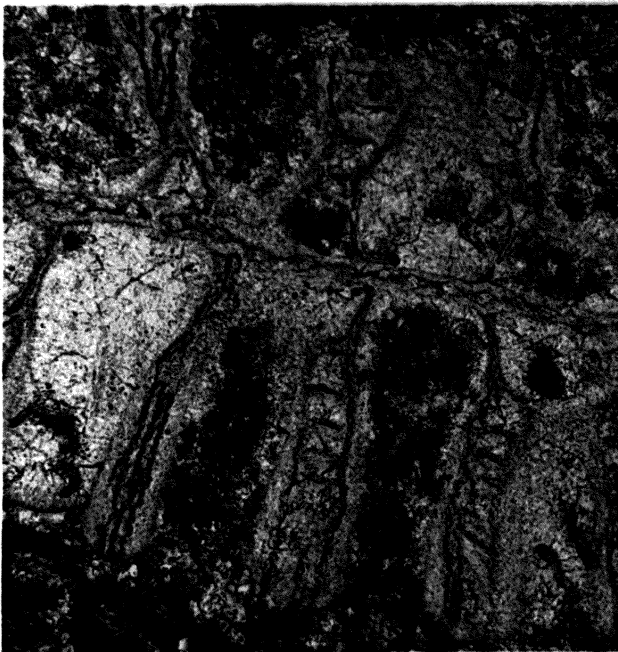
x63

1



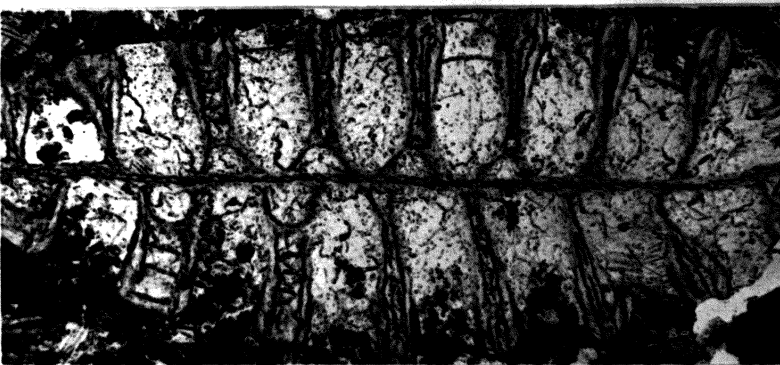
x160

2



x160

3



x63

4



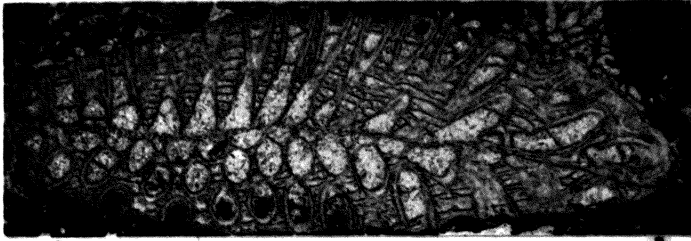
x63

5

Explanation of Plate 16

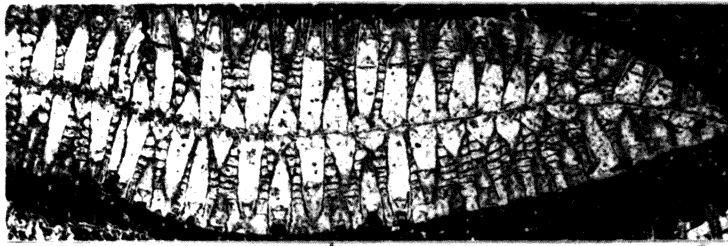
Figs. 1-6. Athrophragma sheldonensis (Ross), Lincolnshire Limestone, Harrisonburg, Virginia. 1, Oblique transverse view showing shape of colony, median lamina, and well developed tabulate zooecial interspace, note some diaphragms in zooecial cavities, sample CG-13; 2, transverse view showing alternate budding pattern of zooecia along the median lamina, well developed tabulate interspace, very narrow endozone, and the beginning of the exozone marked by the base of the tabulate interspace areas, sample CG-14; 3, longitudinal view showing median lamina, very extensively developed cystose tabulate interspace areas, and diaphragms in zooecial cavities, sample CG-14; 4, transverse view showing median lamina with well defined tubulae, sample Cl-D; 5, transverse view showing shape of zooecial cavities, median lamina with tubulae, bifurcating zooecial boundaries, distinctly laminate zooecial walls in exozone, and well developed tabulate interspace areas, sample CG-13; 6, longitudinal view showing flexuous median lamina, shape of zooecial cavities, zooecial boundaries, and tabulate interspace areas, sample CG-13.

