December, 1975

To the Graduate Council:

I am submitting herewith a thesis written by William W. Payne, III entitled "Paleoenvironmental Study and Geologic Map of Lower and Middle Ordivician Strata Near Knoxville, Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

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PALEOENVIRONMENTAL STUDY AND GEOLOGIC MAP OF LOWER AND MIDDLE ORDOVICIAN STRATA NEAR KNOXVILLE, TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

William W. Payne, III

December 1975

1266280

ACKNOWLEDGEMENTS

I would like to thank Dr. K. R. Walker, Dr. D. W. Byerly, and Dr. Garrett Briggs of the University of Tennessee for serving on my thesis committee and offering assistance and encouragement in the completion of this thesis. Special recognition goes to Dr. Walker, who originated the idea of this particular thesis, aided greatly in its organization, and critiqued the manuscript. Dr. Briggs made extensive editing comments on the manuscript.

ABSTRACT

The purpose of this investigation was to produce a more accurate geological map and a detailed outcrop map of an area of critical significance to the interpretation of Middle Ordovician stratigraphy in eastern Tennessee. The strata of the study area consist of seven interfingering, lens-shaped lithologic units, all but one of which are repeated in two or more formations. This repetition of lithologies, complicated by structural deformation, makes assignment of a particular outcrop to a definite formation difficult except in a few well-defined areas.

A consideration of paleoenvironmental data and field relationships from a facies viewpoint, combined with conventional methods of field mapping by plotting outcrop attitudes and lithologies on a topographic base map, allowed a reconstruction of the facies patterns. This reconstruction shows the stratigraphy of the formations to be more complex and the overall structure of the study area to be simpler than previously believed.

The Mosheim and Lenoir/Holston units within the subject study area are facies equivalents representing supratidal, intertidal, and subtidal environments, respectively. The Chapman Ridge Sandstone marks the beginning of a terrigenous influx which altered the broad, stable supratidal, intertidal, and subtidal environments. These environments were integrated into

a shifting pattern of subtidal reefoid structures, oncolites, and terrigenous sand, silt, and clay; intertidal oolite shoals; and supratidal mud flats: depositional environments which are inferred for rocks of the Ottosee Formation.

The supratidal Knox lithology of this area was onlapped by the intertidal Mosheim lithology, which was onlapped by the subtidal Lenoir/Holston lithologies. This transgression continued with the deposition of the intertidal/subtidal Chapman Ridge and the supratidal/intertidal/subtidal Ottosee formations.

Local variations of bedding attitudes, caused by small, insignificant folds superimposed on major structures, rendered strike and dip readings virtually useless. Since bedding attitudes are not consistent with the general structure, map control of formation boundaries was based primarily on rock types in outcrop or float and tracing of lithologic contacts. A map study of the resulting configuration of formations was required to determine the overall structure (two synclines and an anticline) of the study area.

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CHAPTER I

INTRODUCTION

I. GENERAL DISCUSSION

The Ordovician rocks of East Tennessee present a complex array of lithogies which has long led to difficulties in classifying, accurately mapping, and correlating the lithic units involved. Difficulties with mapping and correlation are the result of four basic factors: (a) formations are composed of more than one lithology; (b) each lithology occurs in two or more formations in various combinations; (c) facies are random in distribution rather than exhibiting a particular pattern; and (d) crustal shortening caused by folding and faulting has made time correlation within the sequence particularly difficult.

Earlier mappers of this region, assuming that the sequence of beds was originally composed of lithologically uniform, tabular units, invoked tectonism to explain the proximity of the varied lithologies.

The interpretation presented here suggests that the structure may be less significant than previously implied, and that the close association of varied lithologies reflects deposition in a complex pattern of depositional environments. The many small anticlines and synclines observed in this area are considered to be minor structures not appreciably

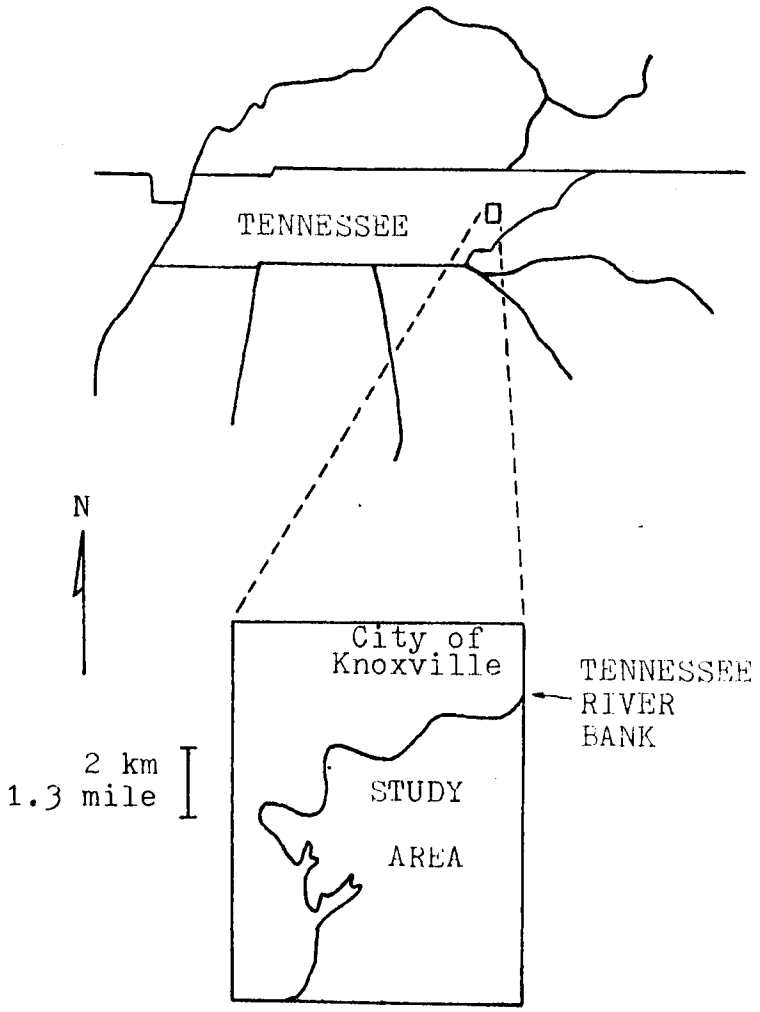
affecting the general outline of the formation boundaries.

II. PURPOSE OF INVESTIGATION

At the outset, it was believed that a consideration of paleoenvironmental data and field relationships of various lithologies as possible facies equivalents might produce a geologic map of more accurate interpretation than the one published (Cattermole, 1958). Previous studies of this area have revealed only the gross structural and stratigraphic relationships of major rock types. This more detailed study of the area shown in Figure 1 was initiated to: (a) produce an areal geologic map of the widely varying lithologies by combining conventional methods of correlating lithic units with paleoenvironmental information inferred from laboratory study of samples, and (b) produce a more detailed outcrop map of an area of critical significance to the interpretation of Middle Ordovician stratigraphy in eastern Tennessee (cf. Walker and Ferrigno, 1973).

III. METHOD OF INVESTIGATION

A seven and one-half minute Tennessee Valley Authority quadrangle was used as a base map. The study area includes approximately 24 square km (16 square miles) immediately south of Knoxville. This study was initiated in the northern portion of the study area where rock exposures, mainly in quarries and roadcuts, are more extensive and



Knoxville Quadrangle

Figure 1. Location map of thesis study area (see Plates 1 and 2 (In pocket) for additional detail).

structural and stratigraphic relationships are fairly clear. The remaining three-fourths of the map area is complicated by vertical repetition of lithologies, complex distribution of facies, and structural deformation. To compensate for the lack of well-exposed, complete sections, up to 20 outcrops per square kilometer (35 per square mile) were examined and related to each other by plotting outcrop attitude and lithology on the base map. Rock samples were collected at 75 stations for possible laboratory analysis. Figures 10 through 13, Appendix A, show photographs of some outcrops and photomicrographs of thin-sections of selected samples.

Sample numbers correspond to station numbers which are circled on the outcrop map (Plate 1, In pocket). Samples of stations referred to in the text of this report are given a map location in parentheses following the number (e.g., station 1 (E-5)). These locations are based on a coordinate system on the accompanying outcrop map.

This map differs from most geologic maps in that it is primarily an outcrop map of the study area. A particular color was designated for each outcrop lithology, with the exception of nodular chert found only at locality A-7. The outcrops are plotted on the map with: (a) a strike and dip symbol if the bedding attitude was determinable, and (b) the color corresponding to the outcrop lithology. Contact lines delimit the formations which appear as a variety of spot colors reflecting the outcrop distribution and lithology

on Plate 1 (In Pocket). Plate 2 (In Pocket) is a geologic map with each formation represented by a single color. Formation thicknesses were computed from map measurements.

After acetate peels were made of the 75 samples, 32 were selected for thin-sectioning. An effort was made to prepare thin-sections for the complete range of lithologies (with the exception of shale/siltstone), using samples representing the entire areal extent of the map.

The laboratory analysis procedure included: (a) making a macroscopic examination of the acetate peels using a binocular stereomicroscope and two polarizing filters over a light table, and (b) making a microscopic study and point-count of the thin-sections, averaging 600 points per 5-by 7.5-cm (2-by 3-inch) slide. The point-count data are presented in Appendix B. Figures 12 and 13, Appendix A, exhibit selected photographs of identified bryozoa. Dolomicrite was distinguished from micrite by using alizarin red stain on thin-section slides. Information derived from the peels and thin-sections was combined with outcrop data to reconstruct the depositional environments, which were then keyed to their respective sample locations on the outcrop map. These sample locations were used in combination to define the three-dimensional environmental pattern discussed in Chapter III. The photographs of Figure 10 F and Figure 11 C, E, Appendix A, are from an oolite outcrop 0.6 km (0.4 mile) south of the study area, but the outcrop is similar in lithology to poorer exposures within

the study area.

IV. PREVIOUS INVESTIGATIONS

Figure 2 summarizes the geologic units present in the study area as defined by earlier workers. The previous investigators, with the exception of Cooper, mapped the rocks as a sequence of tabular layers. Cooper's classification reflects his belief that the lithologic units are related as facies members of restricted lateral and vertical extent. This study utilizes Cattermole's terminology but attempts to follow Cooper's approach of considering the units as complexly interrelated facies patterns.

The Vestal "Marble," a term used by Cattermole (1958), is not shown in Figure 2. The Vestal "Marble," a term first used by Gordon (1926), is a member of the Ottosee Shale.

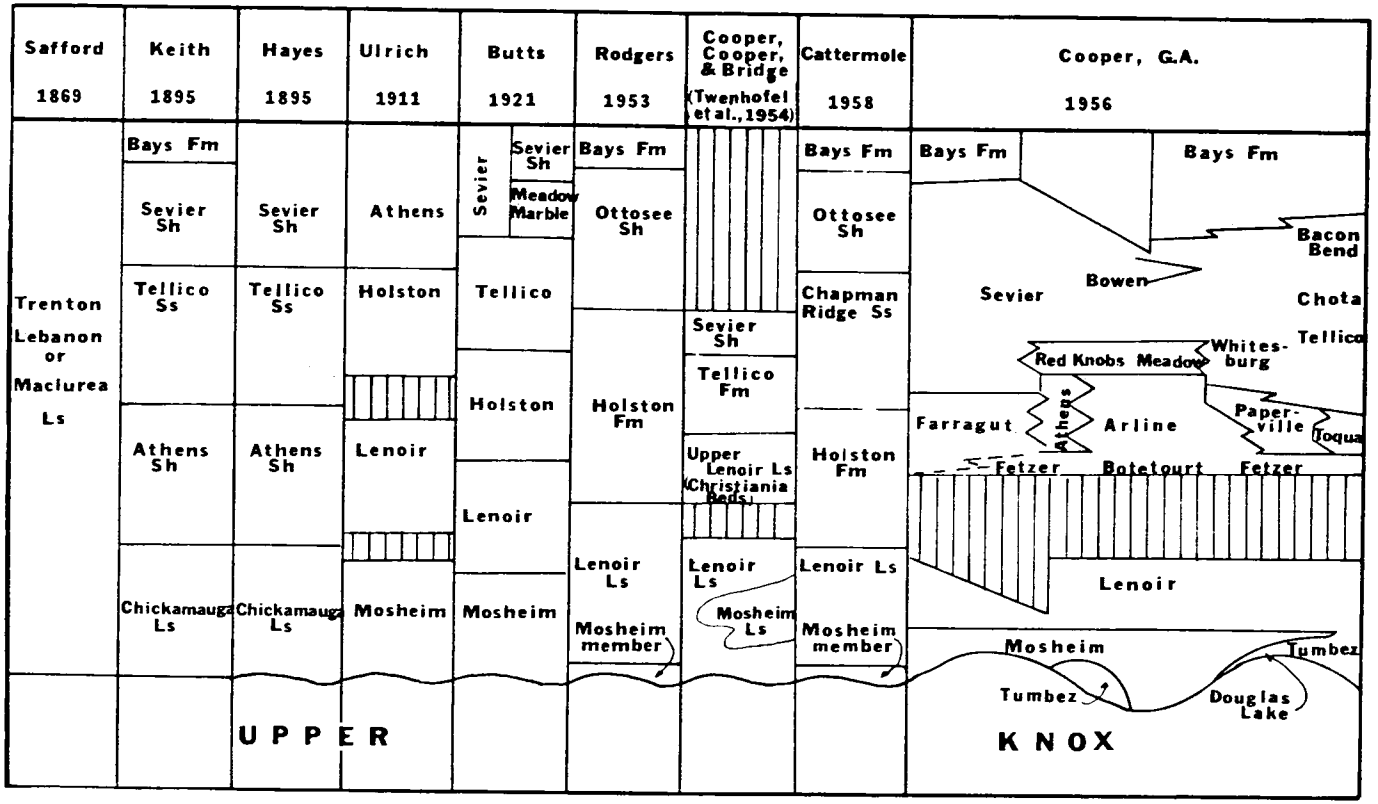


Figure 2. Comparison of Middle Ordovician stratigraphic terminology applied in the middle and eastern belts in East Tennessee (McLaughlin, 1973).

