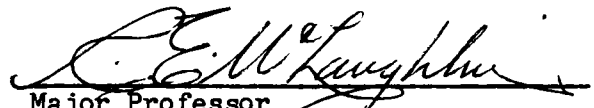


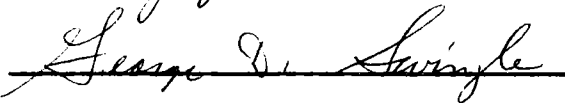
August 6, 1965

To the Graduate Council:

I am submitting herewith a thesis written by William Ralph Moehl entitled "A Study of the Lenoir Limestone in the Knoxville-Friendsville Belt, Knox and Blount Counties, Tennessee." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.


Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:


Dean of the Graduate School

**A STUDY OF THE LENOIR LIMESTONE IN THE KNOXVILLE-FRIENDSVILLE BELT,
KNOX AND BLOUNT COUNTIES, TENNESSEE**

**A Thesis
Presented to
the Graduate Council of
The University of Tennessee**

**In Partial Fulfillment
of the Requirements for the Degree
Master of Science**

**by
William Ralph Moehl
August 1965**

PREFACE

Efforts in the past to correlate and establish facies relationships among several named units of the Chickamauga and equivalent rocks in the Valley and Ridge province have led to many conflicting opinions.

At the suggestion of Dr. Robert E. McLaughlin of the Department of Geology and Geography, The University of Tennessee, the following study of a portion of the Lenoir Limestone, one of the units involved in the controversy, was undertaken. The writer wishes to express his deepest gratitude to Dr. McLaughlin for his encouragement, suggestions, criticism, and guidance throughout the course of the field work and preparation of the manuscript. Thanks are due also to Drs. Harry J. Klepser and George D. Swingle for enlightening discussions of the problem and for helpful criticism in reviewing the thesis.

Many fellow graduate students extended assistance and offered useful suggestions during the course of the investigation, and a special debt is owed to one, Mr. Sam Pickering, Jr., for making specimen photographs used in the thesis. For many hours contributed to assisting him in assembling fossil collections and measuring sections in the field, the writer is especially grateful to his patient wife, Sandra.

A grant from a departmental fund supplied by the Mobil Oil Company helped defray expenses of the thesis and is acknowledged with gratitude.

TABLE OF CONTENTS

CHAPTER	PAGE
I. INTRODUCTION.	1
General Introduction.	1
Previous Investigations	1
Present Investigation	3
II. STRATIGRAPHY.	8
Introduction.	8
General Geologic History.	8
General Stratigraphy.	9
Lower Ordovician Series	9
Newala Formation.	9
Middle Ordovician Series.	10
Lenoir Limestone.	10
Mosheim Member.	10
Main Body of Lenoir	12
Holston Formation	14
Chapman Ridge Sandstone	15
Ottosee Shale	19
Bays Formation.	19
Description of Measured Sections.	20
Introduction.	20
Section A	20
Section B	25

CHAPTER	PAGE
Section C.	29
Section D.	32
Section E.	34
Section F.	38
III. PALEONTOLOGY AND PALEOECOLOGY.	41
Introduction	41
Systematic Paleontology.	42
Introduction	42
Composite Biota.	42
Zonal Associations	44
Zone I	44
Zone II.	45
Zone III	46
Zone IV.	46
Zone V	48
Zone VI.	48
Zone VII	49
Paleoecology	62
Introduction	62
Zone I	62
Zone II...	66
Zone III	67
Zone IV.	70

CHAPTER	PAGE
Zone V.	78
Zone VI	78
Zone VII.	81
Gastropod Element	82
Sponge Element.	83
Cryptozoan-Stromatolite Element	84
Cephalopod Element.	85
Brachiopod and other Elements	87
IV. THE CORRELATION PROBLEM	88
Introduction.	88
Stage and Inter-formational Correlation	88
The " <u>Christiania</u> Beds".	90
Conclusions Regarding Correlation	93
V. SUMMARY AND CONCLUSIONS	94
Knoxville-Friendsville Lenoir	94
Regional Implications	96
Suggestions for Further Investigations.	101
BIBLIOGRAPHY.	104

LIST OF FIGURES

FIGURE	PAGE
1. Comparison of Stratigraphic Sections Friendsville-Knoxville Portion, Main Red Belt, Ordovician Rocks of East Tennessee	4
2. Contrasting Facies Interpretations of Ordovician Rocks in the Knoxville, Tennessee, Region. A. By John Rodgers. B. By Byron Cooper. (From W. H. Twenhofel, <u>et al.</u> , 1954)	5
3. Location and General Geologic Setting of Thesis Area	6
4. Contact Between the Mosheim Member and Overlying Typical Lenoir Exposed South of Blue Grass, Tennessee. This Photograph Illustrates the Contrasting Lithologies and the Erosional Surface on Top of the Mosheim. T.G.C. are 541,125 N. and 2,574,375 E.	11
5. Brecciated Zone at the Base of the Mosheim Exposed at Blue Grass, Tennessee. The Breccia Consists of Mosheim Fragments in a "Marble-like" Matrix. It is Probably the Result of a Sink Filling. T.G.C. are 541,000 N. and 2,574,200 E.	13
6. Lenoir-type Lithology Exposed Along Alcoa Highway, Knoxville, Tennessee. A Thin Shaly, Nodular Limestone Resembling the Lenoir Commonly Occurs in or Immediately on Top of the Holston. In this Exposure the Shaly Limestone is Found Between two Holston Units. T.G.C. are 565,375 N. and 2,577,065 E.	16
7. Lenoir-type Lithology Exposed in Blue Grass Area Quarry. An Impure, Nodular Limestone Resembling the Lenoir Caps the Holston in most Marble Quarries in the Thesis Area. T.G.C. are 538,450 N. and 2,574,875 E.	17
8. Abandoned Quarry in Upper Portion of the Lenoir Limestone in Section A. T.G.C. 502,100 N. and 2,555,400 E.	22
9. Zone II Beds Exposed Along Pastured Hillsides. This Exposure Occurs in Section B just North of Gooseneck Road in Blount County, Tennessee. T.G.C. are 508,600 N. and 2,556,590 E. Erosion Produces a Number of Benches in the Slightly Dipping Beds.	26

FIGURE

PAGE

10. Relatively Fresh Exposure of Lenoir Limestone Along
Alcoa Highway, Knoxville, Tennessee. This Photograph
Illustrates the Thick-bedded Nature of the Lenoir.
Differential Weathering is Already Taking Place and
Eventually it will Create the Characteristic Nodular
or Cobbly Weathered Appearance of the Limestone.
T.G.C. are 565,880 N. and 2,567,000 E. 35
11. Fossils of the Lenoir Limestone Characteristic of
Zone I. 50-51
12. Fossils of the Lenoir Limestone Characteristic of
Zone II 52-53
13. Fossils of the Lenoir Limestone Characteristic of
Zone III. 54-55
14. Fossils of the Lenoir Limestone, Zones I, IV,
and VII 56-57
15. Fossils of the Lenoir Limestone, Zones II and VI. 58-59
16. Fossils of the Lenoir Limestone Characteristic of
Zone VII. 60-61
17. Maclurites-dominated Zone I. This Photograph Illustrates
the Large Size and Abundance of Maclurites Casts in
Zone I. T.G.C. are 618,600 N. and 2,726,350 E. 64
18. Shaly, Chert-bearing, Unfossiliferous Beds of Zone III,
Section C. This Exposure is Located Approximately
2 Miles Northeast of Friendsville. T.G.C. are
511,300 N. and 2,559,190 E. 68
19. Porous, Yellow-brown Chert Nodules Weathered Out of
Beds in Zone III, Section C. Chert of this Type is
Common in Both the Lower and Upper Portions of the
Lenoir. T.G.C. are 511,300 N. and 2,559,190 E. 69
20. "Christiania Beds," Subzone IV a., Section B. A. Massive,
Resistant Ledges with Typical Nodular or Cobbly
Appearance. Note the Development of Residium which is
Distinctive and Typical of this Subzone. B. Concentration
of Christiania subquadrata. T.G.C. are 507,100 N. and
2,557,825 E. 72

FIGURES

PAGE

21. Quarry in Zone IV. This Photograph Illustrates the Massiveness of the Zone. This is a Former Blount County Quarry just Recently Abandoned. T.G.C. are 518,400 N. and 2,577,400 E. 74
22. Weathered Exposure of Subzone IV b., Section B. This View Illustrates the Rubbly Surfaces of Small Slabby Blocks and Chips formed by this Subzone in Contrast to Subzone IV a. which retains its Massive Appearance. T.G.C. are 506,680 N. and 2,557,825 E. 75
23. Zone VI, Section A. Sponges are Often Abundant in this Zone and as Illustrated by this Photograph they may be Partially Responsible for the Nodular or Cobbly Weathered Appearance. T.G.C. are 501,710 N. and 2,553,090 E. 80
24. Close Association of Maclurites and Cryptozoans in Zone VII. The Large Cryptozoan in this Photograph is Flanked by Casts of Maclurites Indicated by the Circles on the Outcrop. In this same Location Cryptozoans were Found Encrusted on Casts of the Gastropod. T.G.C. for this Location are 529,435 N. and 2,570,875 E. 86
25. Suggested Regional Relationship of the Knoxville-Friendsville Lenoir Section (A-A') 98
26. Argillaceous Partings in the Lenoir Limestone. These Clay Stringers are very Common Throughout the Lenoir. They are Especially well Developed in Subzone IV a., the "Christiania beds." The Partings Probably Play an Important Role in the Development of Soil and the Lenoir Characteristic Weathered Appearance. 100

CHAPTER I

INTRODUCTION

General Introduction

The stratigraphy, subdivision, and correlation of the rocks of the Chickamauga Group or their equivalents have long been the subject of controversy (Rodgers, 1953, p. 64). In the east central belts of the Valley and Ridge province, interpretation of the Lenoir Limestone is a major issue involved in the controversy. The Lenoir proper or Lenoir-type lithologies have been widely recognized in the southern Appalachians, from Virginia to Alabama. The type locality and distinctive outcropping belts of this formation are located in central East Tennessee.