PLATE 16



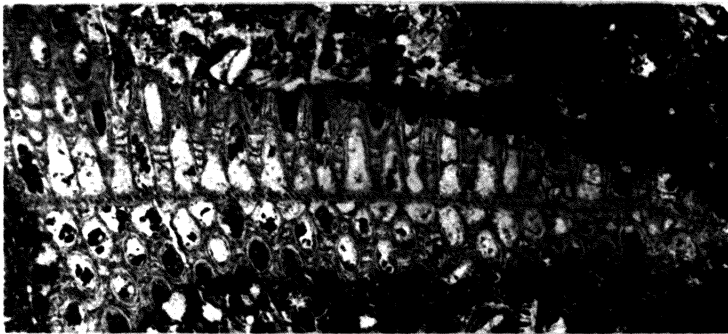
x25

1



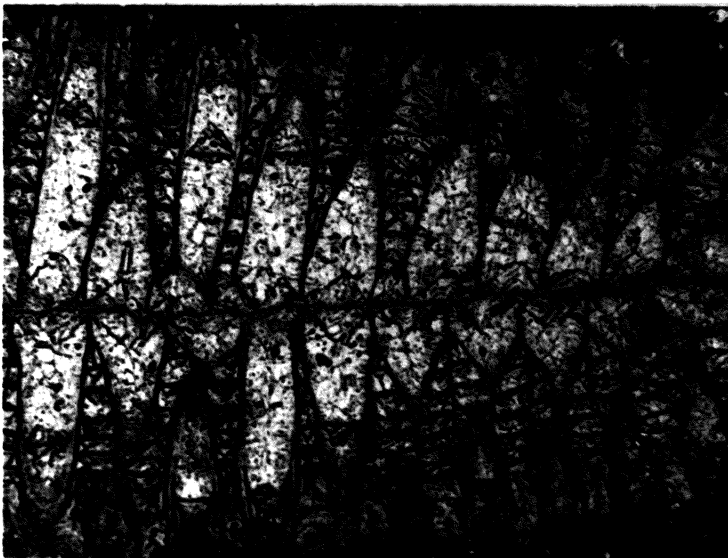
x25

2



x25

4



x63

5



x25

3



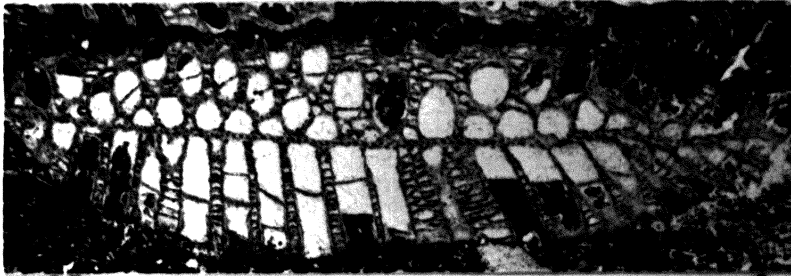
x63

6

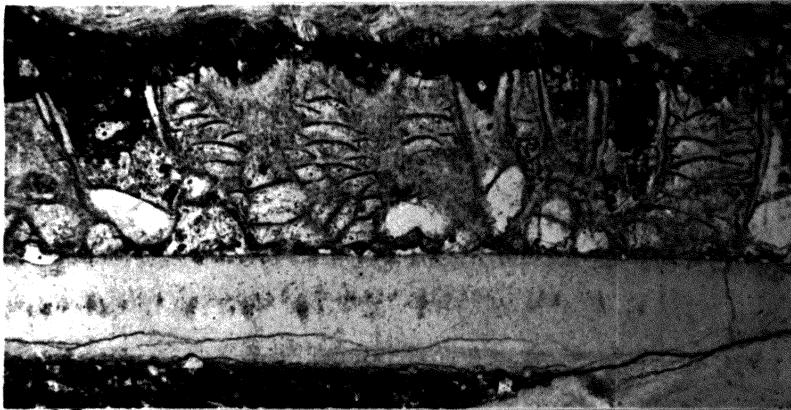
Explanation of Plate 17

Figs. 1-6. Athrophragma sheldonensis (Ross), Lincolnshire Limestone, Rockingham County, Virginia. 1, Oblique transverse view showing shape of zooecial cavities, median lamina with tubulae, and tabulate interspace areas surrounding zooecial openings, sample CG-14; 2, encrusting form showing poorly developed basal lamina, unusual budding pattern of zooecia, and cystose interspace areas, sample CG-22b; 3, slightly oblique longitudinal view showing median lamina and tubulae, very narrow zooecial walls in endozone, tabulate and cystose interspace areas, and diaphragms in zooecial cavities, sample CG-14; 4, oblique transverse and deep tangential views showing shape of zooecial cavities, median lamina with tubulae, distinct zooecial boundaries in both transverse and deep tangential views, tabulate interspace areas, and diaphragms in zooecial cavities, CG-19; 5, longitudinal view of lateral edge of colony showing shape of zooecia, median lamina and tabulate interspace areas, sample CG-3a; 6, shallow tangential view showing alignment of zooecia, their boundaries, and laminate zooecial interspaces, sample CG-13.