CHAPTER II

GENERAL STRATIGRAPHY

I. GEOLOGICAL SETTING

The Knoxville area is situated within the Valley and Ridge physiographic province of the Southern Appalachians. Within the study area, a broad anticline and syncline expose rocks from the Lower Ordovician Knox Group up through an oolite member of the Middle Ordovician Ottosee Shale. Although outcrops are well distributed across the study area, continuous stratigraphic sections are rare. Close spacing of sample localities is mandatory in producing a map of this area because of common small scale deformation and the restricted areal extent of many lithologies.

II. LITHOLOGIC DESCRIPTIONS, ENVIRONMENTAL INTERPRETATION, AND OCCURRENCE

Introduction

Because several lithologies are repeated in different formations, the conventional approach of describing each formation in ascending stratigraphic order is not appropriate. Instead, each lithology is described separately, the corresponding depositional environment is inferred from the data, and the distribution of each lithology within the stratigraphic sequence is discussed.

Color descriptions conform to the Rock-Color Chart of Goddard et al., (1963). Letter/number designations following the colors (e.g. moderate red (5 R 5/4)) refer to the color classification scheme used in the Rock-Color Chart.

Thicknesses are defined as follows:

(a) thin-bedded - 1/2 to 2 cm (3/16 to 3/4 inch)

(b) medium-bedded - 2 to 5 cm (3/4 to 2 inches)

(c) thick-bedded - 5 cm to 1 m (2 inches to 1 yard)

(d) massive - bedding not apparent.

Chert

Lithologic description. The chert in weathered outcrop forms light- (5 YR 5/6) to moderate- (5 YR 4/4) brown nodules in a brown, deeply-weathered soil. No fossils or internal structures were observed in the chert nodules.

Environmental interpretation. Since silica now dissolved in seawater is far below the saturation point, many workers believe that all chert associated with sedimentary rock is biogenically derived. Diagenetic or epigenetic mobilization of the silica might explain the lack of siliceous fossils and the concentration of the silica into nodules. Present understanding of chert formation is insufficient to allow a confident environmental interpretation of this component (Dunbar and Rodgers, 1975; Garrels and Christ, 1965; Pettijohn, 1957).

Occurrence. Megascopic chert is restricted to one exposure

near the upper contact of the Knox Group 60 m (200 feet) east of station 140 (A-7). Thin-section analysis reveals trace amounts of sand-sized chert among grains of the terrigenous sandstones (page 19).

Dolostone

Lithologic description. The medium-gray (N-5) to moderate-red (5 R 5/4) dolostone generally consists of dolomicrite with minor amounts of interstitial calcite cement. The color is vertically gradational in some exposures, being predominately medium-gray with moderate-red interbeds less than one cm (3/8 inch) thick. Bedding planes are poorly- to well-developed. Station 140 (A-7) exhibits a siltstone interbed approximately 37 cm (15 inches) thick with light-gray (N 7) dolostone below and moderate red (5 R 5/4) above.

A thin-section and an acetate peel of sample 75 (C-5) exhibit a drusy dolomite filling irregular voids among well-rounded medium-gray (N 5) dolomicrite intraclasts (?) about one cm (3/8 inch) in diameter and some druse-filled spherical voids about 1/2 cm (3/16 inch) across (Figure 10 A, Appendix A). Under cathodeoluminescence abundant dolomite rhombs are revealed.

Environmental interpretation. Modern penecontemporaneous dolomite formation is restricted to supratidal areas (Shinn, Ginsburg, and Lloyd, 1965; Illing, Wells, and Taylor, 1965; Shinn, Lloyd, and Ginsburg, 1969) or to zones near and below supratidal areas in the case of dolomitization cross-cutting bedding (Deffeyes, Lucia, Weyl, 1965). Dolomicrite of sample

90 (I-5) is interbedded with calcium carbonate oolites, indicating penecontemporaneous formation of the dolomicrite during a temporary supratidal condition. Thicker sequences of dolomite are interpreted as representing broad supratidal flats similar to those described by Shinn, Ginsburg, and Lloyd (1965), and Shinn, Lloyd, and Ginsburg (1969).

The druse-filled voids of sample 75 (C-5) described in the previous section are similar to "birdseye" structures illustrated by Shinn (1968) and attributed by him to infilling of gas bubbles and dessication cracks in carbonate muds. Such "birdseye" structures were found by Shinn (1968) only in intertidal and supratidal sediments.

Occurrence. Thin-bedded to massive dolostone is found in the Knox Group which forms the lowermost units mapped. Thin interbeds of dolomicrite which are lithologically indistinguishable from Knox dolomicrites are found in the oolite sequence of the Ottosee Shale at station 90 (H-5).

Dismicrite

Lithologic description. The dismicrite is a fine-grained, medium-gray (N 5) micritic limestone with drusy spar filling original void spaces (Bathurst, 1958). These void fillings, termed "birdseyes," commonly assume one of two forms:

(a) bifurcating laminar partings less than 1 mm (1/30 inch) thick by 2 or 3 cm (about 1 inch) long.

(b) spherical or anastomosing cylindrical shapes averaging

1/2 cm (1/4 inch) across by several cm (1 to 2 inches) in length (Figure 10 B, Appendix A).

Thin-section 38 (C-4) reveals a few randomly oriented disarticulated and articulated spar-filled ostracode valves.

Environmental interpretation. Shinn (1968) found that similar "birdseye" structures form in modern supratidal and intertidal sediments from entrapped gas and shrinkage partings due to dessication, suggesting that the dismicrites are supratidal or intertidal in origin. The sparcity of fossils supports this conclusion since euryhaline supratidal and intertidal environments would not have been hospitable to most forms of Ordovician life. The occasional randomly oriented disarticulated and articulated ostracode valves suggest an intertidal zone of low energy and active deposition.

Occurrence. Dismicrites are found in the Mosheim Member of the Lenoir Limestone which ranges in thickness from perhaps 10 m (33 feet) to about 25 m (81 feet) in the study area.

Cobbly-Weathering Limestone

Lithologic description. The cobbly-weathering biomicrite ranges in color from medium gray (N 5) to moderate red (5 R 5/4), the color being homogeneous in a single outcrop. Algal laminations of micrite are common, forming oncolites (algally-coated grains) and possibly the irregular bedding surfaces that are characteristic of this lithology. Medium-gray (N 5) biomicrite is commonly concentrated into nodules

surrounded by dark-gray (N 3) micrite (Figure 10 C, Appendix A). Stevenson, Walker, and McLaughlin (1973), in the area of this study, found the cobbly-weathering biomicrite to include Nuia siberica (probably red alga), Girvanella (green (?) alga), and dasycladacean algae; oncolites and intraclasts; brachiopod and ramose bryozoan fragments; pelmatozoan debris, and some tabulate corals, gastropods, sponges, and orthoconic cephalopods. Such a diverse fauna suggests a subtidal environment.

Environmental interpretation. Oncolite formation, according to Logan, et al. (1964), is restricted to water depths of less than 6 m (20 feet) in Holocene environments. The close association of oncolites with abundant subtidal fauna indicates a subtidal origin of deposition. The presence of 50 to 80% micrite in this lithology suggests that the water of deposition must have been somewhat turbid. This turbidity would have restricted sunlight penetration of the water, impairing efficient algal photosynthesis below about 6 to 10 m (20 to 35 feet). Thus, the presence of abundant algae lends further support to the contention of a shallow subtidal origin.

Occurrence. Medium-gray (N 5) cobbly-weathering biomicrite occurs primarily in the main body of the Lenoir Limestone (that part exclusive of the Mosheim Member) which has an average thickness of about 180 m (500 feet). Medium-gray (N 5) to moderate-red (5 R 4/6) biomicrite is also found locally in the Ottosee Shale.

Shale/Siltstone

Lithologic description. These two lithologies are treated as one because they are found thinly interbedded in many localities and therefore must represent only slight differences in the depositional environment.

The shale is usually lighter in color, normally a light brown (5 YR 5/6), and more resistant to weathering than the siltstone which ranges in color from light brown (5 YR 5/6) to medium gray (N 5) and grayish red (5 R 4/2). With weathering the siltstone usually disaggregates while the shale breaks down into small, persistent flakes 1 to 2 cm (3/8 to 3/4 inch) across. The shale/siltstone is bound by calcareous cement. The siltstone occasionally displays small ramose bryozoan fragments averaging 2 mm (3/16 inch) across by 1 to 2 cm (less than 1 inch) long. The mineralogy of the shale/siltstone grains has not been determined.

Intense deformation of the shale/siltstone producing folds measured in meters is very common (Figure 10 E, Appendix A). The shale/siltstone often displays cleavage, possibly developed across original bedding.

Environmental interpretation. The localized presence of ramose bryozoan fragments in this lithology indicates a marine environment of deposition. The thin parallel bedding and generally fine grain size indicate a fairly quiet area of deposition of terrigenous material.

Occurrence. Siltstone is interbedded with dolostone of the Knox at station 140 (A-7). Weathered shale of the Knox (?) is exposed in (E-1, 2). A thick unit of shale crops out within an area mapped as Lenoir (F-8) and is believed to be interbedded with the Lenoir. Siltstone partings are frequently observed within the Chapman Ridge. Thick beds of shale/siltstone are found through the Ottosee and are used to define the base of the Ottosee where it contacts the Upper Holston or Chapman Ridge. Within the Ottosee oolites thin, fossiliferous, irregular pods of grayish-brown (5 YR 3/2) siltstone occur.

Biosparite

Lithologic description. The biosparite ranges in color from very light (N 8) to medium gray (N 5), light (5 R 6/6) to moderate red (5 R 4/6), or pinkish gray (5 YR 8/1). The biosparite is weathered deeply in places to a dusky-red (5 R 3/4) soil.

The predominant constituents of the fossil assemblage are ramose bryozoa (Figure 12 A, B, C, E, G, I, J and Figure 13 A, D, E, F, G, H, Appendix A), and algally-bored pelmatozoan debris (Figure 11 A 1, Appendix A). Many of the bryozoa, especially the more delicate ramose types, occur as abraded fragments with micrite-filled zooecial tubes (Figure 11 A 2, Appendix A), indicating that they laid exposed on the bottom, acting as fine-sediment traps, for some time between death and burial. Figure 3 depicts the relative abundances of these fossils in thin-sections.