Previous Investigations

In 1869, Safford first recognized the Blue or Maclurea Limestone, which he and Killebrew (1876) later named the Lenoir Limestone for Lenoir City, Tennessee. Keith (1895, 1896) noted that the lower portion of the Chickamauga Limestone (named by Hayes, 1891), consisted of a blue-gray argillaceous limestone in the Knoxville and Loudon quadrangles. He observed the fossiliferous nature of these beds, now called Lenoir, and their relationship to the underlying Knox Group. He also named the "marble" portion of the Chickamauga the Holston Formation. Hayes (1895), while doing folio mapping in East Tennessee, described the various

CHAPTER I

INTRODUCTION

General Introduction

The stratigraphy, subdivision, and correlation of the rocks of the Chickamauga Group or their equivalents have long been the subject of controversy (Rodgers, 1953, p. 64). In the east central belts of the Valley and Ridge province, interpretation of the Lenoir Limestone is a major issue involved in the controversy. The Lenoir proper or Lenoir-type lithologies have been widely recognized in the southern Appalachians, from Virginia to Alabama. The type locality and distinctive outcropping belts of this formation are located in central East Tennessee.

Previous Investigations

In 1869, Safford first recognized the Blue or Maclurea Limestone, which he and Killebrew (1876) later named the Lenoir Limestone for Lenoir City, Tennessee. Keith (1895, 1896) noted that the lower portion of the Chickamauga Limestone (named by Hayes, 1891), consisted of a blue-gray argillaceous limestone in the Knoxville and Loudon quadrangles. He observed the fossiliferous nature of these beds, now called Lenoir, and their relationship to the underlying Knox Group. He also named the "marble" portion of the Chickamauga the Holston Formation. Hayes (1895), while doing folio mapping in East Tennessee, described the various

lithologies of the Chickamauga. Ulrich (1911) subsequently named the lower member of the formation the Mosheim Limestone for Mosheim, Tennessee, where it is well exposed.

Raymond (1925, 1928, 1940) wrote several papers on fossils present in the Lenoir. Butts described and illustrated the Lenoir and Mosheim and their representative fossils in Alabama (1926) and Virginia (1940). In the latter paper, Butts attempted to correlate the Virginia section with presumed Chazyan age equivalents in Central Tennessee, Central Pennsylvania, and the Champlain Valley of New York.

Rodgers (Twenhofel, et al., 1954) pointed out that the contact between the Athens and the underlying Lenoir is gradational and that there is also a lateral gradation of the Athens Shale into the Lenoir Limestone. He concluded that the lowest beds of the Lenoir occur under the shale while the rest is equivalent to the Athens. Again, Rodgers (1953) described the Chickamauga Group throughout East Tennessee, making belt to belt comparisons and pointing out north-south variations within each individual belt.

B. N. Cooper and G. A. Cooper (G. A. Cooper, 1956) restricted the term Lenoir to the sequence exposed at the type locality at Lenoir City, Tennessee. This excluded the portion of the section in the Knoxville-Friendsville belt which in part contains distinctive beds of the brachiopod, Christiania. These authors then called this "Upper Lenoir," the Arline Formation, named for the railroad switch of Arline, Blount County, Tennessee.

G. A. Cooper (1956) has provided a very detailed account of the brachiopods in the type section Lenoir and in the Arline upper division.

In the past several years, a number of unpublished University of Tennessee theses directed at a stratigraphic study of Middle Ordovician formations in East Tennessee have included descriptions of all or parts of the Chickamauga Group.

Present Investigation

Published sections (Figure 1) and facies diagrams (Figure 2) interpreting the stratigraphy and relationships of the Lenoir and associated formations point up the need for further examination of these rocks. The purpose of this thesis is to present a detailed investigation of the Lenoir Limestone in the Knoxville-Friendsville belt between the Knoxville and Rocky Valley faults on the northwest and the Chestusee and Dumplin Valley faults on the southeast (Figure 3). This area was selected because of its well known and developed section, its fairly continuous exposure, and comparative lack of structural complexity. The portion of the belt examined extends from one mile southeast of Friendsville, Tennessee, to Cherokee Bluff on the southeast shore of Fort Loudon Lake in Knoxville, Tennessee (see Plate 1). Other Lenoir exposures outside this area were examined for comparative purposes.

In the present study, observations were made of the various lithologic changes in the formation and the faunal types were recorded

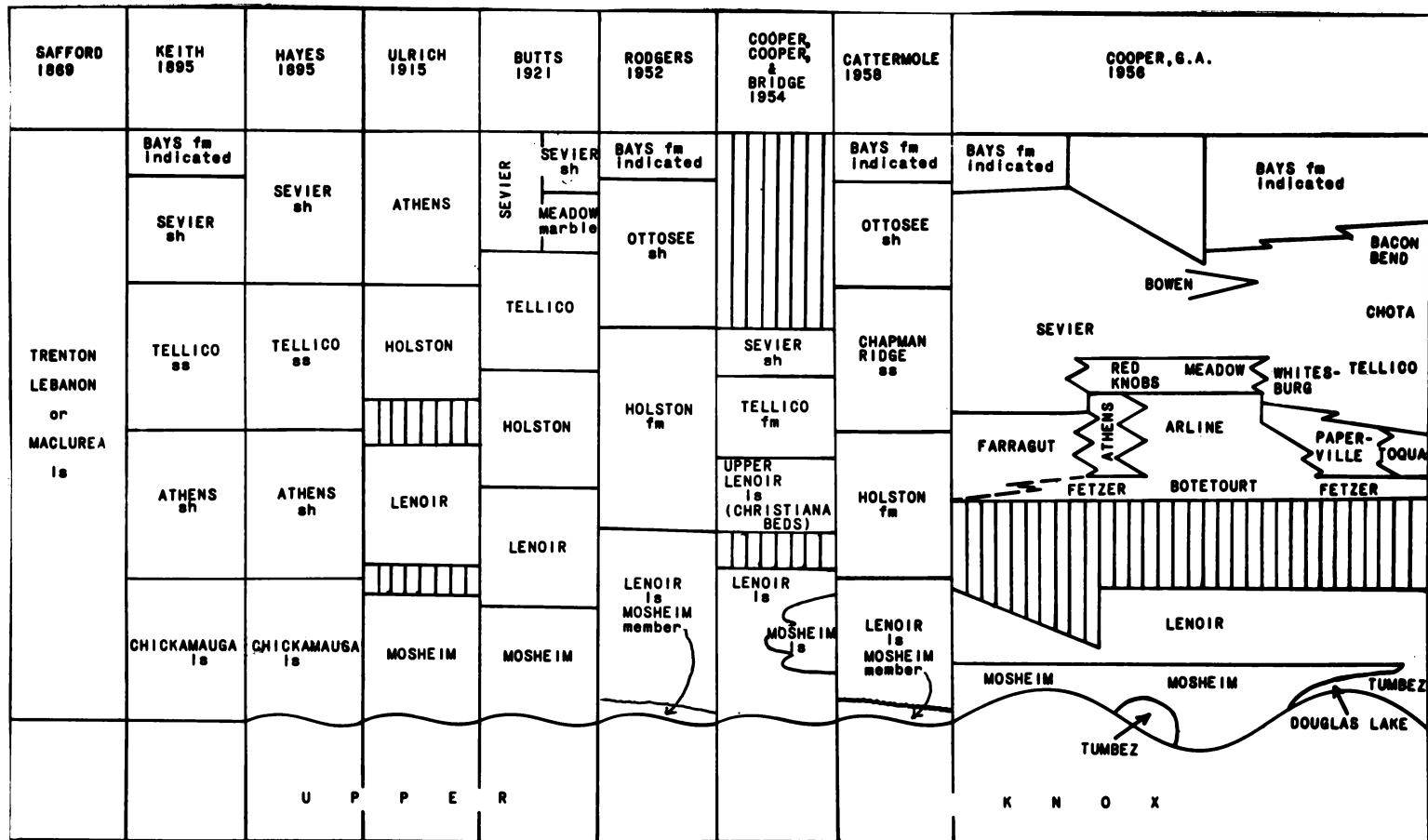
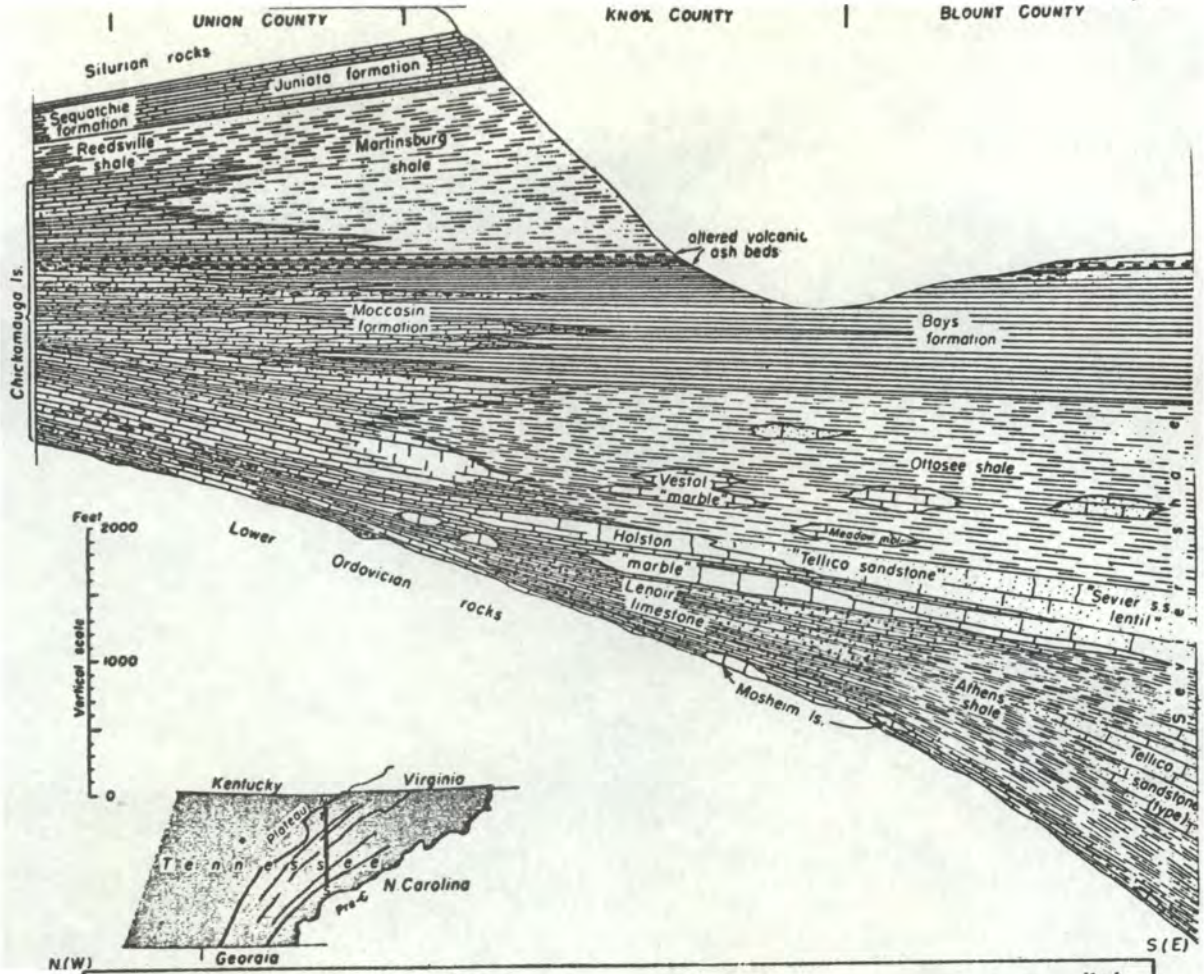