PLATE 17



x25



x63



x25

3



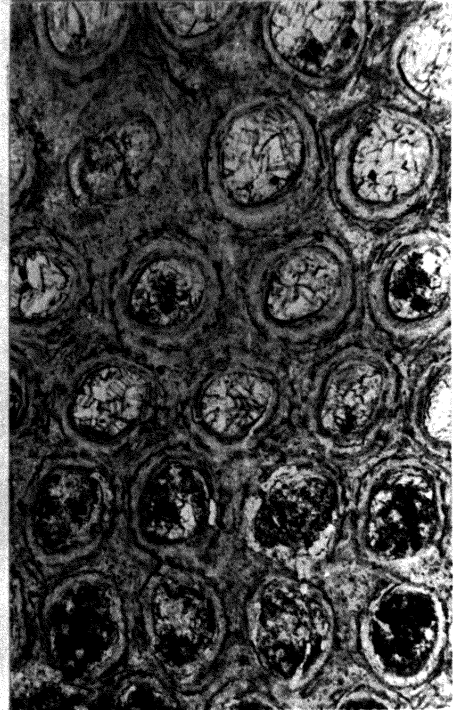
x63

4



x63

5



x63

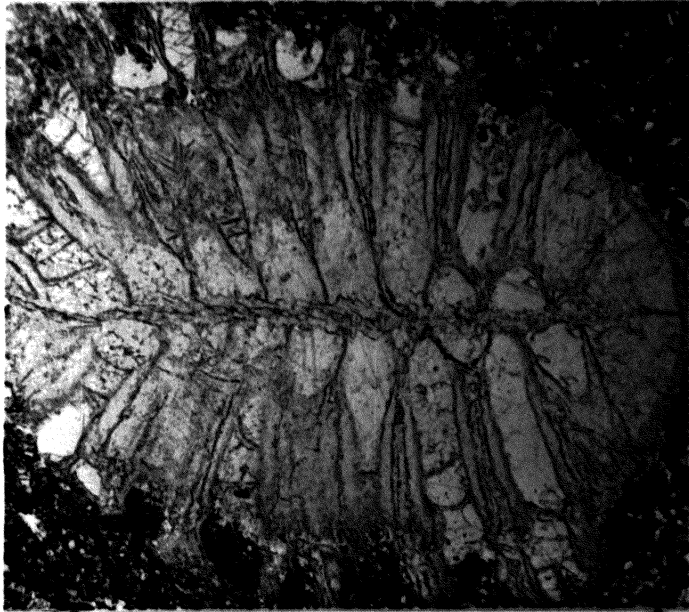
6

Explanation of Plate 18

Fig. 1. Eopachydictya gregaria (Ross), Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing ovate zoarium, shape of zooecia, median lamina with tubulae, zooecial and range boundaries, few diaphragms present in zooecial cavities, and poorly developed tabulate interspace areas, sample CG-22b.

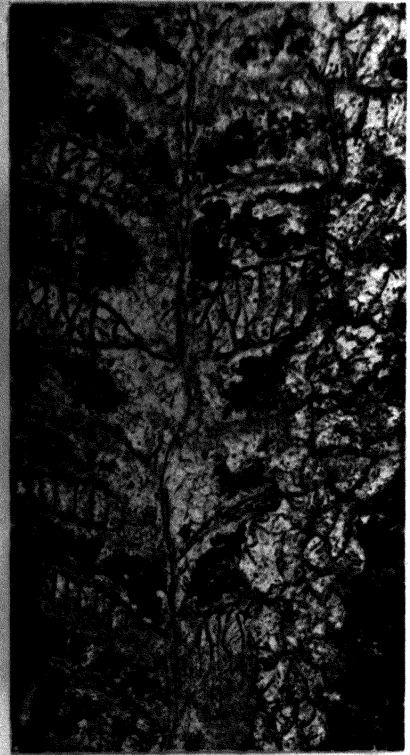
Figs. 2-4. Athropragma sheldonensis (Ross), Lincolnshire Limestone, Harrisonburg, Virginia. 2, Longitudinal view showing flexuous median lamina, distinct zooecial boundaries, and tabulate and cystose interspace areas, sample C1-D; 3a, transverse view showing shape of zooecia, median lamina with tubulae, and tabulate interspace areas, sample C1-L; 3b, enlarged view of 3a showing median lamina with distinct median tubulae, sample C1-L; 4, oblique section through median lamina showing median tubulae, and tabulate interspace areas surrounding zooecial cavities, sample CG-19.

PLATE 18



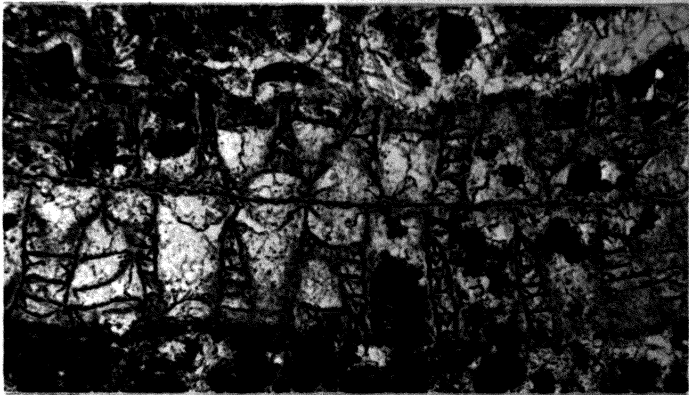
x63

1



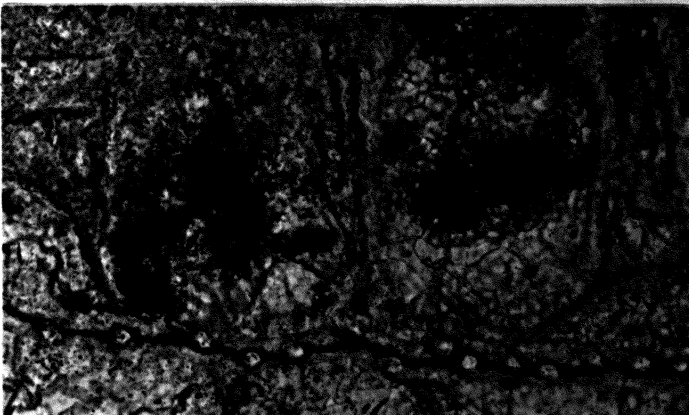
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2



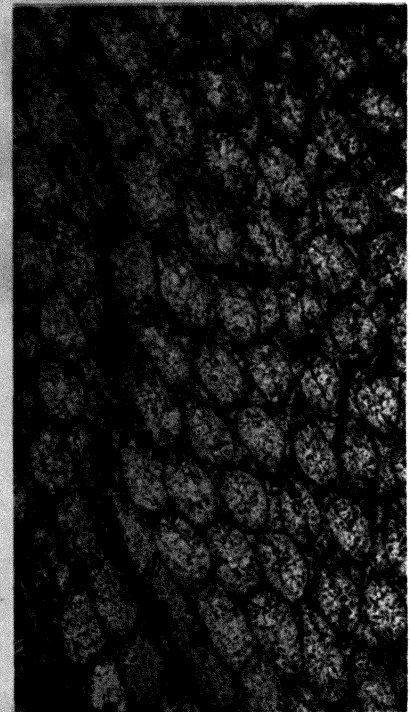
x63

3a



x250

3b



x63

4

Explanation of Plate 19

Figs. 1-3. Ottoseetaxis Bassler, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Oblique transverse view showing median lamina that does not extend to lateral margins of zoarium, distinct zooecial boundaries, and laminate wall structure, note polygonal shape of zooecial cavities, sample C1-I; 2, deep tangential view parallel to median lamina showing laminate wall structure, polygonal shape of zooecia, and few diaphragms, sample C1-14; 3, longitudinal section showing median lamina, unique shape of zooecial cavities, distinct zooecial boundaries, and occasional diaphragms in zooecial cavities, sample C1-14.