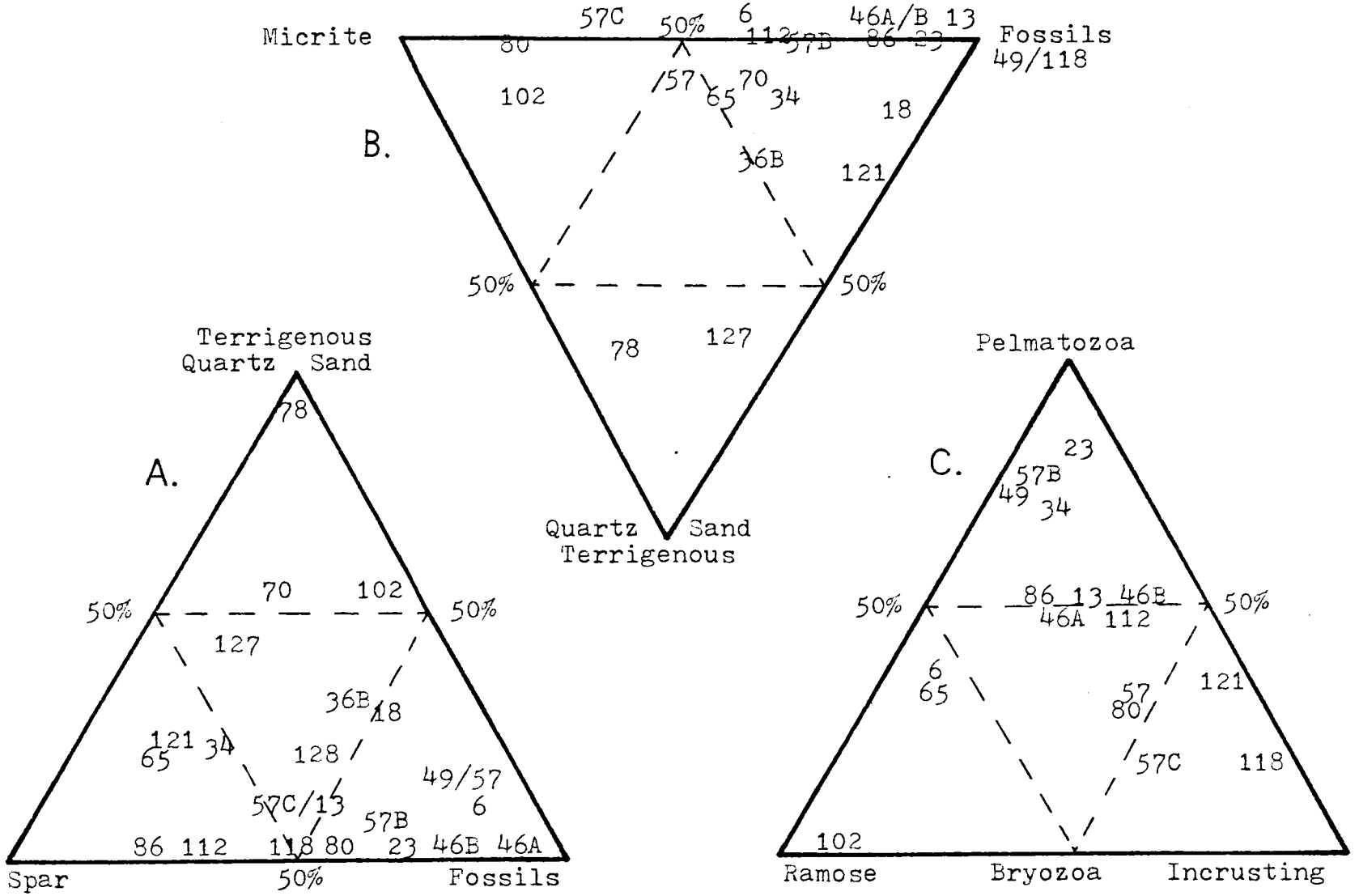


Figure 3. (A) Terrigenous sandstone versus biosparite, (B) terrigenous sandstone versus biomicrite, and (C) pelmatozoa versus bryozoa of (A) and (B).

The algal bores in fossil fragments are filled with micrite, which, in the case of extensive boring, may be observed as an envelope of micrite encasing the remainder of the fragment (Bathurst, 1971, p. 388). Swinchatt (1969), studying the Great Barrier Reef, concluded that algal boring of skeletal material is almost certainly restricted to depths less than 40 m (130 feet), and more likely to depths less than 15 to 18 m (50 to 60 feet).

Bedding is poorly developed in the biosparite except in some areas where low- to high-angle (10 to 30°) cross-beds several meters long are observed.

Environmental interpretation. Reef complexes within the Holston Formation at Deane quarry, approximately 10 km (6 miles) southwest of the study area, have been described by Walker and Ferringo (1973) who found that incrusting bryozoa dominate the reef core and ramose bryozoa and pelmatozoan debris dominate high-angle cross-bedded reef flank material. Sitterly (1973) reached similar conclusions about Meadow "Marble" of the Ottosee Shale near Friendsville, Tennessee.

Good exposures of biosparite/biomicrite occur south of station 74 (D, E-4) along the railroad at and south of station 139 (E-6). These outcrops reveal the biomicrite reef core and cross-bedded biosparite reef flank relationships which occur through this pair of lithologies. Since biosparite and biomicrite are so closely associated, they are indicated by a single color on the geologic map (Plate 1, In pocket).

Occurrence. The Holston Formation, averaging about 300 m (1000 feet) thick, consists primarily of biosparite and pink to maroon biomicrite. The biosparite is also found in the Mosheim (E-1, 2), the Chapman Ridge, and the Ottosee in quantities thick enough to quarry at H-5 and J-9 on the outcrop map. The Vestal "Marble" contains some biosparite.

Thick-Bedded to Massive Biomicrite

Lithologic description. The biomicrite varies, sometimes within a single outcrop, from medium gray (N 5) to dusky red (5 R 3/4). At station 4 (D-7) a moderate-brown (5 YR 4/4) weathering color truncates the thick, very irregular bedding at approximately right angles (Figure 11 G, Appendix A), apparently following fracture patterns in the rock. These thick-bedded to massive biomicrites contain terrigenous clastic clay, silt, and sand, bound with calcareous cement, and are closely associated or interbedded with the shale/siltstone and sandstone lithologies (Figure 3, page 16). The matrix, when low in terrigenous material, consists of a finely crystaline spar or microspar.

The fossil assemblage of the biomicrite at station 4 (D-7) is comprised of 33% pelmatozoan debris and in situ root attachment structures, 20% incrusting bryozoa, 6% ramose bryozoa, 1% ostracode fragments, and 40% unidentified fragments (Metcalfe, 1972).

Environmental interpretation. Walker and Ferrigno's (1973) analysis of the Holston Formation in Deane quarry

revealed that the biomicrite, dominated by incrusting bryozoa, formed the reef core deposits. They have similarly interpreted the Holston exposure along Alcoa Highway (D-4), and Sitterly (1973) has used this interpretation in his study of the Meadow "Marble" of the Ottosee Shale near Friendsville, Tennessee. The fossil assemblages of the thick-bedded to massive biomicrites within this study area indicate that they represent analogous reef core deposits.

Occurrence. Thick-bedded to massive biomicrite is found in areas of the Holston Formation and in lensoid and locally massive deposits in the Vestal "Marble" of the Ottosee Shale.

Terrigenous Sandstone

Lithologic description. The terrigenous sandstones vary from very dusky red (10 R 2/2) to very light gray (N 7). Commonly these two colors are interbedded (Figure 11 B, Appendix A), in which case the lighter beds consist of biosparite with some terrigenous sand, and the darker beds contain abundant terrigenous sand and opaque iron (?) grains with calcareous cement. The terrigenous sandstone grades laterally and vertically into the oolite and biosparite lithologies (Figure 3, page 16, and Figure 4). Sandstone is also closely associated and thickly interbedded with shale/siltstone.

The terrigenous sand particles are normally fine grained, subrounded quartz sand with minor amounts of chert, perthite, glauconite, and clasts composed of oolitic grains bound by calcareous cement. The fossils, mainly ramose bryozoa with

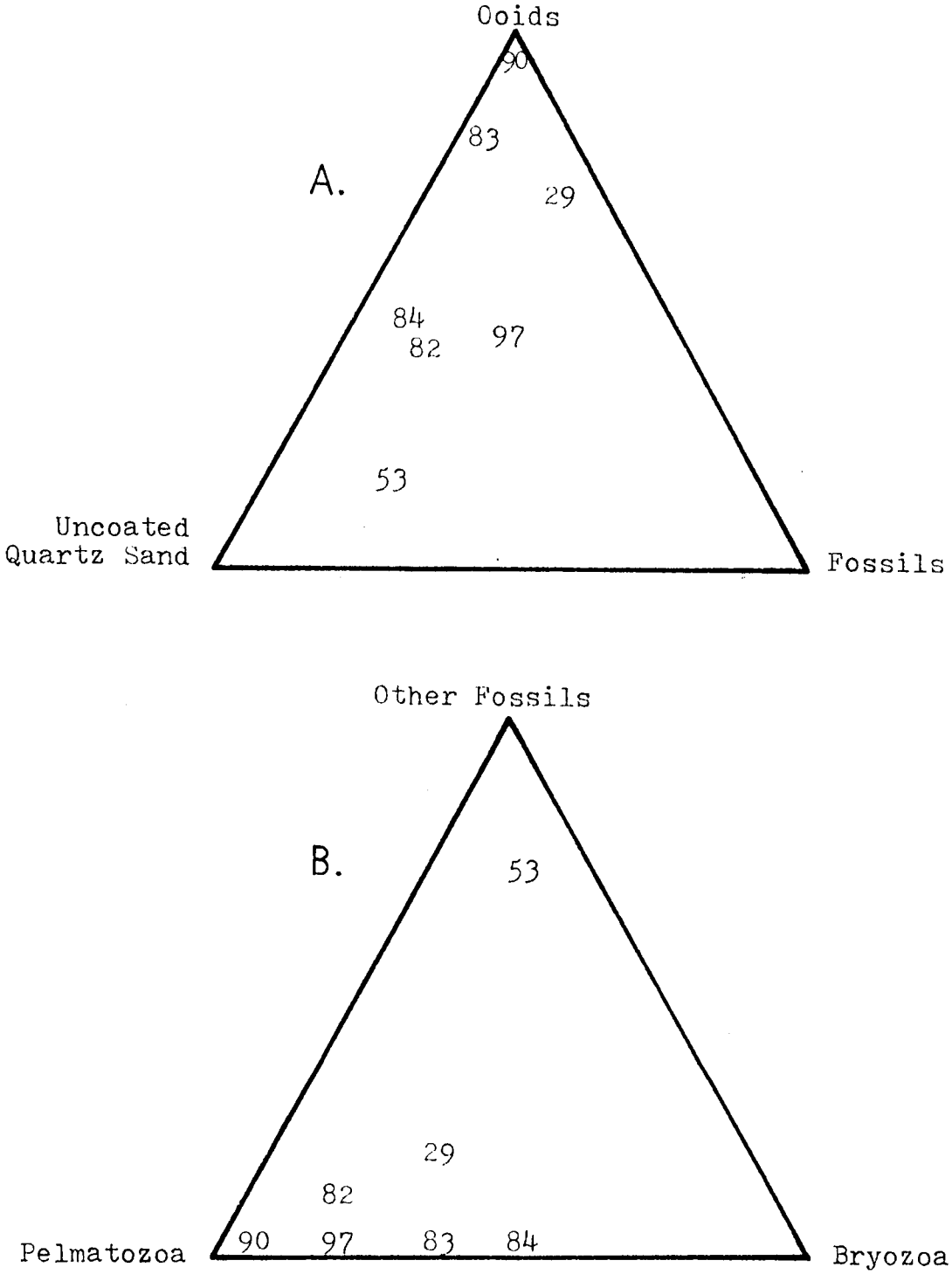


Figure 4. (A) Ternary diagrams of oolite lithology and (B) fossils of the oolite lithology.

some pelmatozoan debris and occasional brachiopod valves, are broken and abraded, and commonly exhibit algal boring. The bryozoa have many micrite-filled zooecial tube openings (Figure 11 A, Appendix A). Ripple drift cross-beds or small, low-angle cross-beds up to several meters long are also present. Cut and fill structures up to 20 cm (8 inches) thick by 1 m (1 yard) wide are common. Fossils are sometimes concentrated in the middle of these features, as can be seen along Alcoa Highway west of station 83 (E-4).