Figure 1. Comparison of stratigraphic sections
Friendsville-Knoxville Portion, Main Red
Belt, Ordovician rocks of East Tennessee.

A



B

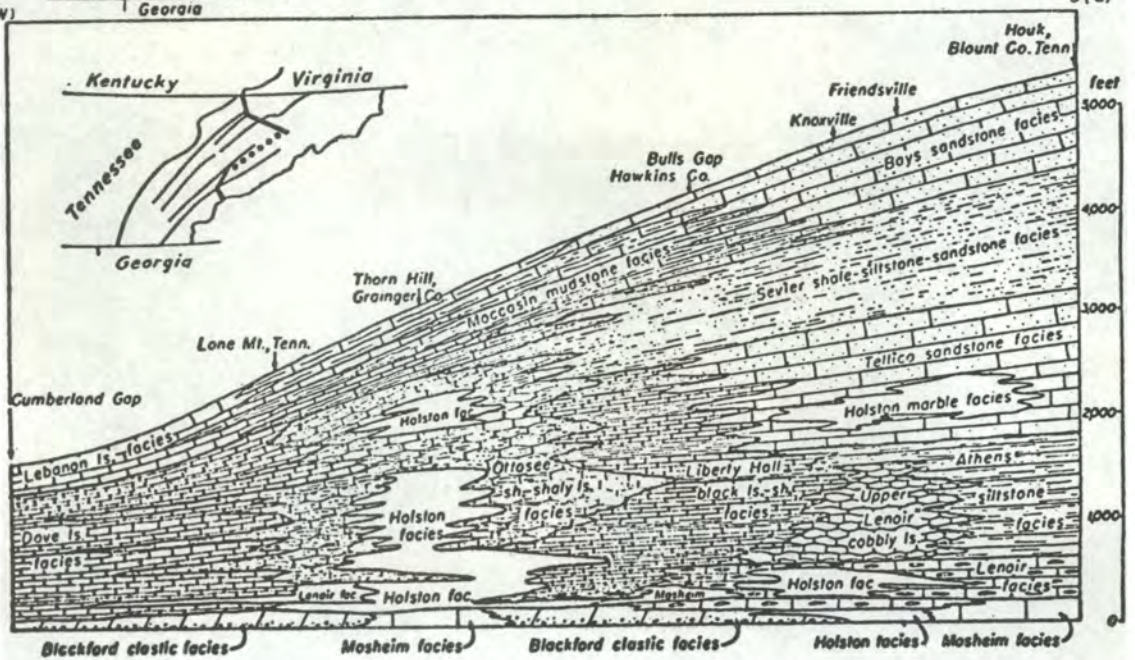


Figure 2. Contrasting facies interpretations of Ordovician rocks in the Knoxville, Tennessee, region. A. By John Rodgers. B. By Byron Cooper. (From W. H. Twenhofel, et al., 1954.)

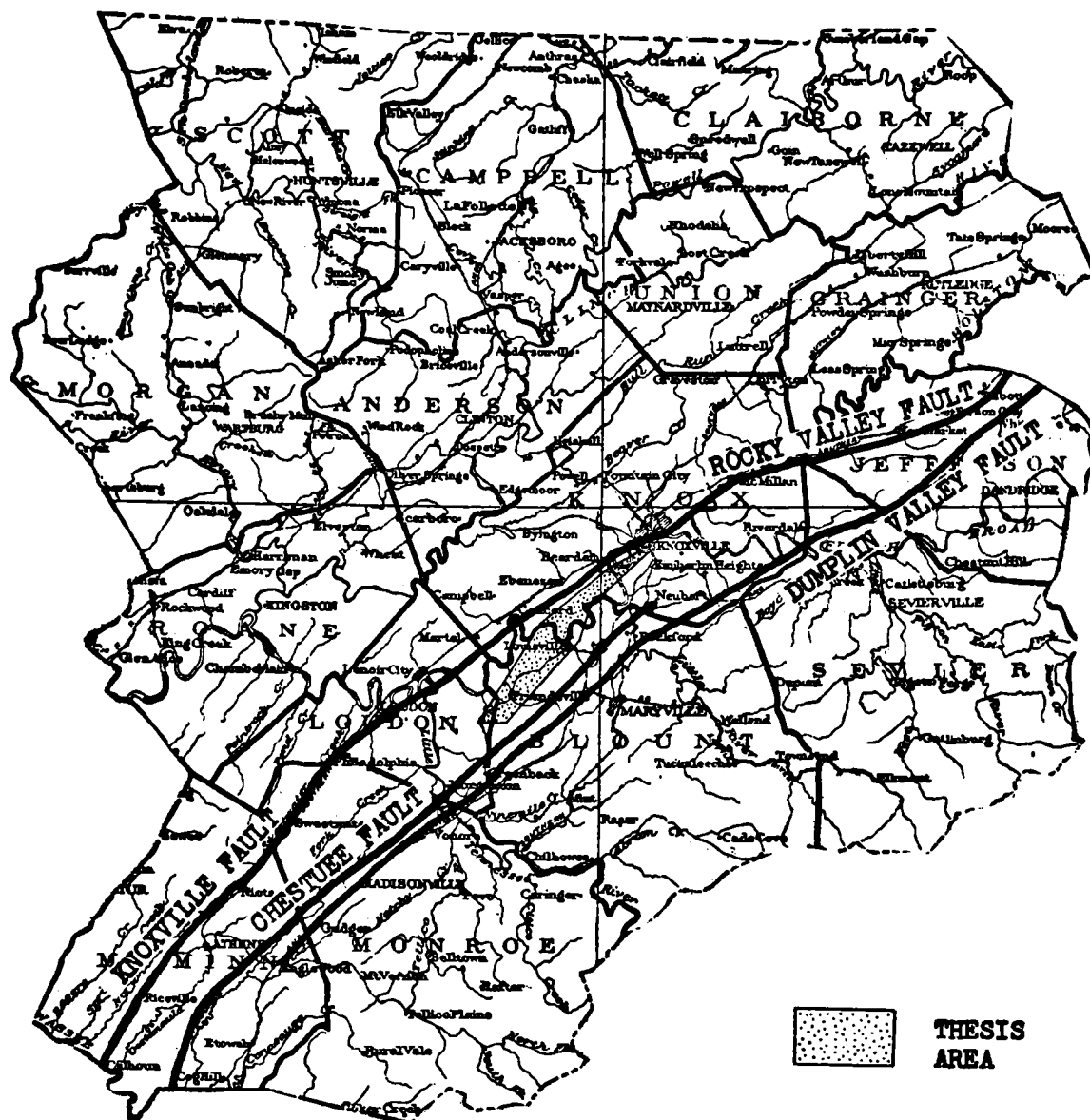


Figure 3. Location and general geologic setting of thesis area.

and examined as to stratigraphic position, correlation value, and paleoecological implications. These results were obtained from numerous reconnaissance traverses of the area and from detailed measured sections where better exposures of rocks permitted. Locations of data obtained in this study are plotted on Plate I. Tennessee Grid Coordinates (abbreviated T.G.C.) were used for more precise locations cited in the text.