Fig. 4. Ulrichostylus? Bassler, Lincolnshire Limestone, Harrisonburg, Virginia. 4, Transverse view showing radial growth plan, central axis, and shape of zooecial cavities, sample C1-I.

PLATE 19



x63

1



x63

2



x63

3



x63

4

Explanation of Plate 20

Figs. 1-6. Ulrichostylus Bassler, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse section showing radial growth plan and shape of zooecia, sample C1-C; 2, longitudinal view through central axis (lower part of photo), showing diaphragms present in zooecial cavities, and zooecial wall structure, sample C1-D; 3, transverse view of young colony, sample C1-D; 4, transverse view showing radial growth plan of zooecia about the central axis, laminate zooecial walls with intermittent boundaries, sample C1-C; 5, transverse view of mature colony showing budding pattern and shape of zooecia; zooecial walls distinct with a dark line forming zooecial boundary; zooecial walls distinctly laminate; zooecia bud alternately about central axis, sample C1-D; 6, transverse view showing growth plan and dark zooecial boundaries in exozone, sample C1-D.

PLATE 20



x63

1



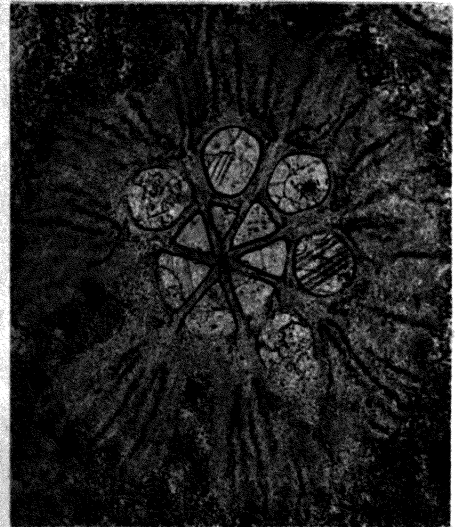
x63

2



x160

3



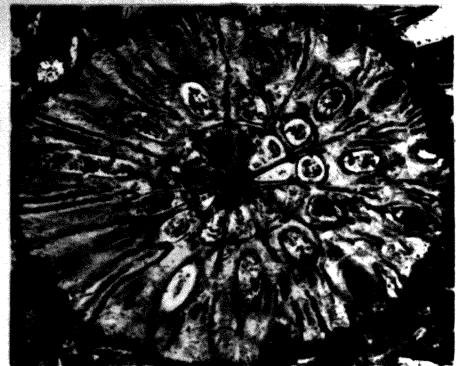
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4



x160

5



x63

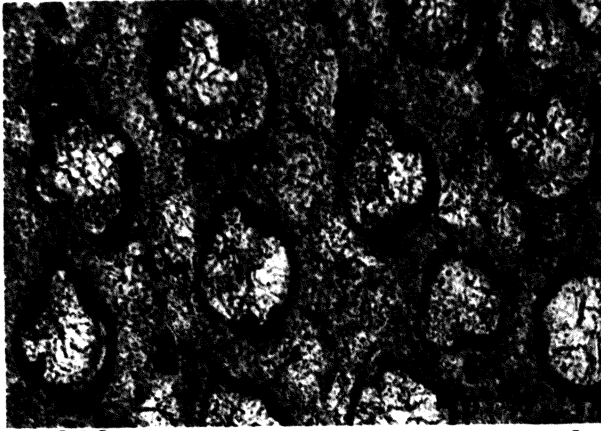
6

Explanation of Plate 21

Figs. 1-3. Constellaria? Dana, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing shape of zooecial cavities and lunarial structures, sample CG-19; 2, longitudinal view showing shape of zooecia and numerous diaphragms in zooecia, sample CG-19; 3, oblique view showing arrangement of zooecia and lunarial structures, sample CG-19.

Figs 4-6. Constellaria, cf. C. islensis Ross, Lincolnshire Limestone, Harrisonburg, Virginia. 4, Longitudinal view in peripheral region through stellate monticule structure, sample C1-32; 5, longitudinal view showing relation of mesopores and zooecia, sample C1-15; tangential view showing clusters of mesopores, sample C1-32.

PLATE 21



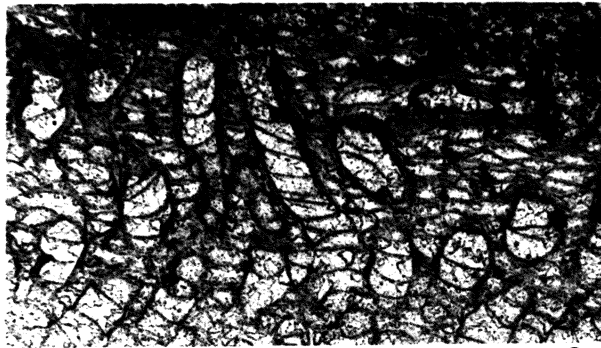
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1