Environmental interpretation. Compared to the widely variable fossil assemblages of the reef areas (biosparite/biomicrite lithologies), the fossil abundance and variety preserved in sandstone is drastically reduced. The fossils basically consist of ramose bryozoa (many of which are bifoliate), pelmatozoan debris, and a minor percentage of fragmented ostracodes, trilobites, bivalves, and echinoid spines (?). At first glance, one might attribute this reduction to selective destruction of chemically and physically weaker hard parts in an assemblage during transportation from its life site (cf. Johnson, 1960, Model III). However, experiments by Chave (1964) indicate that the delicately structured hard parts of ramose bryozoa would be destroyed quickly relative to the more solid parts such as valves and pelmatozoan debris that would endure longer. The high percentages of well-preserved ramose bryozoa observed in thin-sections and some terrigenous sandstones (17.1% in sample 102) suggest that they were buried close to

their life sites soon after death. This may indicate that other factors discussed below were responsible for the lower faunal diversity of the sandstone fossil record.

A cross-bedded sand represents a high energy environment. Due to the high energy of this environment, clay, silt, and finer food particles are kept in suspension above the bottom, eliminating the food source for deposit-feeding animals (swallowers) and browsers (collectors) such as ostracodes and trilobites (cf. Turpavea, 1957; Walker and Bambach, 1974). Low profile sessile organisms such as incrusting bryozoa and some bivalves (low-level suspension feeders) would be unable to survive here because they would find few stable places to attach and would be subject to rapid burial by the shifting substrate. High profile benthonic organisms (high-level suspension feeders), including ramose bryozoa and pelmatozoa, feeding from the higher bottom layers, would be well adapted in the sand zones where agitated water would provide a good exchange medium, bringing in fresh nutrients and washing away waste products.

Bretsky and Lorenz (1969) reasoned that onshore environments (typically sandy) are less stable than their offshore counterparts (represented here by reefs), and that this instability produces harsher conditions, which further tend to limit the number of faunal types able to live there.

Additional indications of shallow-water deposition of the sandstones are occasional zones of mudcracked micrites (Ferrigno and Walker, 1973) and oolitic sand (see Oolite

Environmental interpretation, page 24) and prevalence of blue-green algal borings in fossils (Swinchat, 1969).

Occurrence. The major terrigenous sandstone units occur in the Chapman Ridge Sandstone, which ranges in thickness from 0 to about 300 m (975 feet) in the study area. Thick terrigenous sandstone lenses are found within the Ottosee Shale and thin, irregular, iron-rich, terrigenous sandstone beds about 1/2 cm (1/4 inch) thick are found in the oolite. The Chapman Ridge Sandstone abruptly pinches out in several places (C-10, D-9, G-7), indicating the lateral discontinuity of this unit.

Oolite

Lithologic description. The oolitic zones are medium light gray (N 6). They may contain:

(a) grayish-brown (5 YR 3/2), iron-rich interbeds of quartz sand 1 to 2 cm (about 1/2 inch) thick,

(b) irregular, grayish-brown (5 YR 3/2), iron-rich, fossiliferous silt interbeds 0 to 7 cm (0 to 3 inches) thick, or

(c) evenly disseminated quartz grains and fossils (Figure 4, page 20).

The ooids have a maximum diameter of about 1/2 mm (3/64 inch). Sorting of ooids according to size is not evident in the samples studied. The nucleus, when observed, is usually a quartz grain, but may be a micrite pellet or skeletal grain. Surrounding the nucleus are one or more carbonate laminations, which, in some cases, durin' recrystallization, developed a

radial structure with relict concentric layers. Some superficial ooids (ooids with 0 to 5 laminae) exhibit radial structure or no structure at all. Superficial ooids are not segregated but are found among good ooids (more than five laminae). Instead of calcium carbonate, opaque iron oxide forms the oolitic structure around the nuclei of the ooids in thin-section 53 (G-5). All oolite samples are grain-supported rocks with interstitial spar and less than 5% micrite and opaque iron oxide filling pore spaces.

Sample 90 (I-5) is an oosparite with an interbed of dolomicrite. There are some oolite aggregates in the dolomicrite and rare dolomicrite intraclasts contained in the overlying oolite.

The fossils within the oolites consist primarily of abraded, disarticulated pelmatozoa columnals averaging about 2 1/2 mm (3/32 inch) across (Figure 4, page 20). Some samples also contain less than 1% bivalve fragments 1/10 mm (1/254 inch) thick and up to 3 1/2 mm (1/8 inch) long.

Low-angle (less than 10 degrees) cross-beds 1 to 3 m (3 to 10 feet) long are commonly observed in extensive oolite outcrops.

Environmental interpretation. Cayeux (1935) first outlined the conditions necessary for inorganic growth of aragonite as: elevated temperature, abundant supply of $CaCO_3$, saturation of the solution, agitation and a source of nuclei. Illing (1954) and Newell et al. (1960), working on modern

oolite shoals, agreed with Cayeux's parameters and reasoned that saturation of the solution was achieved not only by agitation and elevation of temperature but also by photosynthesis of benthic plants. Newell et al. (1960, p. 497) found the highest proportion of coated nuclei in a water depth of 2 m (7 feet) on the oolite shoal, concluding that this depth provides the best growth conditions on the Bahamian shoal.

Similar shallow-water shoal areas are envisioned for the formation of the oolites found in this study area. Algally-bored fossil fragments suggest that algae may have assisted in saturating the seawater with $CaCO_3$ through removal of CO_2 during photosynthesis.

Oolite intraclasts (Figure 11 E, Appendix A) indicate early (pre-burial) cementation of the ooids. Bathurst (1971, p. 316-318) and Monty (1967), as a result of their study of the origin of grapestone, believe that carbonate grains, immobilized in a subtidal algal mat and surrounded by pore water reduced in dissolved CO_2 by algal photosynthesis, are bound together by the precipitation of micritic aragonite. The relatively high energy of the shallow subtidal zone of the shoals would be sufficient to form the oolite intraclasts and the common low-angle cross-beds.

The conditions for modern oolite and grapestone formation indirectly offer support for the existence of algae in the oolite zones as indicated by algally-bored fossil fragments associated with the oolites.

Occurrence. Oolitic grains are found locally in the Chapman Ridge Formation (e.g., station 123 B (E-4)), and extensively in the Ottosee Formation (Plate 1, H-4; I-4, 5, 6; J-4 (In pocket)).

Terrace Deposits

Lithologic description. The terrace deposits consist of unconsolidated particles grading from dark reddish-brown (10 R 3/4) silt to dark yellowish-orange (10 YR 6/6) well-rounded siliceous cobbles about 15 cm (6 inches) in diameter.

Environmental interpretation. This unconsolidated material is believed to be fluvial, possibly of Pleistocene age.

Occurrence. Three observations of the terrace deposits were made near the Tennessee River (D-2 and F-2).

CHAPTER III

FACIES RELATIONSHIPS

I. INTRODUCTION

The central principle of facies relationships is contained in Walther's Law, which says: "The various deposits of the same facies areas and similarly the sum of rocks of different facies areas are formed beside each other in space, though in cross-section we see them lying on top of each other. As with biotopes, it is a basic statement of far-reaching significance that only those facies and facies areas can be superimposed primarily which can be observed beside each other at the present time" (Middleton, 1973; Figure 5).

Walker (1973) reasoned that as a corollary to Walther's Law, ". . . those vertically contiguous facies which have entirely gradational contacts must have been horizontally contiguous as well, because if any other facies had horizontally intervened it would also vertically intervene or be represented by a sharp (erosional or non-depositional) contact."

II. LATERAL AND VERTICAL FACIES PATTERNS

The strata in this study area, with the exception of the top of the Knox Group and Holocene terrace deposits, fail to show any evidence of a major hiatus. These strata (from the Mosheim through the oolites of the Ottosee Shale) are believed

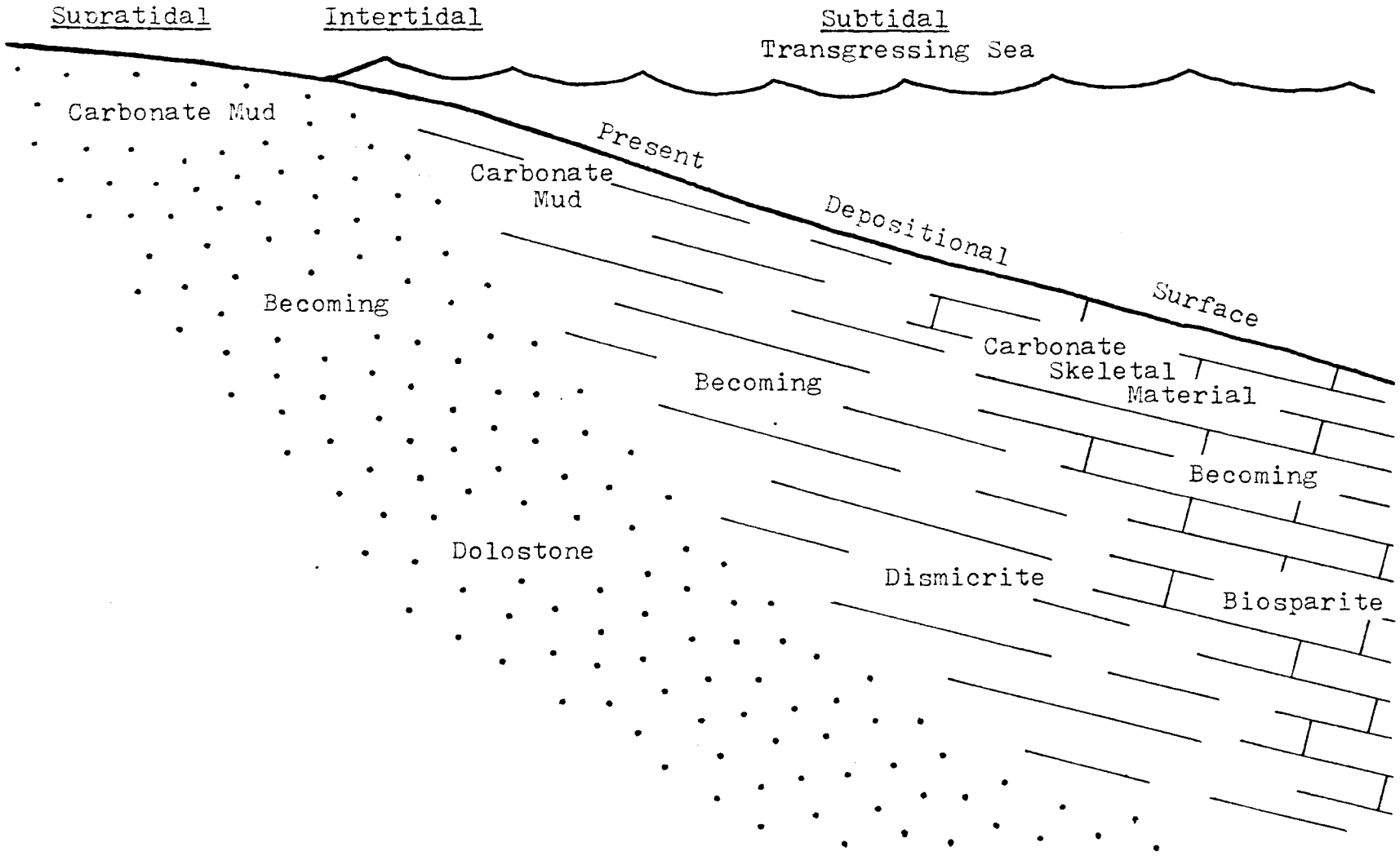


Figure 5. Illustration of Walther's Law. Primarily superimposed facies may be observed beside each other at the present time.

to be a vertical expression of a horizontal transgressive facies pattern eventually onlapped by terrigenous material.

A broad, gently sloping seacost is envisioned as being responsible for the lithologic distribution described herein. The dolostones represent broad supratidal flats occasionally inundated by water which deposited siltstone (A-7) and shale/siltstone (E-1, 2) beds. The intertidal area was a zone of periodic submergence where lime muds were deposited and subsequently lithified as dismicrites. The higher agitation and current velocity of the subtidal area resulted in contemporaneous deposition of micritic and biomicritic material, yielding a lithology with a characteristic cobbly-weathering appearance.

Further offshore, reef tracts established a stable base and allowed a variety of organisms to build a complex community structure.

These extensive reef tracts were diminished in size and number by an influx of terrigenous material from the southeast (Figure 6). This terrigenous material is represented by the sandstone and shale/siltstone lithologies. The reefs became patchy, shifting with the sands, being smothered in some areas and gaining a tenuous new hold in areas temporarily protected from the terrigenous environment. As the influx of terrigenous material gradually decreased, shallow-water shoals were developed where ooids formed. Some parts of the area occasionally emerged as supratidal islands, as evidenced by some dolomicrite interbeds. Thin interbeds of iron-stained quartz sand may have

Figure 6. Highly diagrammatic sketch showing facies relationships in the Chickamauga Group (after Hardeman, 1966).