CHAPTER II

STRATIGRAPHY

Introduction

General Geologic History

The Middle Ordovician rocks are separated from the Lower Ordovician Newala Formation of the Knox Group by a widespread erosional unconformity. Generally this unconformity is not continuously well exposed, but the relief on this erosional surface is known to reach as much as 200 feet (Rodgers, 1953, p. 59). The rocks immediately above the unconformity are chiefly limestone in contrast to the predominantly dolomitic strata below.

The Middle Ordovician rock sequence in East Tennessee is wedge-shaped, thicker to the southeast and thinner to the northwest. It is believed that the Middle Ordovician sea spread across the eroded Knox surface from the southeast making the lower beds above the erosional surface older in the southeast than in the northwest (Rodgers, 1953, p. 92). In the sea, lime-muds and lime-sands were deposited in the open sea or accumulated during growth of reef masses, and a considerable amount of mud and sand was brought in from a probable southeastern source. This clastic material was gradually and somewhat irregularly moved northwestward, changing environmental conditions and hence animal populations along the way. At times there were periods of sand and hematite, deposition reef growth, and intermixing of the various types.

The different lithologies in the section reflect intertonguing, and lateral and vertical gradation of these sediments.

Toward the end of the Paleozoic rocks of the region were uplifted, folded, and faulted in the Appalachian orogeny. Such tectonic alterations combined with inherent interfingering and gradations between lithologies make correlation from one belt to another very difficult.

General Stratigraphy

Although primarily concerned with the Lenoir Formation, in order to establish field relationships this investigation involved study of a section from the upper portion of the Knox Group to the uppermost Chickamauga unit present in the Knoxville-Friendsville belt. The units involved are the Lower Ordovician Newala Formation, and the Middle Ordovician: Lenoir Limestone including its Mosheim Member; the Holston Formation; the Chapman Ridge Sandstone; the Ottosee Shale; and the Bays Formation. All except the last two named were included in field mapping at one place or another.

Lower Ordovician Series

Newala Formation

The Newala Formation in the area consists of a combination of the Kingsport Formation and the Mascot Dolomite as described elsewhere. Only the upper portion was observed and it is composed of finely crystalline or saccharoidal, relatively unfossiliferous, dolomite. It is light gray

to cream or tan and medium to thick bedded. The formation produces light colored chert on weathering.

Middle Ordovician Series

Lenoir Limestone

As previously noted, the Lenoir Limestone is separated from the Knox Group by an erosional unconformity. The formation consists of a separately distinct lower Mosheim Member and the main body of Lenoir. This thesis is chiefly concerned with the latter and the term "Lenoir" is used in that sense throughout. However, a description of the Mosheim Member is included below for completeness.

Mosheim Member. Ulrich (1911) believed that the Mosheim was everywhere separated from the overlying Lenoir by a disconformity. The disconformity is present in some exposures (Figure 4), but it has been shown that the Mosheim and Lenoir interfinger laterally and in some places typical Lenoir lithology underlies the Mosheim (Cooper and Cooper, 1946, p. 51-53). The Mosheim was relegated to member status of the Lenoir by subsequent workers. It is a dove- to dark-gray, cryptocrystalline limestone, weathering to blue gray to white. Weathered surfaces are generally smooth but commonly have striking radial flutings produced by differential weathering. The blocky Mosheim outcrops are sparingly fossiliferous, with the fossils when present exposed on the smooth weathered surfaces. The most common fossils are large gastropods,



Figure 4. Contact between the Mosheim Member and overlying typical Lenoir exposed south of Blue Grass, Tennessee. This photograph illustrates the contrasting lithologies and the erosional surface on top of the Mosheim. T.G.C. are 541,125 N. and 2,574,375 E.

orthoconic cephalopods, and ostracods. Distinctive lithologic features of the Mosheim are birds-eye calcite and conchoidal fracture. The term vaughanite has been used to define the Mosheim and similar lithologies.

In the Knoxville-Friendsville belt, the Mosheim is nearly everywhere present; in fact, the absence of the Mosheim is the exception rather than the rule in this segment of the belt.

A brecciated zone was observed at the base of the Mosheim exposed just south of Blue Grass (T.G.C. 541,000 N., 2,574,200 E.). Chert conglomerate has been reported in the basal Mosheim but this breccia, which may represent a sink filling, is composed of angular limestone fragments in a red, coarse grained matrix resembling a marble lithology (Figure 5). In some places, the typical Mosheim lithology is totally or partially replaced by a coarsely crystalline marble. This is well displayed behind the Friends Church in Friendsville, Tennessee.

Main Body of Lenoir. The Lenoir Limestone has been described as a shaly, nodular ("cobbly") limestone. It is more accurately referred to as an argillaceous or silty limestone with a rubbly or nodular weathered appearance in places. The Lenoir in the belt under consideration grades to the south into calcareous shale and impure limestone and eventually into the Athens Shale at a point immediately south of the McMinn-Monroe County line about 10 miles northeast of Athens, Tennessee (T.G.C. 416,600 N., 2,453,000 E.).

In the Knoxville-Friendsville belt the Lenoir consists of several lithologic types. In the Friendsville area, directly above the Mosheim,



Figure 5. Brecciated zone at the base of the Mosheim exposed at Blue Grass, Tennessee. The breccia consists of Mosheim fragments in a "marble-like" matrix. It is probably the result of a sink filling. T.G.C. are 541,000 N. and 2,574,200 E.

the lower half of the Lenoir is composed of beds of finely to coarsely crystalline limestone marked by red or brown tints that resemble certain Holston color types, overlain by fossiliferous and nonfossiliferous layers of argillaceous limestone with interbedded layers of shale. The upper portion of the Lenoir consists of the much discussed beds of rather distinctive nodular appearance, some containing layers with abundant specimens of the brachiopod Christiania subquadrata. These beds in turn are overlain by beds with lithologic and paleontologic resemblance to the lower units. The limestone is basically the same: a medium to dark gray, finely crystalline limestone, weathering light gray, or buff. Commonly it is thick bedded but where it contains clay partings, weathering produces a nodular or thin-bedded appearance. Coarsely crystalline limestone may occur at any horizon in the section.

Holston Formation

The Holston Formation is a coarsely crystalline limestone, generally gray or pink with the former color usually dominating the lower half of the formation and the latter the upper half. The thick-bedded to massive Holston is the well-known Tennessee marble and quarrying activities are centered at Friendsville and Knoxville. Fossils are rare to abundant and can often be observed on weathered surfaces. There appears to be some zoning of brachiopods, crinoids, and other fossils but detailed analysis of this fauna is beyond the scope of the present thesis.

What appears to be a tongue of Lenoir-type lithology interfingering with the Holston in the upper portion of the formation can be observed along Alcoa Highway near Knoxville, in Blue Grass area quarries, and above the Holston quarries in the Friendsville area (Figures 6 and 7).

Many sinks and caves are present in the Holston Formation. An alignment of small sinks formed at or near the contact of the Holston with the Lenoir can be used to trace the Lenoir-Holston contact on a topographic map in several places.

The Holston and the overlying Chapman Ridge Sandstone form topographic highs. The marble weathers to form a deep red clay residuum that is easily recognized even at a distance. This residuum is thick and commonly covers the top of the Lenoir. Chunks of hematite and manganese oxides are common in the residuum. At the Alcoa Highway exposure cited above a slight disconformity surface below the Lenoir-lithology tongue bears small hematite and manganese incrustations.

Chapman Ridge Sandstone

The Chapman Ridge Sandstone was named by Cattermole (1955) for the exposure along Alcoa Highway in Knoxville for what had previously been called Tallico. As defined, it is chiefly a calcareous, fine- to medium-grained sandstone with interbedded layers of shale, siltstone, and some marble lenses. The dominant sandstone is gray with dark bands and graded bedding where fresh but weathers to porous, sandy, red, hematite-rich, masses surrounded by deep residuum. These friable masses



Figure 6. Lenoir-type lithology exposed along Alcoa Highway, Knoxville, Tennessee. A thin shaly, nodular limestone resembling the Lenoir commonly occurs in or immediately on top of the Holston. In this exposure the shaly limestone is found between two Holston units. T.G.C. are 565,375 N. and 2,577,065 E.