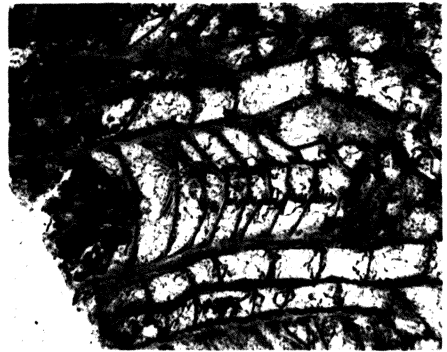
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2



x63

3



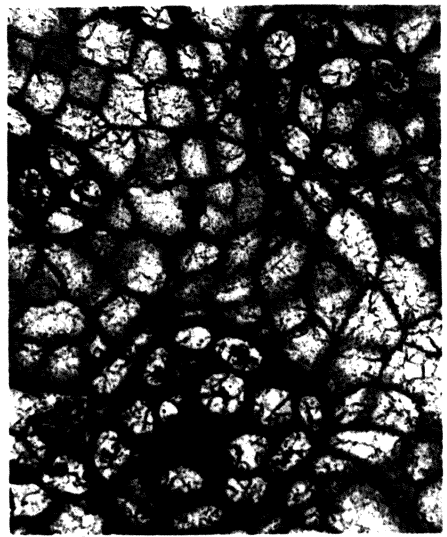
x63

4



x63

5



x63

6

Explanation of Plate 22

Fig. 1 Ceramophylla, cf. C. vaupeli (Ulrich), Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view through a hollow ramose colony; 2, longitudinal view showing basal laminae, shape of zooecial cavities, laminate zooecial walls, and prominent acanthopores; 3, tangential view showing ovate zooecial openings with distinct lunarial structures, large acanthopores and mesopores; 4, enlarged transverse view showing basal laminae, zooecial budding pattern, and laminate zooecial walls.

All views of specimens are from sample C1-19a.

PLATE 22



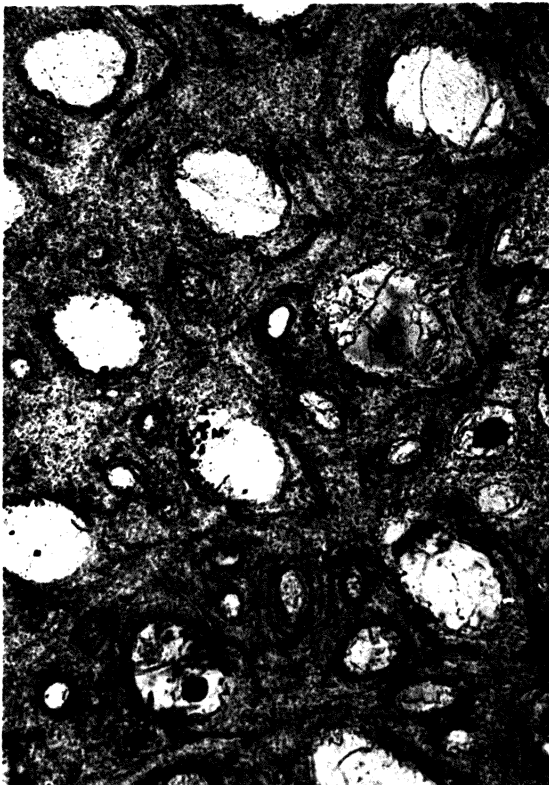
x25

1



x160

2



x160

3



x160

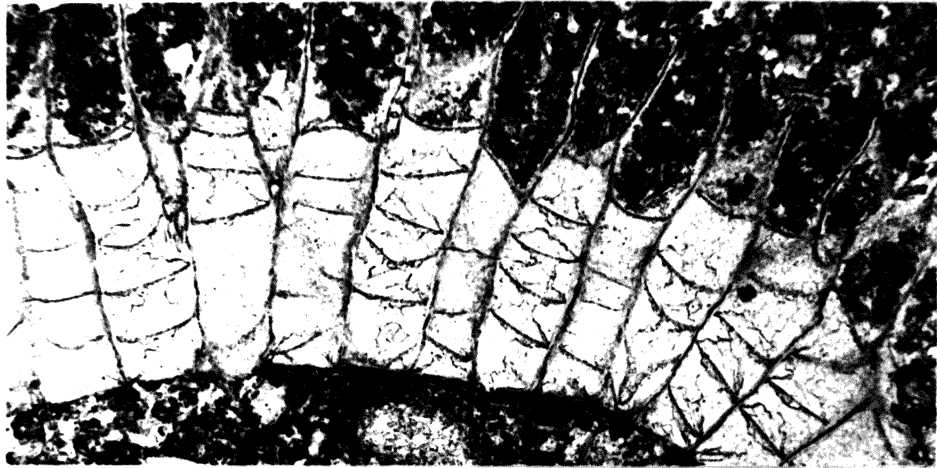
4

Explanation of Plate 23

Fig. 1. Dianulites? Eichwald, Lincolnshire Limestone, Harrisonburg, Virginia. 1, View of encrusting form showing basal lamina, shape of zooecial cavities with numerous diaphragms, and very thin zooecial walls, sample Cl-14.