To the northwest of Knoxville the Chickamauga Group (Och) is predominately a limestone sequence which becomes thicker and more clastic to the southeast. In the area of Knoxville the Lower Chickamauga Group is divided into the Lenoir Formation (Ol), Holston Formation (Oh), and the Ottosee Shale (Oo). The Lenoir Limestone grades southwestward into the Athens Shale (Oa), which is a medium- to dark-gray, calcareous, graptolitic shale, calcareous gray sandstone, siltstone, and locally fine-pebble quartz conglomerate with nodules of shaley limestone near the base. The Athens, Holston, and Ottosee grade southeast into the Sevier Shale (Osv), a calcareous bluish-gray shale with thin gray limestone layers, sandstone, siltstone, and becoming locally conglomerate to the east.

Och: Chickamauga Group

Oo: Ottosee Shale

Oh: Holston Formation

Ol: Lenoir Limestone

Oa: Athens Shale

Osv: Sevier Shale

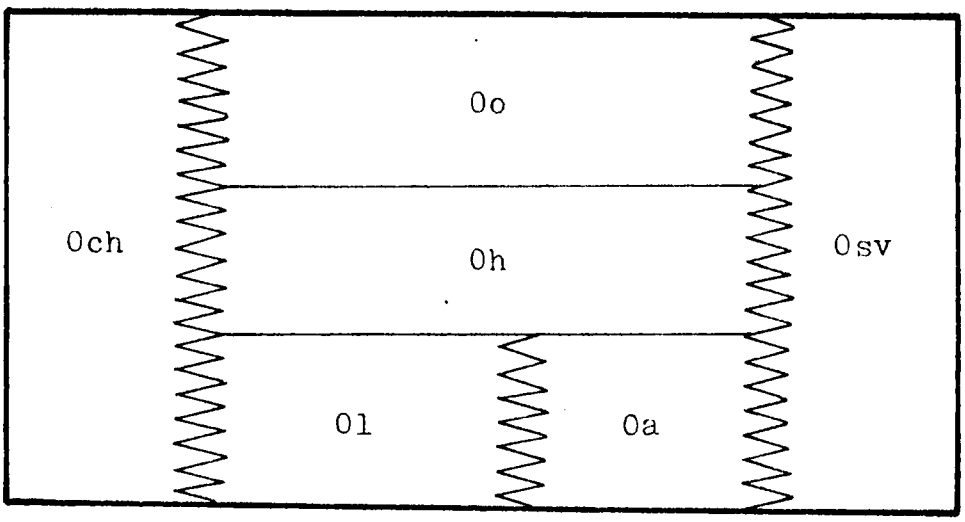


Figure 6

resulted from periodic resurgent storm (?) waves providing the energy to move this sand from outside (southeast of) the oolite zone across the shallow-water shoals. Fossiliferous, silty interbeds were formed within the oolite zone in areas temporarily protected from the stronger wave action, possibly by offshore bars or a wave-baffling reef similar to the one described by Sitterly (1973). The sandstone and shale/siltstone lithologies are interbedded in some areas (e.g., station 142 (G-5)) and form facies members in others (G-6, 7; D-9; and B-10), revealing the contemporaneous nature of these deposits. At station 87 (H-4) oolite grades upward into biosparite which is in turn overlain by shale, indicating that these lithologies are facies equivalents if Walker's corollary (1969) to Walther's Law holds true.

The biosparite of station 80 (G-7) is mapped as being the lateral equivalent of the shale on either side, although it may actually underlie or overlie the shale. The bedding attitudes are not distinct enough and the outcrops are not continuous enough to determine which is the case. Since the biosparite and biomicrite lithologies are closely associated and completely gradational, differentiation of the two at the map scale would have been difficult; thus both are shown by a single color.

III. SUMMARY

The sequence of rocks described does not represent a series of independent sedimentary environments, but rather a

more or less continuous record of deposition within a complex environmental pattern. The intertidal zone (Lenoir) and reef complex (Holston) were members of an extensive, stable, slowly transgressing facies pattern. This pattern was broken up and altered by the terrigenous influx caused by a regressive terrigenous clastic facies pattern migrating toward the northwest from a southeasterly source area, forming an interwoven pattern of frequently smaller scale facies, as seen in the Chapman Ridge and Ottosee Formations. Figure 7 shows approximately what lithologies may be found within each formation.

Proof of the lateral contemporaneity of the various lithologies is evidenced by the intimate interbedding of lithologies. Shale is found between biomicrites at station 139 (E-6) and 0.5 km (0.3 mile) south of station 139 (E-6) along the railroad. Sandstone/siltstone and shale interbeds are seen at station 142 (G-6), and interbeds of sandstone and oolite may be found at station 129 (J-4). Fragments of one lithology within another (e.g. station 90 (H-5)), and the cross-mixture of particle types (e.g. oolitically coated sand grains of station 123 B (E-4,5)) give further evidence of the lateral contemporaneity of various lithologies.

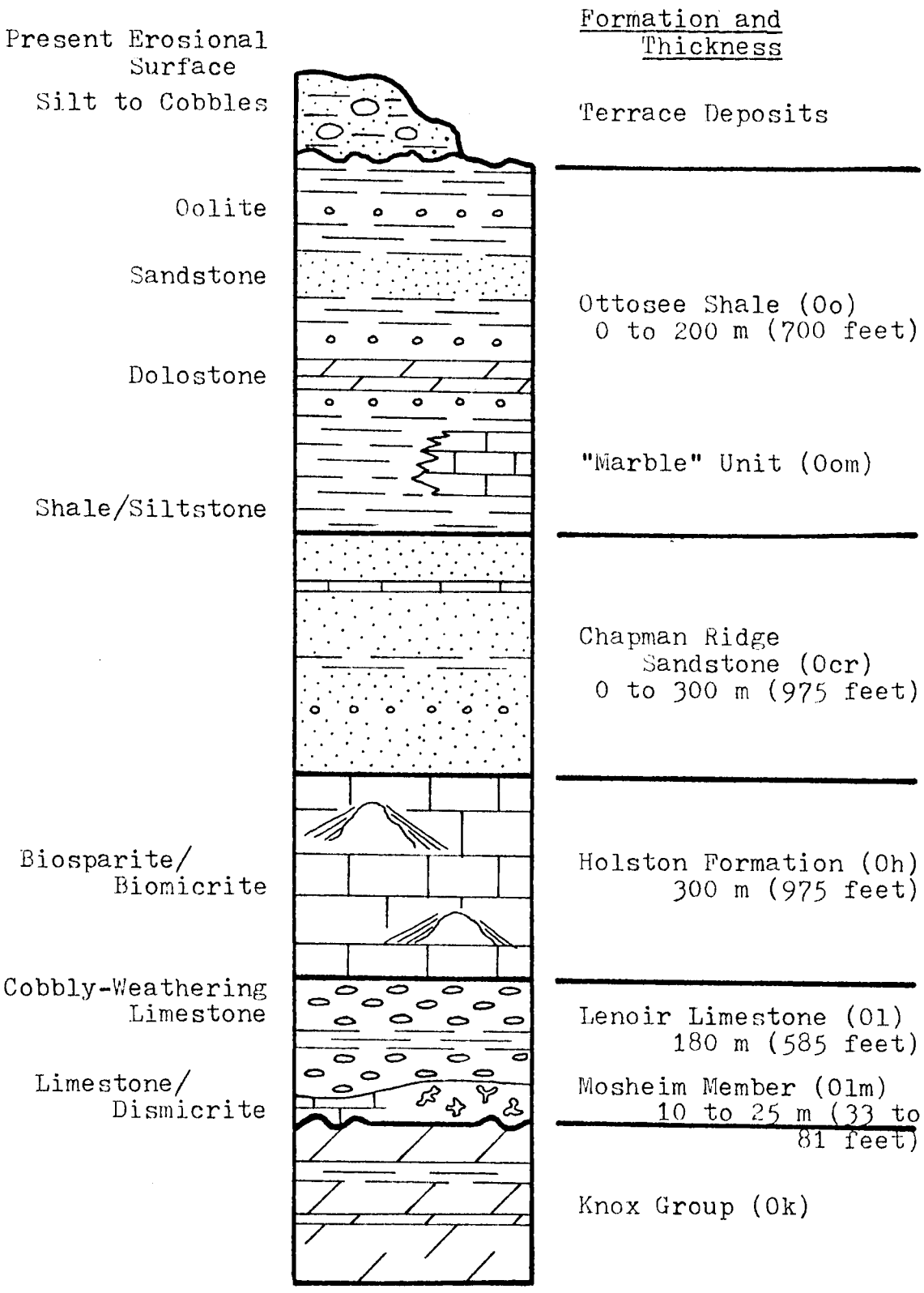


Figure 7. Composite columnar section.

CHAPTER IV

STRUCTURE AND GEOMORPHOLOGY

This area has undergone crustal shortening of perhaps as much as 1.5 km (1 mile) by folding and minor thrust faulting (Plate 2, In pocket). The northeastern half of the area is characterized by a northeast plunging syncline and a southwest plunging anticline. The plunge is gentle, becoming almost horizontal near the middle of the map. Crustal shortening in the southwestern half of the map is accomodated by a monoclinal downfold in the northwest which grades into smaller scale folding, commonly observed as chevron folds (Figure 11 F, Appendix A), and rare small scale thrust faulting to the southeast.

A glance at the geologic map shows that bedding attitude is commonly not congruent with the overall large scale structure. These varying attitudes (strike and dips) result from small scale folds developed on the larger anticlines and synclines during deformation. The small scale folds are of minor significance; therefore strike and dip measurements were given little weight in drawing formation boundaries. Instead, the location of the formation boundaries on the map is controlled primarily by lithologic distributions and by topography.

Areas underlain by the Holston Formation and, to a lesser extent, the Lenoir Limestone, commonly exhibit sinkholes which follow the outcrop trend of the Holston and Lenoir (e.g.,

Plate 1, D-9, In pocket). The Chapman Ridge Sandstone forms prominent ridges (Plate 1, H-7, In pocket), in sharp contrast to the low rolling topography characteristic of the Ottosee Shale (Plate 1, I-7, In pocket).

CHAPTER V

CONCLUSIONS

The Mosheim and Lenoir/Holston units within the subject study area are facies equivalents representing supratidal, intertidal, and subtidal environments, respectively. The Chapman Ridge Sandstone marks the beginning of a terrigenous influx which altered the broad, stable supratidal, intertidal, and subtidal environments. These environments were integrated into a shifting pattern of subtidal reefoid structures, oncolites, and terrigenous sand, silt, and clay; intertidal oolite shoals; and supratidal mud flats: depositional environments which are inferred for rocks of the Ottosee Formation.

The supratidal Knox lithology of this area was onlapped by the intertidal Mosheim lithology, which was onlapped by the subtidal Lenoir/Holston lithologies. This transgression continued with the deposition of the intertidal/subtidal Chapman Ridge and the supratidal/intertidal/subtidal Ottosee formations.

The variety of lithologies which may be found within a single formation, the repeated occurrence of these lithologies in two or more formations in different combinations, random distribution of facies within the Chapman Ridge and Ottosee Formations, and structural deformation are factors responsible for the difficulties encountered in mapping these strata. To produce a geologic map of this area, an understanding of the

facies relationships of the strata is mandatory. The combination of detailed field examination coupled with laboratory analysis of thin-sections and acetate peels yielded a good understanding of both the structure and facies relationships of the strata within the study area.

Map control of the formation boundaries was based primarily on rock types in outcrop (or on float where no outcrops could be found), taking into account the facies relationships of lithologies. A map study of the resulting configuration of formations was required to determine the overall structure (two synclines and an anticline) of the area. The strike and dip of beds in outcrop is rarely consistent with the overall structure, but rather indicates the existence of many minor folds superimposed on the major ones.

The following is a discussion of discrepancies between the most recently published geologic map of this area (Cattermole, 1958) and the geologic map of this report, which are diagramatically compared in Figures 8 and 9.