Figure 7. Lenoir-type lithology exposed in Blue Grass area quarry. An impure, nodular limestone resembling the Lenoir caps the Holston in most marble quarries in the thesis area. T.G.C. are 538,450 N. and 2,574,875 E.

commonly display differentially weathered markings resembling bedding and cross-bedding. It has been observed that "slaty" cleavage may be developed in the finer-textured portions of the sandstone, and cleaved fragments may weather to resemble a "shaly" outcrop.

According to Cattermole (1958) the marble lenses in the Chapman Ridge are not persistent and may occur at any level. Field observations of these marble lenses reveal a lithology similar to portions of the Holston, particularly that occurring near contact with the sandstone. At these places, the sandstone takes on a marble-like appearance and inclusion within one or the other subjacent formations appears to be arbitrary. Gordon (1924) reports disagreements concerning marble lenses above the Holston. In his opinion, supported by "some government geologist," the Meadow Marble belongs to the Tellico. Butts and others at that time considered the Meadow Marble a lentil at or near the base of the Ottosee.

The Chapman Ridge was found in some places, for example just northeast of Louisville, to be in direct contact with the Lenoir.

The Chapman Ridge generally holds up the highest ridges of the Middle Ordovician units. The residuum is a dark-red, clayey sand and in the Knoxville-Friendsville area it is commonly capped by thick deposits of alluvium, dominated by large, well-rounded quartzite pebbles. These appear to help preserve the high relief of the unit.

This formation was formerly referred to as the Tellico Sandstone (Keith, 1895, and others) but it has been claimed (Cattermole, 1955) but

questionably demonstrated (H. J. Klepser and G. D. Swingle, personal communication, 1965) that the Chapman Ridge is stratigraphically higher than the type Tellico.

Ottosee Shale

Only limited observations of the Ottosee Shale were made in this thesis area. It consists of a mixture of shale, limestone, some siltstone, sandstone, and marble. In one exposure (T.G.C. 540,200 N., 2,598,200 E.) the Ottosee consists of chiefly calcareous shale and blue-gray limestone in approximately equal proportions. Both lithologies were very fossiliferous with large numbers of bryozoans, brachiopods, and sponges.

The Ottosee in many exposures very closely resembles the Lenoir. The well-exposed Ottosee in the Lenoir City Park (T.G.C. 516,700 N., 2,524,000 E.) northeast of Fort Loudon Dam has a Lenoir-type lithology. In the same belt near Ebenezer on the Bearden Quadrangle (T.G.C. 553,000 N., 2,571,500 E.), the Ottosee resembles the Lenoir and contains a cryptocrystalline limestone similar to the Mosheim Member of the Lenoir.

Bays Formation

Outcrops of the Bays Formation occur at several places in the thesis area but no exposure is extensive. It consists mainly of dark-red silty limestone, limy siltstone, and shale along with interbedded blue, silty limestone (Rodgers, 1953). The Bays is the youngest

unit of this portion of the belt. No detailed observations of the Rays were made in the thesis area.

Description of Measured Sections

Introduction

In the Friendsville vicinity and elsewhere in the area of study, it was found that the main body of the Lenoir can be subdivided into a number of zones, which will be described generally in the following measured sections. Lithologic and paleontologic characteristics serve to typify each of the zones which, in the view of the writer, reflect paleoecological conditions. Superficial weathering and other features are included in the descriptions as further aids in field identification. The zones while distinct are gradational in their lower and upper limits and the boundaries set are somewhat arbitrary in places. In some cases thicknesses are combined for this reason.

In these sections the Mosheim is treated apart from the zones designated in the main body of the Lenoir.

Section A

This section (Plate I) is at Friendsville, Blount County, Tennessee (Concord Quadrangle, T.V.A. 138-SW) along Gallagher Creek and the adjacent highway leading southeast out of town. It was measured from the Knox-Lenoir contact to the Lenoir-Holston contact (T.G.C. 503,850 N., 2,552,350 E. to 502,500 N., 2,555,840 E.).

The well known fossil locality exposed behind the Friends Church in the northeast section of Friendsville is at the base of this section (Cooper, 1956, pp. 72, 78). This exposure may also be noted for the fact that marble and argillaceous limestone occurs in place of the lower portion of the Mosheim. The brachiopod-bearing Lenoir beds are here interbedded with the marble. The lower half of the section, below the Christiania-bearing beds, is mostly covered and the limestone is not well exposed. A yellow-brown to brown soil is typically developed over rocks in the lower half of the section.

Exposures in the upper portion of the Lenoir are fairly continuous (Figure 8). The upper portion exhibits greater relief, holding up a ridge 120 feet high. Because of better exposure, the upper zones present are more easily recognized.

Zonal Designation	Description	Zonal Thickness	Cumulative Thickness
VII	Limestone, impure, finely crystalline, medium gray; weathers to blue gray to buff in small slabby blocks; consistently fossiliferous with <u>Maclurites</u> sp., <u>Allosaccus</u> sp., cryptozoans, large strophomenid brachiopods commonly with beekite, and orthoconic cephalopods dominant--all tending toward large size; much of this zone and contact with the Holston covered by residuum derived from the latter formation.	126.3	768.2
VI	Limestone, impure, finely crystalline, medium gray; weathers to light gray to buff in small slabby blocks to cobbly or nodular blocks giving a thin-bedded, rubbly	60.8	641.9



Figure 8. Abandoned quarry in upper portion of the Lenoir Limestone in Section A. T.G.C. 502,100 N. and 2,555,400 E.

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
	appearance; layers of thinly fractured limestone slabs are loosened around more resistant masses; soil rapidly removed from bare surfaces; sparingly fossiliferous with <u>Allosaccus</u> most persistent form with occasional brachiopods, orthoconic cephalopods and trilobites.		
V	Limestone, impure, finely crystalline, medium gray; weathers to light gray to buff in blocky or nodular fragments creating rubbly surfaces, clay partings on irregular surfaces; relatively unfossiliferous with some brachiopods in lower portion.	68.6	581.1
IV b.	Limestone, impure, finely crystalline, medium gray; weathers light blue gray to buff in small slabby or nodular blocks giving a thin-bedded rubbly appearance; very fossiliferous with brachiopods especially abundant, trilobites, sponges, bryozoans, and orthoconic cephalopods common; some nodular chert produced.	35.9	512.5
IV a.	Limestone, impure, finely crystalline, medium to dark gray; weathers light blue gray to buff; outcrops in massive, resistant blocks and ledges; clay partings on irregular surfaces create a nodular or cobbly appearance; distinctive yellow-orange to red clayey soil developed that is identifiable from a distance; fossiliferous with <u>Christiania subquadrata</u> in concentrated layers in upper portions along with a few other brachiopods.	97.7	476.6

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
III	Limestone, impure, finely crystal- line, medium gray; weathers blue to buff in small slabby blocks creating a rubbly appearance; yellow-brown soil developed; sparingly fossiliferous.	(II,III) 255.0	378.9
II	Limestone, impure, finely crystal- line, medium to dark gray; weathers to blue gray to buff in blocky or slabby fragments giving a thin- bedded weathered appearance; fossil- iferous with sponges dominant.		
I	Limestone, impure, finely to coarsely crystalline; resembles a marble lithology; medium to dark gray with some red and brown coloration; outcrops in thick- bedded elongate slabby blocks; a strong fetid odor produced when broken; brown soil developed; fossiliferous with brachiopods and crinoids common.	81.8	123.9
Mosheim Member	(Mosheim in upper portion consists of marble and of argillaceous limestone in the lower portion.) Limestone, cryptocrystalline, dove gray with birds-eye calcite and conchoidal fracture; weathers to light blue gray to white; outcrops in massive, resistant blocks; sparingly fossiliferous. Limestone (marble), medium to coarsely crystalline, light gray, dark gray, and pink; weathers gray; outcrops in massive, resistant blocks; fossiliferous with some beds crinoidal and others with abundant brachiopods.	42.1	42.1

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
	Limestone, impure, finely to coarsely crystalline, light to medium gray; weathers gray to buff; interbedded with marble; very fossiliferous with brachiopods, bryozoans, and crinoids all abundant; some sponges and other fossil fragments.		

Section B

Section B was measured from the Knox-Lenoir contact to the Lenoir-Holston contact along Gooseneck Road in Blount County, Tennessee (SW corner Louisville Quadrangle, T.V.A. 138-SE and SE corner Concord Quadrangle, T.V.A. 138-SW). The section is approximately 0.8 mile northeast of Friendsville (T.G.C. 508,650 N., 5,555,900 E. to 506,600 N., 2,558,550 E.).

The lower half of the Lenoir is better exposed than in Section A. Outcrops in this portion occur along the pastured hillsides (Figure 9). The upper half of the Lenoir is well exposed. Outcrops are fairly continuous. Zones can be easily recognized. A fairly large collection of fossils from the various zones was obtained. The brachiopod bearing beds of Zone IV have been noted by Cooper (1956), who made extensive collections from the fine exposure of that zone in this section.



Figure 9. Zone II beds exposed along pastured hillsides. This exposure occurs in Section B just north of Gooseneck Road in Blount County, Tennessee. T.G.C. are 508,600 N. and 2,556,590 E. Erosion produces a number of benches in the slightly dipping beds.