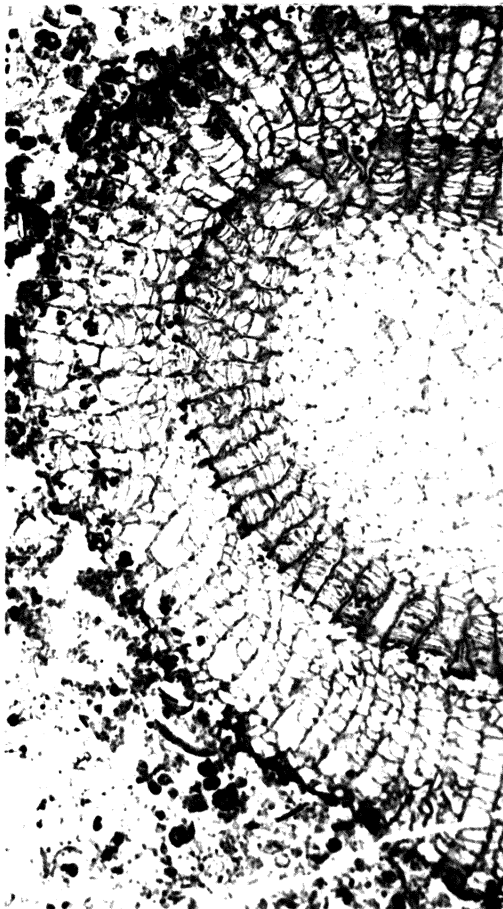
Figs. 2a, 2b. Monticulipora cf. M. mammulata d'Orbigny and Eridotrypa cf. E. crownensis Ross, Lincolnshire Limestone, Harrisonburg, Virginia. 2a, Transverse view of Monticulipora colony encrusting an Eridotrypa colony showing shape of colonies and zooecia; 2b, enlarged view of 2a showing distinct cystiphragms in zooecia of Monticulipora and closely spaced diaphragms in zooecia of Eridotrypa, sample Cl-L.

PLATE 23



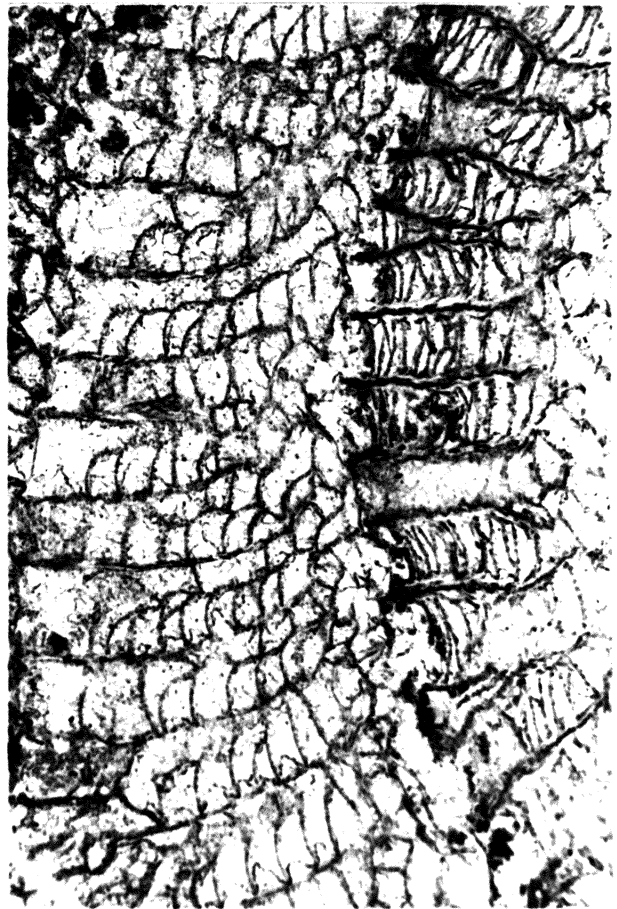
x63

1



x25

2a



x63

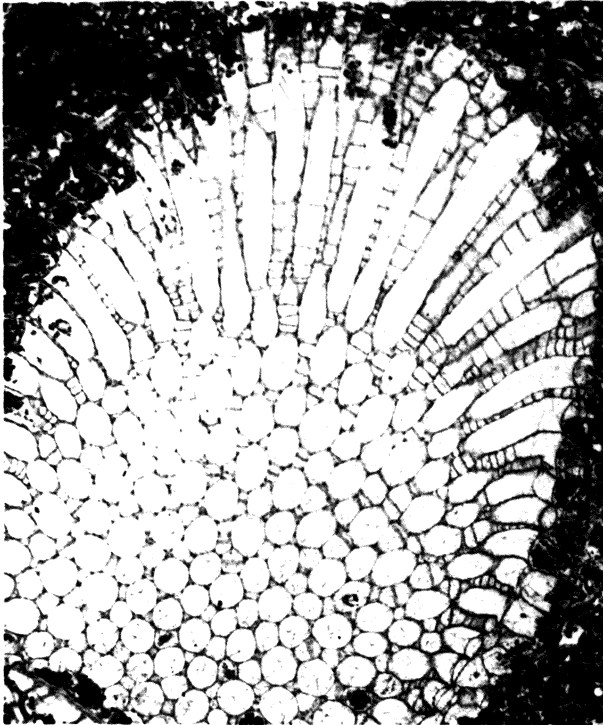
2b

Explanation of Plate 24

Figs. 1-4. Hallopora cf. H. ovata (McKinney), Lincolnshire Limestone, Harrisonburg, Virginia. 1, Oblique section showing zooecia and tabulate mesopores in peripheral portion of colony, circular zooecial cavities surrounded by tabulate mesopores; 2, longitudinal view showing arrangement of zooecial cavities and tabulate mesopores in endozone; mesopores become "walled-over" in exozone; zooecial walls thickly laminate in exozone with distinct zooecial boundaries; 3, longitudinal view showing shape of zooecia in exozone; zooecial walls bifurcate forming wall structures of mesopores; 4, oblique tangential view showing thickly laminate integrate wall structure, many large mesopores in the deeper part of the section, (upper center), and few small mesopores in the more shallow region, (bottom center).