In the northwestern part of Cattermole's map, three irregularities (Figure 8, Points A) are observed to be associated with three faults and two anticlines. No field evidence for the existence of these faults was seen, and the anticlines are not believed large enough to produce the irregularities in the outcrop pattern as Cattermole mapped. A doubly plunging anticline (Figure 8, Point B) is required to expose an isolated bit of Chapman Ridge, and a southwest plunging anticline, apparently an extension of the one that exposes Lenoir 3 km (2

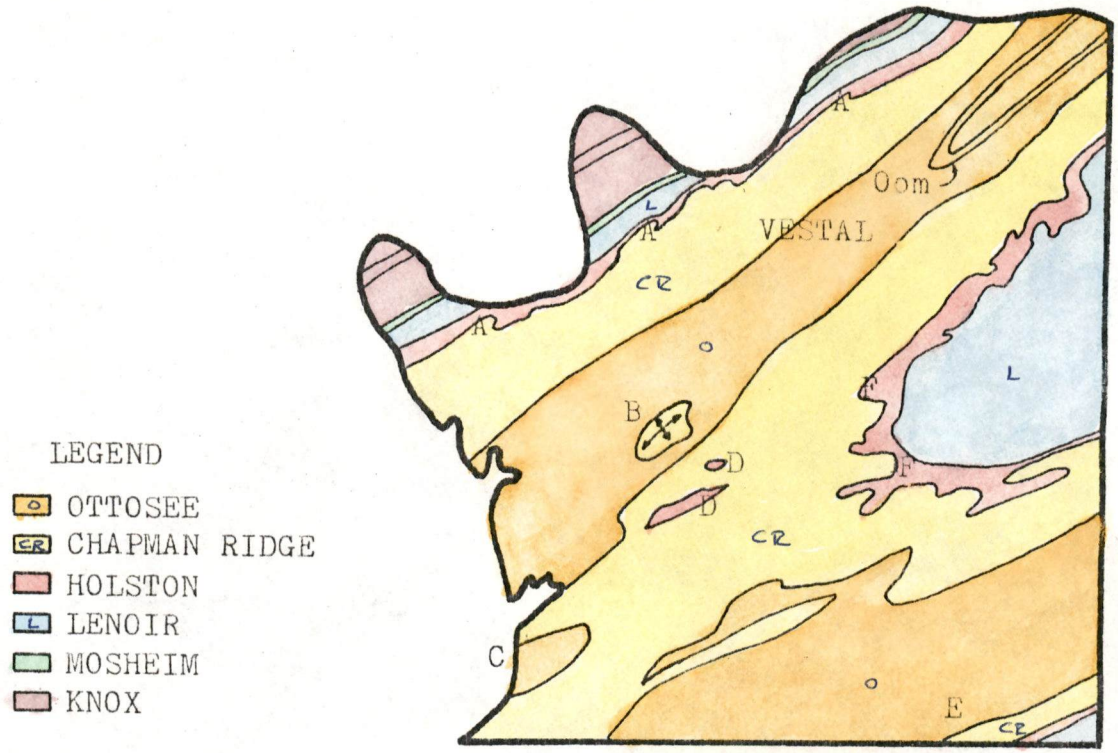


Figure 8. Geologic map after Cattermole (1958).

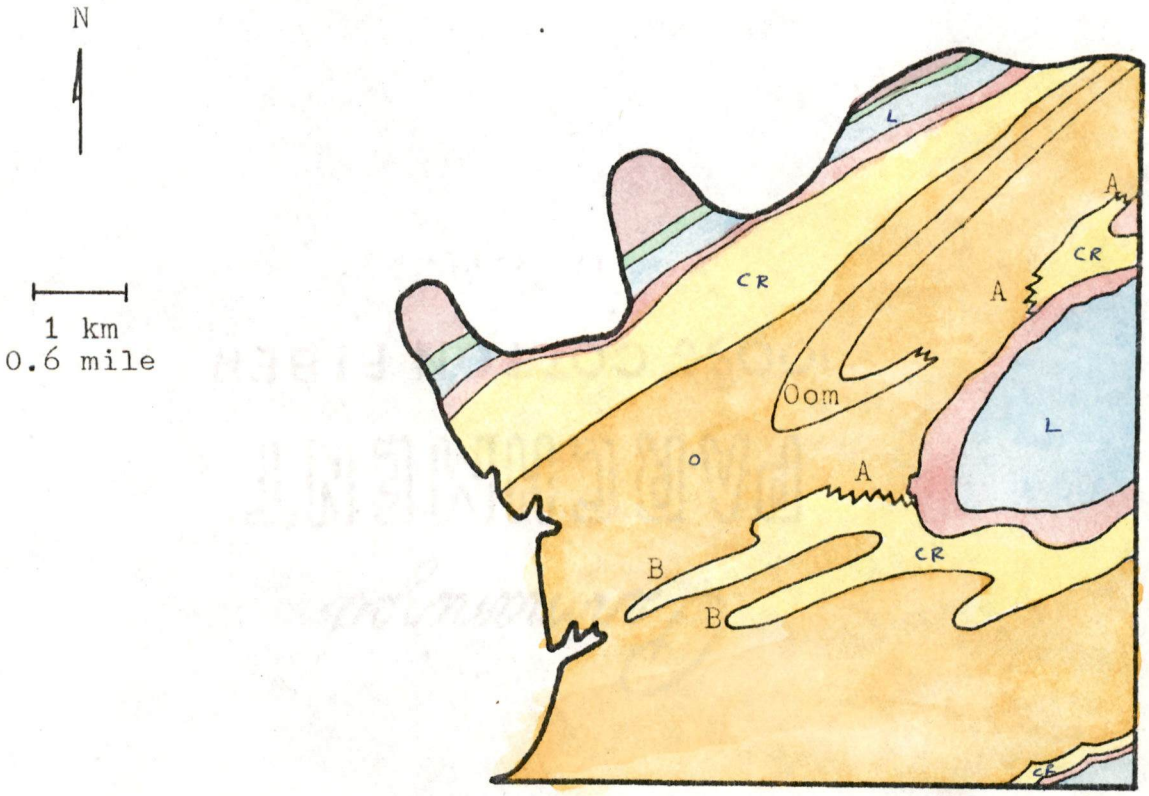


Figure 9. Geologic map of Payne (1975).

miles) to the northeast, is called upon to expose Ottosee (Figure 8, Point C). Ottosee, being higher in the section than Chapman Ridge, would normally be preserved in a syncline in this situation with older rocks exposed away from the axis of the fold. Cattermole may have intended for this to be a syncline since five of the six strike/dip symbols around the fold would also indicate a syncline. But a syncline here presents the somewhat unusual, albeit not impossible, situation of having a syncline and an anticline in line with each other along structural strike. A reverse fault and two anticlines were invoked by Cattermole to explain exposures of "Holston" in three areas (Figure 8, Points D). These limestones are believed to be lenses within the lower Ottosee; the reverse fault and two anticlines do not exist. This situation is analogous to one in the southeastern part of the map (Figure 8, Point E) where a limestone quarry is unquestionably mapped by Cattermole as being within the Chapman Ridge. Figure 9 shows the same quarry to be part of the lower Ottosee. The detail of Plate 1 (J-10, In pocket) reveals a distinct lineation in the contour lines representing the crest of the ridge 1.6 km (1 mile) east of the quarry in J-10. This lineation is believed to represent the top of the Chapman Ridge Sandstone, which is overlain to the northwest by less resistant limestone and shale of the Ottosee.

The Chapman Ridge Sandstone is not laterally continuous, but pinches out in three areas (Figure 9, Points A) and is exposed as two long fingers (Figure 9, Points B). The two

long fingers are exposed, not because of uplift due to structural deformation, but because the sandstone is actually thicker in these areas where it is exposed, and thinner or non-existent in the intervening valley where Ottosee Shale is exposed. The Chapman Ridge Sandstone is shown in Figure 9, page 39, to be much more areally restricted than Cattermole believed (Figure 8, page 39), probably because of better outcrop control in the present study.

The Vestal "Marble" (Oom, Figure 8, page 39), according to Cattermole, forms a U-shaped outcrop pattern in the northeast part of the map area, failing by 1/7 km (1.1 mile) to reach the community of Vestal, for which the "Marble" is named and where supposedly the type section of Vestal exists. Marbloid limestones are exposed through the Ottosee Shale. Like the Chapman Ridge, they display poor lateral continuity, as can be seen from Figure 9, page 39, and Plate 1 (In pocket). An attempt was made to depict the boundaries of the Vestal (Oom, Figure 9, Point C, page 39, and Plates 1 and 2 (In pocket)), but this boundary outline of the Vestal is deceptively simple since it includes the complete range of biomicrites and biosparites described in Chapter II.

The outline of the Holston in the east central portion of Cattermole's map (Figure 8, Area F, page 39) is much more irregular than that of Payne (Figure 9, page 39). Cattermole may have assumed that the upper and lower Holston contacts were almost planar at the time of deposition. Subsequent deformation and erosion might have, in Cattermole's opinion,

resulted in an irregular outcrop pattern.

The present study indicates that lenses and beds of one formation may be found within an adjacent formation, making the exact location of the formation contact somewhat arbitrary in many areas. Deformation and topographic relief are not considered sufficient to produce the irregular Holston outcrop pattern of Cattermole. Interfingering of lithologies is a primary depositional feature. Therefore, formation contacts were drawn in smoother curves in Figure 9, page 39, and no attempt was made to include only one type of lithology within a single formation (Plates 1 and 2 (In pocket)).

Most of the modifications of Cattermole's map that are incorporated into Figure 9, page 39, and Plates 1 and 2 (In pocket) are the direct result of a detailed field examination and laboratory analysis of samples of this study area, rather than being an alternate interpretation of the same data on which Cattermole based his map.

This report and accompanying maps provide improved control of the structure and lithologic distributions of the study area. Independent studies of single units in this general area have been and will be conducted to provide additional information about the paleoenvironments of particular lithologies. However, integration of this information would be ad hoc without a geological map to support inferred environmental distributions. Such maps are presented with this report (Plates 1 and 2 (In pocket)) and should clarify the stratigraphy and

structure in this area of critical significance to the interpretation of Middle Ordovician stratigraphy in eastern Tennesee (Walker and Ferrigno, 1973).

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APPENDIXES

APPENDIX A

Figure 10. Photographed thin-sections and outcrops.

A. Drusy dolomite filling irregular voids among well-rounded dolomicrite intraclasts (?): close-up, plane-polarized light, thin-section x 1, Sample 75 (C-5), Knox Group.

B. Bifercating laminar to spherical and anastomosing cylindrical "birdseyes" in fine-grained dolostone matrix: close-up with cross-polarized light, acetate peel x 1, Sample 76 (C-5), Mosheim member of the Lenoir Limestone.

C. Cobbly-weathering limestone: Lenoir Limestone outcrop photograph, station 8 (F-8).

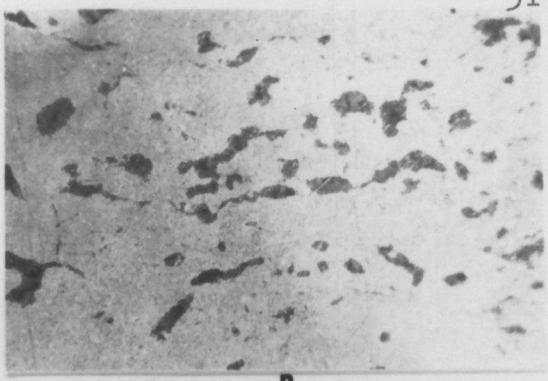
D. Interbeds, from bottom to top, of (1) dolomicrite, (2) ooids with carbonate grain nuclei and some quartz sand appearing as white grains, (3), dolomicrite, and (4) an interbed of terrigenous sand consisting primarily of quartz grains: microphotograph, plane-polarized light, thin-section x 10, Sample 90 (I-5), Ottosee Shale.

E. Large scale deformation of shale/siltstone lithology: bottom of photograph is approximately 16 m (50 feet) across, Ottosee Shale 0.6 km (0.4 mile) west of station 16 (I-9) on north side of John Sevier Highway.

F. Irregular, fossiliferous interbed of siltstone within fossiliferous oolite beds: left side of photograph is approximately 1 m (1 yard) high, Ottosee Shale 0.6 km (0.4 mile) south of study area (J-3), southeast part of Alcoa Highway roadcut.



A



B



D



C



E

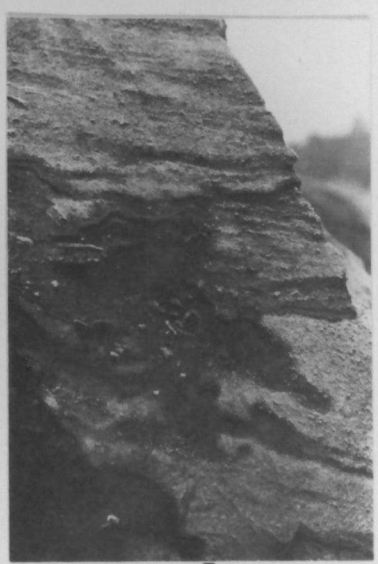


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FIGURE 10

Figure 11. A photographed thin-section and outcrops.