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
VII	Limestone, impure, finely to rather coarsely crystalline, medium gray; weathers to light to dark gray; with smooth and undulating to highly fractured and nodular surfaces; weathered outcrops blocky and massive; fossiliferous with <u>Maclurites</u> sp., <u>Allosaccus</u> sp., cryptozoans, large strophomenid brachiopods commonly with beekite, and orthoconic cephalopods common to abundant, bryozoans locally common; contact with the Holston and much of this zone covered by Holston residuum.	115.2	735.3
VI	Limestone, impure, finely crystalline medium gray; weathers to light gray to buff in small blocks or slabs to cobbly or nodular blocks giving a thin-bedded rubbly appearance; thinly fractured limestone slabs are loosened around more resistant masses; some nodular chert; sparingly fossiliferous with <u>Allosaccus</u> sp., common to abundant, occasional orthoconic cephalopods, trilobites, and brachiopods.	86.0	620.1
V	Limestone, impure, finely crystalline medium gray; weathers light gray to buff in small slabby blocks or shale-like chips producing a rubbly appearance; relatively unfossiliferous.	52.5	534.1
IV b	Limestone, impure, finely crystalline, medium gray; weathers to a light blue gray to buff; clay partings along irregular surfaces weather to create a thin-bedded appearance of slabby to nodular blocks; very fossiliferous with brachiopods abundant in both quantity and variety, sponges, orthoconic cephalopods common, occasional low spired gastropods, crinoid and bryozoan parts.	54.0	481.6

Zonal Designation	Description	Zonal Thickness	Cumulative Thickness
IV a	Limestone, impure, finely crystalline, medium to dark gray; weathers to light blue gray with tan, wavy clay partings giving a cobbly or nodular appearance; outcrops in large massive blocks and ledges; distinctive yellow-orange to red clayey soil well developed; soil can be recognized from a distance.	126.5	427.6
III	Limestone, impure, finely crystalline, clay partings; weathers blue gray to buff to a shaly to nodular appearance; contains some shale and small tan blocky chert; yellow-brown soil developed; relatively unfossiliferous; interval mostly covered.	150.5	301.1
II	Limestone, impure, finely to rather coarsely crystalline; weathers to buff in blocky or slabby fragments giving a thin-bedded appearance; outcrops in ledges creating a benched affect; nodular, porous, yellow-brown chert is abundant; yellow-brown soil formed; very fossiliferous--low spired gastropods, sponges, stromatoporoids (?), coral, bryozoans, and trilobites are common to abundant; crinoids, orthoconic cephalopods and brachiopods are rare to common; interval partially covered.	(I, II) 101.1	150.6
I	Limestone, coarsely crystalline, gray with a brown or red tint; weathers to medium gray color and porous; outcrops in large slabby blocks exhibiting numerous small calcite veins; brown soil developed; fossiliferous with brachiopods abundant, and crinoids and bryozoans locally abundant.		
	Limestone, impure, finely crystalline, dark gray; weathers to light gray to buff in small slabby blocks; contains		

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
	abundant porous, yellow chert nodules and chert incrusts some surfaces; interval partially covered.		
Mosheim Member	Limestone, cryptocrystalline, dense, dove gray; weathers white to light gray or light blue gray; outcrops in massive resistant blocks; contains birds-eye calcite and calcite veins, conchoidal fracture; fossiliferous with fossils exhibited only on weathered surfaces; fauna consists mainly of large gastropods and ostracods; contact with underlying Knox is sharp.	49.5	49.5

Section C

Section C was measured along the Marmor Quarry Road and railroad tracks, approximately 0.8 mile west of Mahoney Mill and 1.6 miles northeast of Friendsville, Blount County, Tennessee (T.G.C. 511,875 N., 2,557,500 E. to 509,250 N., 2,561,450 E.).

The upper portion of the section is well exposed but the outcrops in the lower portion of the formation are somewhat scattered. The lower half is mainly pasture land with the outcrops occurring on the hillsides. The Lenoir in this lower portion appears to be deformed, which may have produced an abnormally thick section. The section is probably thinner than the 827 feet recorded here. Attempts were made in measuring to correct for changes in dip etc., but with poorly exposed strata this is difficult. Six zones can be recognized in this section. A seventh is covered but is present in either direction along strike.

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
VII	Covered interval in this section; elsewhere along strike, limestone, impure, finely to coarsely crystalline, medium to dark gray; weathers to light to dark gray in fairly massive elongate blocks with smooth undulating to highly fractured surfaces; fossiliferous with <u>Maclurites</u> sp., <u>Allosaccus</u> sp., cryptozoans; large brachiopods with beekite, are common; zone and contact partially covered by Holston residuum.	93.0	827.7
VI	Limestone, impure, finely to medium crystalline, medium gray; weathers light gray to buff in slabby to nodular or cobbly blocks giving a thin-bedded rubbly appearance; layers of thinly fractured limestone swirl around more resistant masses; nodular chert present; soil rapidly removed from bare surfaces; fossiliferous with <u>Allosaccus</u> sp. dominant; also occasional orthoconic cephalopods, trilobites, and brachiopods.	(VI, V) 150.6	734.7
V	Limestone, impure, medium gray; weathers light gray to tan or brown in small blocks or shale-like chips to form rubble covered slopes; sparingly fossiliferous to barren, with a few brachiopods and sponges present.		
IV b	Limestone, impure, finely crystalline, medium gray; weathers light blue gray to buff in massive blocks to rubbly material; fossiliferous, with brachiopods abundant both in quantity and type, also sponges, orthoconic cephalopods, trilobites, and occasional gastropods and crinoid parts.	(IV a, b) 86.5	584.1

Zonal Designation	Description	Zonal Thick- ness	Cumulative Thickness
IV a	Limestone, impure, finely crystalline, medium to dark gray; weathers blue gray with tan clay partings which give a nodular or cobbly appearance; outcrops in large massive, resistant blocks and ledges; distinctive yellow-orange to red clayey soil developed; both soil and lithology identifiable from a distance; fossiliferous with abundant <u>Christiania subquadrata</u> concentrated in layers in the upper portions of this zone along with a few other brachiopods.		
III	Limestone, impure, finely to medium crystalline, medium to dark gray; weathers blue gray to buff in small rubbly blocks; outcrops in ledges; contains shale and abundant nodular, porous yellow chert; yellow-brown soil developed; sparingly fossiliferous except for numerous large orthoconic cephalopods.	182.1	388.6
II	Limestone, impure, finely crystalline, medium gray; weathers light gray to buff in small blocks giving a thin-bedded appearance; layers of more coarsely crystalline limestone as in Zone I interbedded; yellow-brown soil developed; fossiliferous with brachiopods, low-spined gastropods, orthoconic cephalopods, bryozoans, trilobites, sponges, crinoid fragments, and coral all common to abundant.	107.6	206.5
I	Limestone, coarsely crystalline, marble-lithology, light to medium gray; weathers to medium gray; outcrops in fairly large slabby blocks	62.8	98.9

Zonal Designation	Description	Zonal	Thick- Cumulative ness Thickness
	with smooth undulating surfaces; brown soil developed; fossilif- erous, with abundant brachiopods and crinoids.		
	Limestone, impure, finely crystal- line, dark gray; weathers light gray to buff in small slabby blocks; contains porous, yellow chert nodules; fossiliferous with small gastropods, brachiopods, and sponges dominant.		
Mosheim Member	Limestone, cryptocrystalline, dove gray, dense, vaughanite lithology; weathers light blue gray or white; crops out in large, massive blocks with conchoidal fracture; sparingly fossiliferous; sharp contact with the underlying Knox.	36.1	36.1

Section D

Section D was measured from the Knox-Lenoir contact to the Lenoir-Holston contact on the Longview Pony Farm (T.G.C. 550,800 N., 2,582,650 E. to 549,350 N., 2,583.190 E.). The section is located south of Northshore Drive, approximately 1.2 miles southwest of Rocky Hill community, Knox County, Tennessee (SW corner of the Bearden Quadrangle, T.V.A. 138-NE). Outcrops are fairly continuous. Portions of all zones except Zone VII were observed. Zonal boundaries were not established, so thickness indicated in the column does not refer to zone thickness. Zones may not be restricted to the measured intervals to which they are referred in the descriptions below. Within each interval, the

number designation for the most characteristic zone present is shown on the left.