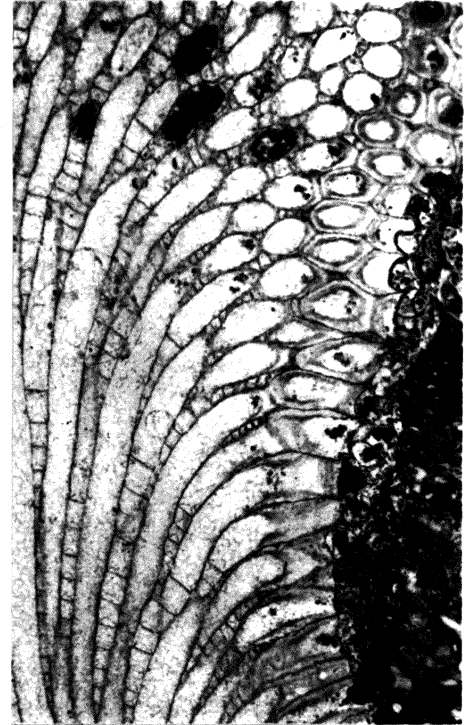
All views of specimens are from sample C1-H.

PLATE 24



x25

1



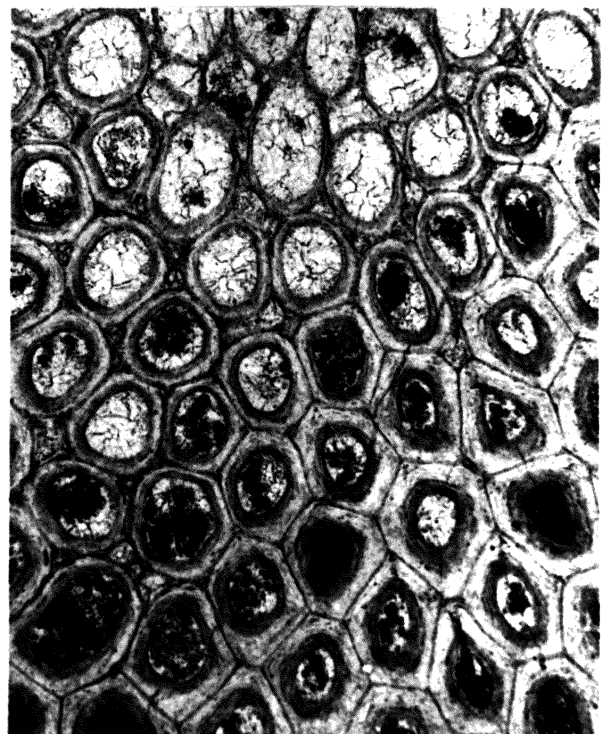
x63

2



x63

3



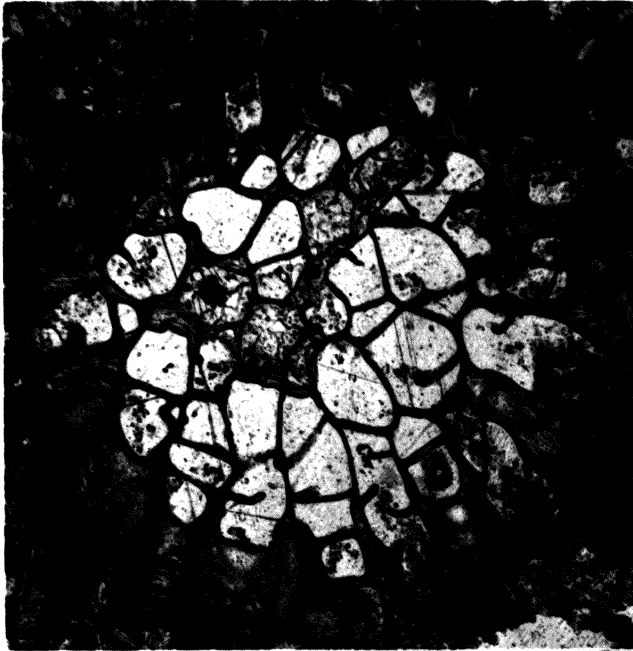
x63

4

Explanation of Plate 25

Figs. 1-2c. Hemiphragma cf. H. pulcra Loeblich, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing thickly laminate zooecial walls in exozone, configuration of zooecia in endozone, prominent acanthopores, and hemiphragms, sample Cl-15; 2a, longitudinal view showing irregular zooecial pattern, thickly laminate zooecial walls, diaphragms, hemiphragms, and distinct acanthopores, sample Cl-H; 2b, tangential view showing irregular zooecial shape, numerous acanthopores and hemiphragms; note "brown-bodies" in some zooecial cavities, sample Cl-H; 2c, oblique section through curved branch showing growth pattern of zooecia, hemiphragms and acanthopores.

PLATE 25



x63



x63

2a



x63

2b



x25

2c

Explanation of Plate 26

Figs. 1-4. Hemiphragma cf. H. irrasum Ulrich, Lincolnshire Limestone, Harrisonburg, Virginia. 1, Transverse view showing laminate zooecial walls in exozone, acanthopores, and development of prominent hemiphragms from both sides of zooecial cavities that bend slightly inward toward endozone; 2, enlarged transverse view showing laminate character of zooecial walls, zooecial lining, and structure of hemiphragms; 3, tangential view showing irregular shape of zooecial cavities, hemiphragms, and acanthopores; 4, longitudinal view showing shape of zooecia, laminate zooecial wall structure, some hemiphragms in the endozone, and occasional "brown-bodies."

All views of specimens are from sample C1-32.