A. Biosparite showing (1) algally-bored pelmatozoan debris, and (2) micrite-filled zooecial tubes of bryozoan fragment: thin-section x 10, Holston Formation, Sample 13 (G-10).

B. Low-angle crossbeds: sandstone lithology of Chapman Ridge Formation, station 51 (H-5).

C. Low-angle crossbeds of dark siltstone and lighter oolite lithologies: bottom of photograph is approximately 0.5 m (0.5 yard) across, Ottosee Formation, 0.6 km (0.4 mile) south of study area (J-3), southwest part of Alcoa Highway roadcut.

D. Weathered shale/siltstone and more resistant sandstone lithologies show close paleoenvironmental association and crustal shortening via intense deformation typical in the southwestern part of the study area: bottom of photograph is approximately 6 m (20 feet) across, Ottosee Formation, station 142 (G-5, 6).

E. Oolite intraclasts within oolite, indicating early lithification of the ooid sand: bottom of photograph is approximately 1 m (1 yard) across: Ottosee Formation 0.6 km (0.4 mile) south of study area (J-3), northeast part of Alcoa Highway roadcut.

F. Intense deformation of sandstone which dies out 30 m (100 feet) to the south (right of photograph) where medium-bedded sandstone dips 7° south southeast: bottom of photograph is approximately 6 m (6 yards) across, Chapman Ridge Formation, station 69 (G-6).

G. Irregular, thick-bedded biomicrite: bottom of photograph is slightly over 3 m (approximately 10 feet) across, Ottosee Formation, station 4 (C-7).



A



B



C



D



E



F



G

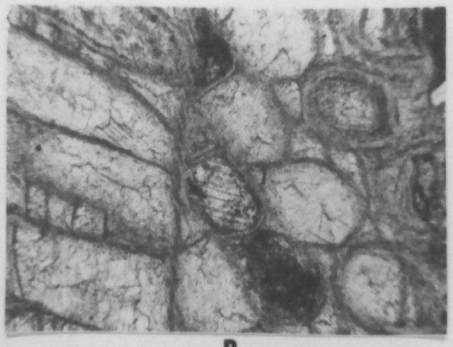
FIGURE II

Figure 12. Thin-section photographs of identified bryozoa.

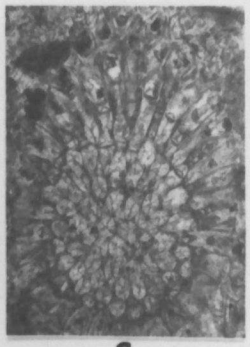
Name	Formation	Station	Magnification
A. Pachydictia	Holston	46A	45
B. Pachydictia	Ottosee	36B	45
C. Eridotrypa	Ottosee	86	10
D. Monticulipora	Vestal	57C	45
E. Phaneopora	Holston	6	10
F. Stictopora	Holston	80	45
G. Hallopora	Holston	6	10
H. Nicholsonella	Holston	112	10
I. Eridotrypa	Holston	46A	10
J. Ottoseetaxis	Ottosee	112	45
K. Eridotrypa	Holston	118	10



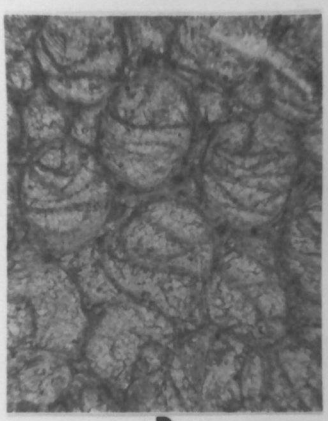
A



B



C



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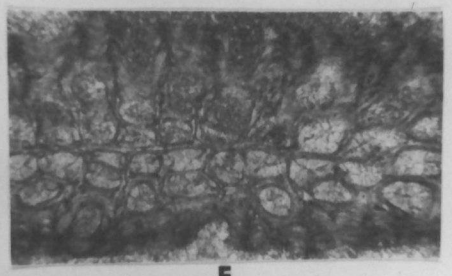


E



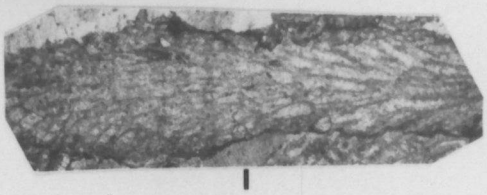
F



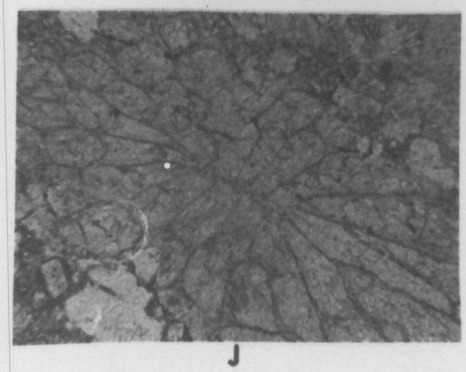
H



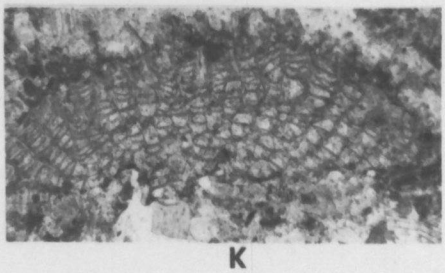
G



I



J



K

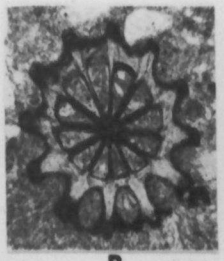
FIGURE 12

Figure 13. Additional thin-section photographs of identified bryozoa.

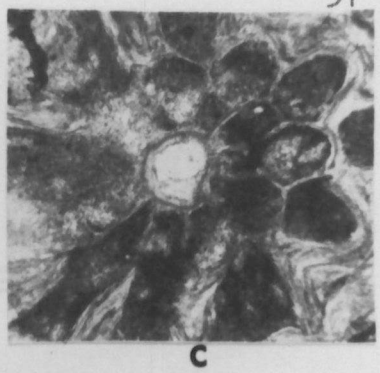
Name	Formation	Station	Magnification
A. Hemiphragma	Ottosee	86	45
B. Helopora	Ottosee	34	45
C. Coeloclema	Holston	46A	45
D. Batastoma	Ottosee	102	10
E. Prasopora	Ottosee	59	10
F. Batastoma	Ottosee	121	45
G. Prasopora	Holston	46A	45
H. Batastoma	Ottosee	121	10
I. Stictopora	Holston	46A	10



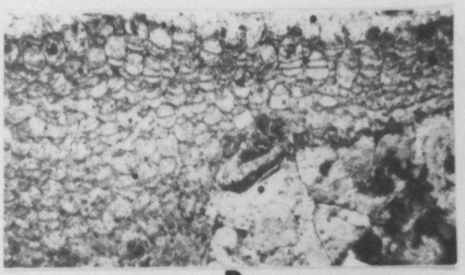
A



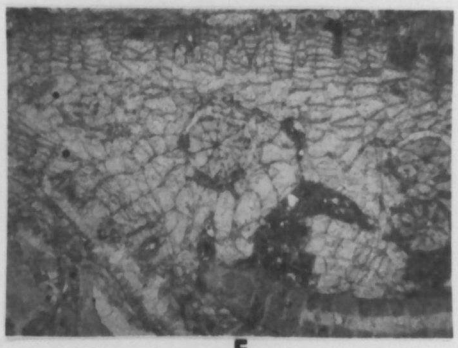
B



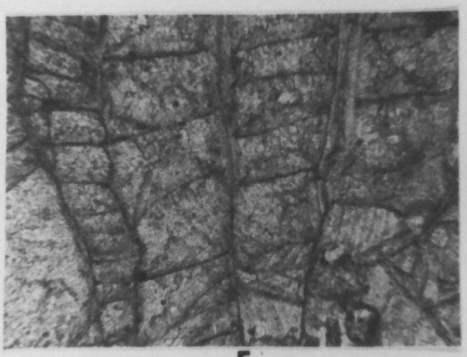
C



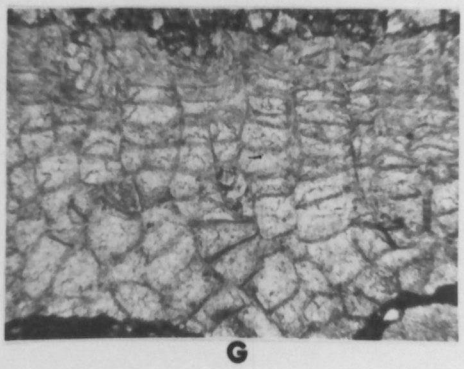
D



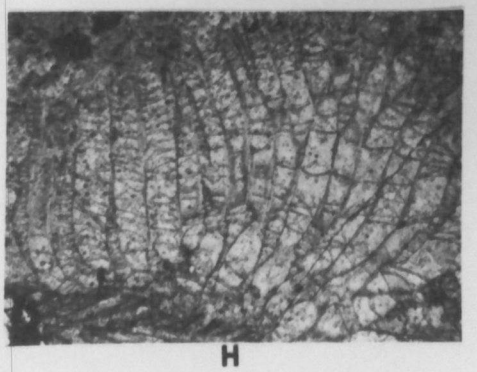
E



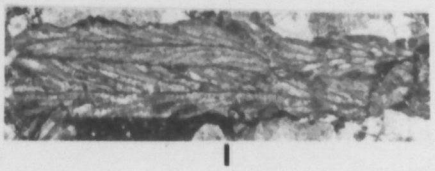
F



G



H



I

FIGURE 13

APPENDIX B

Table I

Point-Count Data

Slide Number (Map Location)	Components	Percentage
6 (E-8)	Bryozoa, identified	
	Eridotrypa	0.5
	Hallopora	5.0
	Ottoseetaxis	0.2
	Pachydictia	1.5
	Phaenopora	0.5
	Prasopora	6.5
	Stictopora	0.2
	Fragments	
	Bivalve	0.3
	Bryozoa	14.5
	Fossil	3.0
	Pelmatozoa	16.0
	Micrite	29.2
	Spar	23.3
13 (F-10)	Bryozoa, identified	
	Ottoseetaxis	0.2
	Pachydictia	0.4
	Stictopora	0.2
	Stictoporella	0.8
	Fragments	
	Bivalve	0.8
	Bryozoa	18.6
	Fossil	0.6
	Pelmatozoa	23.0
	Trilobite	0.2
	Grains, terrigenous	
	Quartz	0.3
	Iron Oxide	1.6
	Micrite	3.4
	Microspar	8.8
	Spar	41.0
18 (H-8)	Bryozoa, identified	
	Helopora	0.2
	Fragments	
	Bivalve	0.3
	Bryozoa	27.8
	Fossil	1.3
	Pelmatozoa	21.8
	Grains, terrigenous	
	Chert	0.4

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Perthite	0.4
	Quartz	9.7
	Iron Oxide	3.8
	Microspar	2.1
	Spar	34.0
23 (G-8)	Bryozoa, identified	
	Batastoma	2.4
	Nicholsonella	3.2
	Pachydictia	0.2
	Fragments	
	Bivalve	0.2
	Bryozoa	24.6
	Fossil	2.0
	Pelmatozoa	22.0
	Micrite	6.4
	Spar	40.7
29 (J-4)	Fragments	
	Bivalve	0.5
	Bryozoa	1.2
	Fossil	0.5
	Grains, intraclastic	
	Micrite	0.3
	Grains, terrigenous	
	Chert	0.3
	Quartz	6.4
	Micrite	3.1
	Ooids	43.5
34 (I-3)	Bryozoa, identified	
	Eridotrypa	0.5
	Helopora	0.2
	Hemiphragma	0.2
	Ottoseetaxis	0.3
	Pachydictia	0.3
	Fragments	
	Bivalve	0.5
	Bryozoa	5.8
	Fossil	3.8
	Pelmatozoa	12.3
	Trilobite	1.4
	Grains, terrigenous	
	Quartz	7.0
	Micrite	8.2
	Microspar	17.7