Zonal Designation	Description	Interval Thickness	Cumulative Thickness
VII	Covered interval to approximate Holston contact.	89.5	550.0
VI	Limestone, impure, finely crystalline, medium gray; weathers to light gray to buff in small slabby blocks; fossiliferous with <u>Allosaccus</u> sp., orthoconic cephalopods common and also trilobite fragments, and low-spined gastropods.	51.0	460.5
V	Limestone, impure, finely crystalline, medium gray; unfossiliferous; mostly covered with a few scattered outcrops.	34.5	419.5
IV	Limestone, impure, finely crystalline, medium to dark gray; weathers to light gray to buff; contains wavy clay partings; fossiliferous with brachiopods including <u>Christiania subquadrata</u> very abundant; also present are small sponges, crinoids, bryozoans, and other fossil fragments; poorly exposed.	87.6	385.0
III	Limestone, impure, finely crystalline, medium gray; weathers light gray to buff in small slabby to nodular or cobbly blocks; sparingly fossiliferous with sponges, small gastropods, orthoconic cephalopods, trilobites and pleosponges present.	119.4	297.4
II	Limestone, impure, finely crystalline, medium to dark gray; weathers light gray to buff in small slabby	92.7	168.0

Zonal Designation	Description	Interval	
		Thick- ness	Cumulative Thickness
	blocks; fossiliferous with <u>Allosaccus</u> sp., small low-spined gastropods, orthoconic cephalopods, and brachiopods common and high-spined gastropods, crinoids, bryozoans, trilobites.		
	Covered Interval	30.4	75.3
I	Limestone, impure, finely to medium crystalline, medium gray; weathers to a light gray in elongate blocks giving a thin-bedded appearance; fossiliferous; mostly covered, may contain some Mosheim.	19.6	44.9
Mosheim Member	Limestone, cryptocrystalline, dense with birds-eye calcite and conchoidal fracture; weathers to a light blue gray in large smooth blocks; sparingly fossiliferous; partially covered.	25.3	25.3

Section E

This section was measured along the east side of Alcoa Highway, U. S. Route 129, approximately 1.5 miles south of the junction with Kingston Pike, U. S. Route 11-70 (Knoxville Quadrangle, T.V.A. 147-NW). The Tennessee Grid Coordinates for this section are 564,250 N., 2,562,400 E. to 564,900 N., 2,568,000 E. This is a new roadcut so the rocks exposed are relatively fresh (Figure 10) and the typical weathered appearance of the Lenoir is not displayed. Furthermore, for the same reason, fossils are not easily observed. This section



Figure 10. Relatively fresh exposure of Lenoir Limestone along Alcoa Highway, Knoxville, Tennessee. This photograph illustrates the thick-bedded nature of the Lenoir. Differential weathering is already taking place and eventually it will create the characteristic nodular or cobbly weathered appearance of the limestone. T.G.C. are 565,880 N. and 2,567,000 E.

offers a good opportunity to observe the unweathered characteristics of the Lenoir. Bedding, which appears to be thin in long weathered exposures, proved to be thick. The limestone is medium to dark gray, finely crystalline, and dense. Some iron concretions and crystalline calcite cavity fillings were also observed. As in the previous section, zones were not measured as such at the time but reference is made here to the zone indicated. The section is measured from the highest Mosheim outcrop to the approximate contact with the Holston.

Zonal Designation	Description	Interval Thickness	Cumulative Thickness
	Covered interval to Holston outcrop.	48.0	450.9
IV	Limestone, impure, finely crystalline, dark gray with tan clay partings; weathers to light gray with a cobbly or nodular appearance; fossiliferous with brachiopods very abundant, especially <u>Christiania subquadrata</u> , also gastropods, sponges, orthoconic cephalopods, bryozoans, and crinoids; interval mostly covered.	65.5	402.9
III?	Limestone, cryptocrystalline to finely crystalline, dense with many small spots of crystalline calcite, medium gray; weathers to light gray and buff; fossils were not observed.	43.5	337.4
III?	Limestone, cryptocrystalline to finely crystalline, dense with stylolites, weathers buff, thick to massive bedding; fossiliferous with orthoconic cephalopods, gastropods, sponges, and coral displayed on weathered surfaces.	25.1	293.9

Zonal Designation	Description	Interval Thick- ness	Cumulative Thickness
III	Limestone, impure, finely crystalline, dark to medium gray with thick tan clay partings; weathers light blue gray with a thin-bedded appearance; bedding is generally thick; pyrite and calcite abundant; sparingly fossiliferous with some crinoid fragments.	92.7	240.8
II	Limestone, finely crystalline, medium to dark gray; weathers to buff, thick bedded; fossiliferous with bryozoans, pleosponges, crinoids, brachiopods, sponges, cryptozoans and corals.	34.3	148.1
I, II	Limestone, impure, finely crystalline, dense with clay partings; weathers medium gray to buff; thick bedded; fossiliferous with bryozoans, crinoids, gastropods, coral, and fossil fragments abundant.	34.3	113.8
	Covered interval, both Mosheim and Lenoir blocks exposed in residuum.	35.8	79.5
Mosheim Member	Limestone, cryptocrystalline, medium to dark gray, extremely dense with birds-eye calcite, calcite veins, and conchoidal fracture; weathers to light to medium blue gray; outcrops in massive blocks with smooth weathered surfaces; strong fetid odor on freshly broken surface; sparingly fossiliferous with a few small gastropods; interval mostly covered.	43.7	43.7

Section F

Section F was measured across the small valley just to the south of the University of Tennessee Hospital approximately 2,000 feet east of and parallel to Alcoa Highway (Knoxville Quadrangle, T.V.A. 147-NW; T.G.C. 565,400 N., 2,567,675 E. to 564,150 N., 2,568,975 E.). This section was largely covered, with outcrops fairly persistent in the lower portion, but mostly lacking in the upper half. Thus, a comparison can be made with the fresh section of the preceding section.

At the time of measuring this section the zonal concept developed in the Friendsville section had not been formulated. As a result, this section was measured from outcrop to outcrop. Present interpretation of these units can be inferred from the zonal designations shown. Four of the seven zones can be recognized. The rest, if present, are covered.

Zonal Designation	Description	Interval Thickness	Cumulative Thickness
	Covered interval to approximate contact with Holston.	80.0	505.5
IV, III	Mostly covered interval with only brachiopod-bearing limestone at top and unfossiliferous limestone blocks occasionally exposed.	132.4	425.5
	Limestone; impure, finely crystalline, medium gray; weathers light gray with tan clay partings to give a nodular or cobbly appearance;		

Zonal Designation	Description	Interval Thick- ness	Cumulative Thickness
	outcrops in massive blocks; fossiliferous with abundant partially silicified brachiopods (IV).		
	Limestone, finely crystalline, medium gray; weathers light gray; no fossils observed (III).		
II	Limestone, impure, finely crystal- line, medium gray; weathers to light gray in small rubbly blocks giving a thin-bedded appearance; fossiliferous with small gastropods, sponges and some brachiopods; interval mostly covered.	89.6	293.1
II	Limestone, impure, finely crystal- line, medium gray; weathers to light gray with a rubbly thin- bedded appearance; fossiliferous with small gastropods, orthoconic cephalopods, trilobites, and occasional brachiopods.	34.7	203.5
II	Limestone, impure, finely crystal- line, medium gray; weathers light gray to buff; fossiliferous with pleosponges, brachiopods, flat- coiled gastropods, high-spined gastropods, and occasional trilobite fragments.	35.7	168.8
II	Limestone, impure, finely crystal- line, medium gray; weathers to light gray to buff and a thin- bedded appearance; fossiliferous with abundant small gastropods, sponges, pleosponges, brachiopods, orthoconic cephalopods, and corals.	26.5	133.1
I	Limestone, impure, finely crystal- line, medium gray; weathers light to dark gray; thick bedded; fossil- iferous with <u>Maclurites</u> sp., small	19.5	106.6

Zonal Designation	Description	Interval Thick- ness	Cumulative Thickness
	low-spined gastropods, many corals (?), abundant bryozoans, orthoconic cephalopods, and cryptozoans.		
I	Limestone, impure, finely to coarsely crystalline, medium gray with some brown; weathers light gray to buff in small blocks to give a rubbly appearance; fossiliferous with more coarsely crystalline type with abundant bryozoans and many fossil fragments or crinoidal; finely crystalline with flat-coiled gastropods, orthoconic cephalopods, and trilobites.	26.1	87.1
I	Limestone, impure, finely to coarsely crystalline, medium gray; weathers to light gray in small blocks giving a rubbly appearance; fossiliferous with bryozoans, <u>Maclurites</u> sp., and brachiopods; interval partially covered.	21.8	61.0
Mosheim Member	Limestone, cryptocrystalline, medium to dark gray, dense with birds-eye calcite, calcite veins, and conchoidal fracture; weathers light to blue gray to white; outcrops in massive, resistant blocks; sparingly fossiliferous.	39.2	39.2

Paleontologic details and inferred paleoecologic implications of the zones described above will be presented and examined further in subsequent chapters of the thesis.

CHAPTER III

PALEONTOLOGY AND PALEOECOLOGY

Introduction

The Lenoir Limestone ranges from sparingly to moderately fossiliferous. Neither a detailed study of the total fauna in East Tennessee has been made nor a complete faunal list compiled. As part of this investigation, a fairly complete collection of representative Lenoir fossils was assembled according to stratigraphic position within the formation in the thesis area. This collection, enumerated in the following section, is repositied in the Paleontological Collections at the University of Tennessee.

Butts (1940) recognized approximately 150 different species from the Lenoir Limestone in Virginia. G. A. Cooper (1956) has listed 71 species of brachiopods alone from the Lenoir (lower and upper portions) in Tennessee and Virginia. Raymond (1925) lists 28 different trilobites from the Lenoir in Tennessee and Virginia. Butts (1940) recognized 8 trilobites in Virginia, and B. N. Cooper (1953) identified 12 different trilobite species from the Upper and Lower Lenoir in Tennessee. Common in the Lenoir also are a number of sponges, corals, bryozoans, gastropods, cephalopods, and, in places, stromatolites.

A summary of the Lenoir biota in a composite sense is presented in the next section after which the fossil types will be discussed

in terms of zonal assemblages as their paleoecological implications are emphasized.

Systematic Paleontology

Introduction

Fossils assembled from the Lenoir Limestone of the Knoxville-Friendsville belt are here presented in composite form and according to zonal association. The following fossil lists are by no means considered inclusive. It is believed, however, that they do contain the major components of the biota characteristic of the formation and individual zones.