PLATE 26



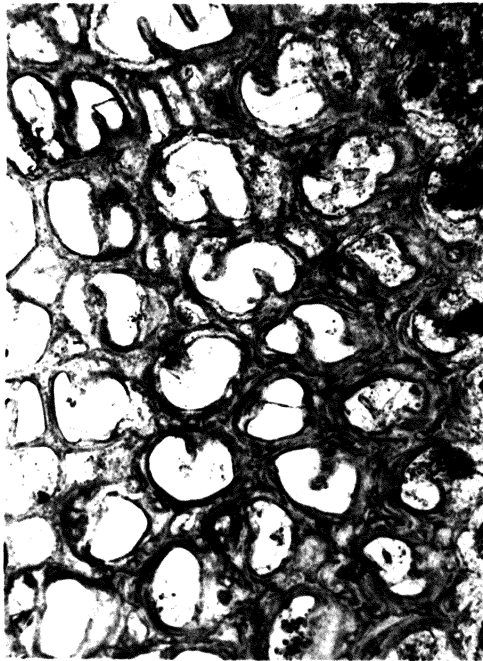
x63

1



x63

2



x63

3



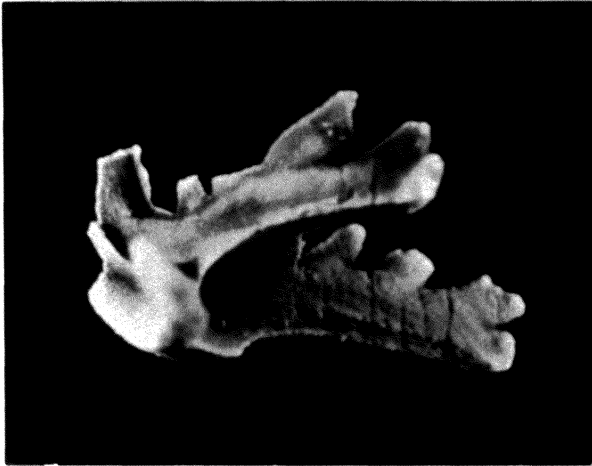
x160

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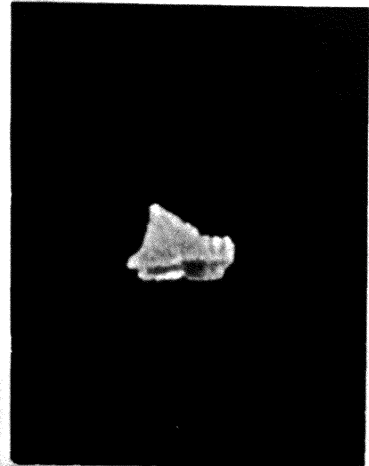
Explanation of Plate 27

Figs. 1-4. Conodonts from the Beekmantown interval of the Park View section, Harrisonburg, Virginia. 1, Tetraprioniodus Lindström, sample C2-19a; Histiodela Harris, sample C2-23; Multioistodus lateralus Cullison, sample C2-21; Multioistodus tridens Cullison, sample C2-22.

PLATE 27



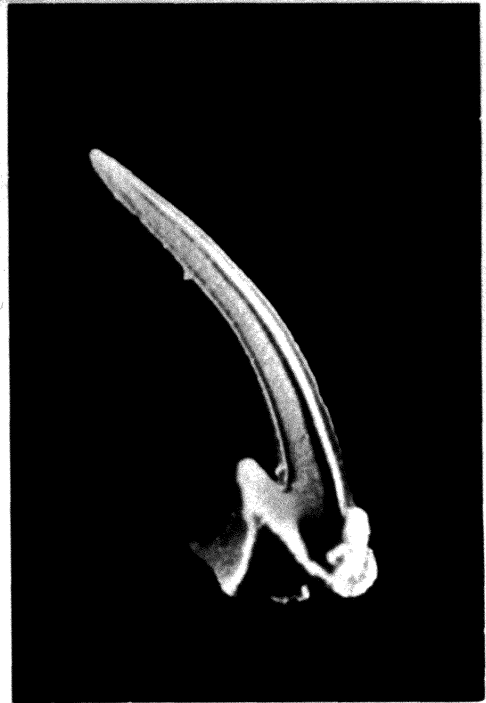
1



2



3



4

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ABSTRACT

The Middle Ordovician Lincolnshire Limestone in Rockingham County, Virginia, contains an abundant, diverse bryozoan fauna. The Lincolnshire is represented by two facies. The Rockbridge facies is a bryozoan-brachiopod biomicrite containing ramose trepostomes, bifoliate cryptostomes, and brachiopods. The Murat facies is a bryozoan-pelmatozoan biosparite containing massive and encrusting trepostomes, some robust, well calcified cryptostomes, and pelmatozoan fragments. In the Rockbridge facies, black chert nodules are abundant, but in the Murat facies, chert is scarce. The Lincolnshire is part of a transgressive carbonate sequence of Middle Ordovician age. Sediments of the Rockbridge facies were deposited in a shallow, protected subtidal environment. Sediments of the Murat facies were deposited in a shallow, but higher energy environment.

Bifoliate Cryptostomata from the Lincolnshire include eight species in four morphologic groups; Chazydictya chazyensis Ross, 1963, C. explanata (n. sp.), Graptodictya perelegans Ulrich, 1878, G. elegantula (Hall), 1847, and Stictoporellina sp. in the escharopoid group; Stictopora fenestrata Hall, 1847, in the stictopoid group; Eopachydictya gregaria Ross, 1963, in the astreptodictyid group; and Athropragma sheldonensis (Ross), 1963, in the athropragmid group. Of the eight species of bifoliate Cryptostomata from the Lincolnshire, C. chazyensis, S. fenestrata, E. gregaria,

and A. sheldonensis were described by J. R. P. Ross from Chazy rocks of north-central and eastern New York State.

Non-bifoliate Cryptostomata include two genera in two families: Otoseetaxis in Rhabdomesidae; and Ulrichostylus in Athrostylidae.

Cystoporata include three genera in three families; Constellaria in Constellariidae; Ceramophylla in Ceramoporidae; and Dianulites in Dianulitidae.

Trepostomes include at least four genera in four families: Monticulipora in Monticuliporidae; Eridotrypa in Batostomellidae; Hallopora in Halloporidae; and Hemiphragma in Trematoporidae.