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Spar	41.8
36B (H-4)	Bryozoa, identified	
	Helopora	0.1
	Pachydictia	1.6
	Fragments	
	Bryozoa	9.2
	Fossil	0.4
	Pelmatozoa	20.0
	Grains, interclastic	
	Micrite	6.5
	Grains, terrigenous	
	Chert	0.4
	Glauconite	0.1
	Perthite	0.1
	Quartz	18.0
	Iron Oxide	10.0
	Micrite	11.5
	Microspar	7.8
	Spar	14.0
46A (E-8)	Bryozoa, identified	
	Coeloclema	0.5
	Eridotrypa	1.9
	Hemiphragma	0.9
	Ottoseetaxis	1.6
	Pachydictia	1.4
	Prasopora	3.8
	Stictopora	0.3
	Stictoporella	2.5
	Fragments	
	Bivalve	0.2
	Bryozoa	22.6
	Fossil	0.9
	Pelmatozoa	32.2
	Trilobite	0.3
	Iron Oxide	1.4
	Micrite	11.1
	Spar	18.9
46B (E-8)	Bryozoa, identified	
	Nicholsonella	3.2
	Prasopora	0.8
	Stictopora	0.6
	Stictoporella	0.8
	Fragments	

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Bivalve	0.5
	Bryozoa	19.8
	Fossil	1.6
	Pelmatozoa	26.4
	Iron Oxide	4.0
	Micrite	8.5
	Spar	31.2
49 (I-5)	Bryozoa, identified	
	Eridotrypa	2.1
	Ottoseetaxis	0.4
	Prasopora	2.7
	Strictopora	2.0
	Fragments	
	Bivalve	0.2
	Bryozoa	11.4
	Fossil	0.8
	Pelmatozoa	35.6
	Trilobite	0.3
	Grains, terrigenous	
	Quartz	0.4
	Micrite	5.2
	Spar	38.8
53 (G-5)	Fragments	
	Bivalve	0.3
	Bryozoa	2.9
	Fossil	3.8
	Pelmatozoa	1.7
	Trilobite	0.5
	Grains, intraclastic	
	Micrite	2.1
	Grains, terrigenous	
	Chert	0.2
	Quartz	13.1
	Iron Oxide	4.2
	Micrite	3.3
	Ooids	9.5
	Spar	58.2
57 (C-10)	Bryozoa, identified	
	Batastoma	1.5
	Nicholsonella	4.4
	Ottoseetaxis	0.3
	Prasopora	1.0
	Stictopora	1.3

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Stictoporella	0.2
	Fragments	
	Bryozoa	11.1
	Fossil	6.0
	Pelmatozoa	7.9
	Trilobite	0.8
	Micrite	40.1
	Spar	25.0
57B (C-10)	Fragments	
	Bryozoa	8.2
	Fossil	0.1
	Pelmatozoa	24.9
	Trilobite	9.2
	Grains, terrigenous	
	Quartz	2.0
	Iron Oxide	1.5
	Micrite	16.9
	Spar	37.8
57C (C-10)	Bryozoa, identified	
	Batastoma	15.3
	Helopora	0.3
	Monticulipora	5.4
	Ottoseetaxis	0.3
	Pachydictia	0.3
	Stictopora	0.3
	Stictoporella	1.1
	Fragments	
	Bivalve	0.5
	Bryozoa	6.0
	Pelmatozoa	5.7
	Micrite	22.8
	Spar	42.5
65 (G-5)	Bryozoa, identified	
	Helopora	0.2
	Ottoseetaxis	0.3
	Stictopora	0.3
	Fragments	
	Bivalves	0.2
	Bryozoa	9.7
	Pelmatozoa	7.5
	Trilobite	0.3
	Grains, terrigenous	
	Quartz	4.7

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Micrite	12.7
	Spar	63.8
70 (G-7)	Fragments	
	Bivalve	0.5
	Bryozoa	15.1
	Pelmatozoa	10.0
	Trilobite	0.2
	Grains, intraclastic	
	Calcareous	21.7
	Grains, terrigenous	
	Chert	0.2
	Quartz	7.7
	Iron Oxide	4.9
	Micrite	18.1
	Spar	22.2
78 (D-5)	Fragments	
	Bryozoa	1.0
	Pelmatozoa	6.0
	Grains, intraclastic	
	Calcareous	22.0
	Grains, terrigenous	
	Perthite	6.0
	Quartz	37.4
	Iron Oxide	13.8
	Micrite	8.9
	Spar	4.9
80 (F-7)	Bryozoa, identified	
	Batastoma	13.4
	Ottoseetaxis	0.3
	Fragments	
	Bryozoa	5.1
	Fossil	0.6
	Pelmatozoa	6.7
	Trilobite	0.1
	Grains, intraclastic	
	Micrite	0.1
	Micrite	47.5
	Spar	25.2
82 (E-7)	Fragments	
	Bryozoa	0.3
	Fossil	0.2
	Pelmatozoa	2.6

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Grains, intraclastic	
	Calcareous	1.5
	Grains, terrigenous	
	Quartz	13.8
	Iron Oxide	0.3
	Ooids	32.9
	Spar	48.3
83	Fragments	
(E-4)	Bryozoa	0.2
	Pelmatozoa	1.3
	Grains, intraclastic	
	Micrite	0.2
	Grains, terrigenous	
	Chert	0.5
	Quartz	10.4
	Iron Oxide	1.6
	Ooids	47.3
	Spar	38.4
84	Fragments	
(E-4)	Bryozoa	1.0
	Pelmatozoa	3.7
	Grains, intraclastic	
	Calcareous	1.6
	Grains, terrigenous	
	Chert	0.3
	Quartz	11.1
	Iron Oxide	1.8
	Ooids	37.4
	Spar	43.0
86	Bryozoa, identified	
(H-5)	Batastoma	1.8
	Eridotrypa	1.0
	Helopora	0.6
	Hemiphragma	0.8
	Ottoseetaxis	0.2
	Stictopora	1.8
	Stictoporella	1.6
	Cephalopod	2.6
	Fragments	
	Bivalve	0.5
	Bryozoa	9.9
	Fossil	0.2
	Pelmatozoa	19.3

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Trilobite	0.3
	Micrite	9.2
	Ostracode	0.2
	Spar	50.2
90 (H-5)	Fragments	
	Pelmatozoa	1.0
	Grains, terrigenous	
	Quartz	1.0
	Micrite	0.7
	Ooids	62.2
	Spar	35.2
97 (I-4)	Fragments	
	Bryozoa	0.7
	Pelmatozoa	7.5
	Grains, terrigenous	
	Quartz	12.2
	Iron Oxide	0.3
	Micrite	7.3
	Ooids	34.0
	Spar	38.1
102 (G-6)	Bryozoa, identified	
	Atactotoechus	2.0
	Eridotrypa	1.3
	Ottoseetaxis	3.2
	Pachydictia	0.5
	Stictoporella	4.3
	Fragments	
	Bryozoa	6.1
	Grains, intraclastic	
	Calcareous	7.9
	Grains, terrigenous	
	Chert	0.2
	Quartz	19.3
	Iron Oxide	1.3
	Micrite	53.9
112 (G-9)	Bryozoa, identified	
	Eridotrypa	1.3
	Helopora	0.3
	Nicholsonella	2.0
	Pachydictia	1.3
	Stictoporella	1.2
	Fragments	

Table I (continued)

Slide Number (Map Location)	Components	Percentage
	Bivalve	3.5
	Bryozoa	6.0
	Pelmatozoa	10.7
	Trilobite	0.3
	Micrite	14.9
	Spar	58.8
118 (G-8)	Bryozoa, identified	
	Monticulipora	5.7
	Fragments	
	Bryozoa	23.4
	Pelmatozoa	4.9
	Grains, intraclastic	
	Micrite	14.6
	Spar	51.4
121 (F-6)	Bryozoa, identified	
	Batastoma	6.6
	Coeloclema	1.0
	Nicholsonella	1.0
	Ottoseetaxis	0.3
	Stictoporella	0.3
	Fragments	
	Bivalve	1.9
	Bryozoa	2.4
	Pelmatozoa	5.8
	Grains, intraclastic	
	Calcareous	5.3
	Grains, terrigenous	
	Quartz	11.4
	Iron Oxide	2.4
	Spar	61.7
127 (G-10)	Bryozoa, identified	
	Pachydictia	1.9
	Fragments	
	Bryozoa	4.3
	Pelmatozoa	11.3
	Grains, intraclastic	
	Micrite	8.0
	Grains, terrigenous	
	Chert	1.4
	Quartz	31.8
	Iron Oxide	5.3
	Spar	38.0

Table I (continued)

Slide Number (Map Location)	Components	Percentage
128 (G-9)	Fragments	
	Bryozoa	10.6
	Pelmatozoa	36.8
	Trilobite	0.1
	Grains, intraclastic	
	Calcareous	0.1
	Micrite	0.1
	Grains, terrigenous	
	Quartz	0.5
	Iron Oxide	3.1
	Spar	46.7

VITA

William Walter Payne, III was born in Birmingham, Alabama on September 10, 1945. He attended elementary schools in that city and was graduated from Shades Valley High School in 1963. The following September he entered Howard College, and transferred the following year to Birmingham-Southern College, where he received a Bachelor of Science degree in Geology.

In September of 1967 he began study toward a Master's degree at the University of Tennessee. He received this degree in Geology in December, 1975.

He is a member of the Association of Exploration Geochemists.

He is married to the former Melinda Carol Zodin of Birmingham, Alabama.

LEGEND

LITHOLOGIES

- TERRACE DEPOSITS
- OOLITE
- BIOSPARITE/BIOMICRITE
- SANDSTONE
- SHALE/SILTSTONE
- COBBLY-WEATHERING LIMESTONE
- DISMICRITE
- DOLOSTONE

ACTIVE QUARRY

INACTIVE QUARRY

PLUNGING ANTICLINE (30 / 10 / 60)

⑦ STATION NUMBER

FORMATION CONTACTS

- GOOD CONTROL
- FAIR CONTROL
- POOR CONTROL
- LEAST CONTROL

FORMATIONS

- Oo OTTOSEE
- Oom OTTOSEE "MARBLE"
- Ocr CHAPMAN RIDGE
- Oh HOLSTON
- Ol LENOIR
- Olm MOSHEIM (LENOIR BASAL MEMBER)
- Ok KNOX

FOR DETAIL SEE FERRIGNO AND WALKER (1973)

SCALE 1:24 000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 KILOMETER

CONTOUR INTERVAL 20 FEET

DATUM IS MEAN SEA LEVEL

UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

1°43' 30 MILS | 9 MILS

ROAD CLASSIFICATION

Heavy-duty — Poor motor road

Medium-duty — Wagon and jeep track

Light-duty — Foot trail

Interstate Route | U. S. Route | State Route

In developed areas, only through roads are classified

QUADRANGLE LOCATION (ILL. KENTUCKY VA. MO. TENNESSEE NC. MISS. ALA. GA. S.C.)

OUTCROP MAP

KNOXVILLE, TENN.

PLATE 1

ALCOA 7 MI. MARYVILLE 9 MI. | MARYVILLE 9 MI. | MARYVILLE 147-SW TIPTON 0.4 MI. | WILDWOOD 7 MI. | SEVIER HOME 0.2 MI. | SHOOKS GAP 6 MI. SEVIERVILLE 20 MI. | SHOOKS GAP 147-NE | (WILDWOOD 147-SE 4265 V SE)

35°52'30" 83°52'30" 57'30" 55'

LEGEND

- Oo — OTTOSEE
- OOM — OTTOSEE "MARBLE"
- OCR — CHAPMAN RIDGE
- OH — HOLSTON
- OL — LENOIR
- OLM — MOSHEIM (LENOIR BASAL MEMBER)
- OK — KNOX

FORMATION CONTACTS

- GOOD CONTROL
- FAIR CONTROL
- POOR CONTROL
- LEAST CONTROL

PLUNGING SYNCLINE

ANTICLINE



SCALE 1:24000

1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
VERTICAL EXAGGERATION 2X

MN GN 1°43 30 MILS ½° 9 MILS

UTM GRID AND 1966 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

ROAD CLASSIFICATION

Heavy-duty ..... Poor motor road .....
Medium-duty ..... Wagon and jeep track _ _ _ _
Light-duty ..... Foot trail .....

Interstate Route U. S. Route State Route

In developed areas, only through roads are classified

QUADRANGLE LOCATION

ILL. KENTUCKY VA. MO. TENNESSEE NC MISS ALA GA SC

GEOLOGIC MAP STRUCTURAL CROSS SECTIONS

KNOXVILLE, TENN.

PLATE 2