A number of references were used to support the identification of specimens. Of these, especially useful were: Bassler (1932), Butts (1926, 1940), B. N. Cooper (1953), G. A. Cooper (1956), Moore (1953, 1955, 1956, 1959, 1960, 1964), Raymond (1908, 1925, 1928), Raymond and Okulitch (1940), Shimer and Schrock (1944), and Wilson (1948).

Composite Biota

ALGAE:

Stromatolites, including cryptozoans

PORIFERA:

Allosaccus prolixus Raymond and Okulitch

Hindia? sp.

Hudsonospongia? sp.

Pleosponges (unidentified as to genus and species)

Receptaculites? sp.

Receptaculites oweni Hall
Sponge spicules

STROMATOPOROIDEA:
 Stromatoporoids?

ANTHOZOA:
Billingsaria parva (Billings)
Tetradium? sp.

BRYOZOA:
Cyphotrypa? sp.
Mesotrypa? sp.
Monoticulipora? sp.
Monotrypa sp.
 Numerous trepostome and cryptostome fragments

BRACHIOPODA:
Atelelasma variabile Cooper
Bimuria sp.
Christiania subquadrata (Hall)
Conotreta? sp.
Cyrtonotrella sp.
Dactylogonia alternata Cooper
Dactylogonia geniculata Ulrich and Cooper
Dorytreta ovata Cooper
Glyptorthis sp., cf. G. concinnula Cooper
Hesperorthis tenuicostata Cooper
Isophragma biseptatum? Cooper
Isophragma sp.
Leptellina tennesseensis Ulrich and Cooper
Lingulella sp.
Macrocoelia obesa Cooper
Mimella nuclea (Butts)
Multicostella plena Cooper
Onychoplecia brevirostris Cooper
Orthambonites blountensis Cooper
Orthambonites friendsvillensis Cooper
Orthambonites sp.
Paurorthis longa Cooper
Paurorthis sp.
Phragmorthis buttsi Cooper
Platymena plana Cooper
Plectorthis compacta Cooper
Plectorthis transversa Cooper
Ptychopleurella globularia Cooper
Ptychopleurella glypta Cooper

Ripidomena sp.
Rostricellula sp.
Schizambon subradiatum Cooper
Schizambon sp.
Taphrorthis sp.
Titanambonites sp.
Valcourea sp.

GASTROPODA:

Holopea? sp.
Liospira? sp.
Maclurites magnus Lesueur
Maclurites sp.
Pleurotomaria? sp.
Raphistoma? sp.
Trochonemella? sp.

CEPHALOPODA:

Unidentified orthocones
 A tarphycerid (unidentified as to genus and species)

TRILOBITA:

Calliops? sp.
Ceraurinella sp.
Ceraurus sp.
Homotelus sp.
Illaenus fieldi Raymond
Illaenus sp.
Isotelus gigas DeKay
Isotelus sp.
Lonchodomas sp.
Pliomerops canadensis (Billings)
Pliomerops sp.
Pterygometopus? sp.
Tetralichas manganensis Billings

Zonal Associations

ZONE I

ALGAE:

Stromatolites

PORIFERA:

Allosaccus prolixus Raymond and Okulitch
Hindia? sp.
Receptaculites? sp.

STROMATOPOROIDEA:

Stromatoporoids?

ANTHOZOA:

Billingsaria parva (Billings)Tetradium? sp.

ERYOZOA:

Monotrypa sp.

Numerous trepostome and cryptostome fragments

BRACHIOPODA:

Atelelasma variabile CooperDactylogonia alternata CooperDorytreta ovata CooperHesperorthis tenuicostata CooperMimella nudes (Butts)Onychoplecia brevirostris CooperPtychopleurella glypta CooperRostricellula sp.Valcourea sp.

GASTROPODA:

Liospira? sp.Maclurites magnus LesueurRaphistoma? sp.

CEPHALOPODA:

Unidentified orthocones

ZONE II

PORIFERA:

Allosaccus prolixus Raymond and Okulitch

Pleospoges (unidentified as to genus and species)

Sponge Spicules

STROMATOPOROIDEA:

Stromatopoids?

ANTHOZOA:

Billingsaria parva (Billings)Tetradium? sp.

ERYOZOA:

Monotrypa sp.

Numerous trepostome and cryptostome fragments

BRACHIOPODA:

Lingulella sp.
Titanambonites sp.
Valcourea sp.

GASTROPODA:

Liospira? sp.
Maclurites sp.
Pleurotomaria? sp.
Raphistoma? sp.

CEPHALOPODA:

Unidentified orthocones

TRILOBITA:

Ceraurus? sp.
Illaenus sp.
Pliomerops canadensis (Billings)
Pliomerops sp.
Tetralichas minganensis Billings

ZONE III

CEPHALOPODA:

Unidentified orthocones

TRILOBITA:

Homotelus? sp.
Pterygometopus? sp.
 This zone is generally barren

ZONE IV

Subzone IV a

BRACHIOPODA:

Christiania subquadrata (Hall)
Orthambonites blountensis Cooper
Palaeostrophomena sp.
Sowerbyella sp.
Valcourea semicarinata? Cooper

Subzone IV b

PORIFERA:

Allosaccus prolixus Raymond and Okulitch
Hindia? sp.
Receptaculites oweni Hall

ERYOZOA:

Cyphotrypa? sp.Mesotrypa? sp.Monotrypa sp.

BRACHIOPODA:

Atelelasma sp.Christiania subquadrata (Hall)Conotreta? sp.Cyrtonotrella sp.Dactylogonia geniculata Ulrich and CooperIsophragma biseptatum? CooperIsophragma sp.Leptellina tennesseensis Ulrich and CooperLingulella sp.Multicostella plena CooperOrthambonites blountensis CooperOrthambonites friendsvillensis CooperOrthambonites sp.Paurorthis longa CooperPaurorthis sp.Phragmorthis buttsi CooperPlatymena plana CooperPlectorthis compacta CooperPlectorthis transversa CooperPtychopleurella globularia CooperRipidomena sp.Schizambon subradiatum CooperSchizambon sp.Taphrorthis sp.

GASTROPODA:

Liospira?Raphistoma? sp.

CEPHALOPODA:

Unidentified orthocones

TRILOBITA:

Calliops? sp.Ceraurinella sp.Ceraurus sp.Illaenus fieldi RaymondIllaenus sp.Isotelus gigas DeKayLonchodomas sp.Pterygometopus? sp.

ZONE V

PORIFERA:

Allosaccus prolixus Raymond and Okulitch

BRYOZOA:

Mesotrypa? sp.

Monotrypa sp.

BRACHIOPODA:

Bimuria sp.

Christiania subquadrata (Hall)

Leptellina tennesseensis Ulrich and Cooper

Orthambonites sp.

Paurorthis sp.

Phragmorthis buttsi Cooper

GASTROPODA:

Liospira? sp.

Pleurotomaria? sp.

TRILOBITA:

Illaenus sp.

ZONE VI

PORIFERA:

Allosaccus prolixus Raymond and Okulitch

BRYOZOA:

Monotrypa sp.

Mesotrypa? sp.

BRACHIOPODIA:

Bimuria superba Ulrich and Cooper

Glyptorthis sp., cf. G. concinnula Cooper

Lingulella sp.

Macrocoelia obesa Cooper

Orthambonites sp.

Paurorthis sp.

Titanambonites sp.

GASTROPODA:

Holopea? sp.

Maclurites magnus Lesueur

Liospira? sp.

Trochonemella? sp.

CEPHALOPODA:

Unidentified orthocones

TRILOBITA:

Homotelus sp.Illaenus sp.Isotelus sp.

ZONE VII

ALGAE:

Stromatolites

PORIFERA

Allosaccus prolixus Raymond and OkulitchHindia? sp.Hudsonospongia? sp.

ERYOZOA:

Monotrypa sp.Monoticulipora? sp.

BRACHIOPODA:

Leptellina tennesseensis Ulrich and CooperMacrocoelia obesa CooperPaurorthis sp.

GASTROPODA:

Liospira sp.Maclurites magnus Lesueur

CEPHALOPODA:

Unidentified orthocones

A tarphycerid (Unidentified as to genus and species)

TRILOBITA:

Illaenus fieldi RaymondHomotelus sp.

Figure 11. Fossils of the Lenoir Limestone characteristic of Zone I.

1. Onychoplectia brevirostris Cooper
Exterior of brachial valve showing ridge on the pseudodeltitium, X9.
Zone I, Section A, just below the southwest side of the Friends Church cemetery, Friendsville, Concord (T.V.A. 138-SW) Quadrangle, Tennessee. Very common.
- 2-3. Dorytreta ovata Cooper
(2) Pedicle and (3) brachial exterior views, X9.
Zone and locality same as preceding. Very abundant.
4. Ptychopleurella glypta Cooper
Pedicle view showing details of the ornamentation.
Zone and locality same as in no. 1 above. Very abundant.
5. Dactylogonia alternata Cooper
Pedicle exterior view, X5.
Locality same as no. 1 above. Very abundant.
- 6-7. Maclurites magnus LeSueur
Basal and top view of a cast, X0.75.
Zone I, east side of Piedmont Road in Rocky Valley, New Market (T.V.A. 155-SE) Quadrangle, Tennessee. Very abundant.
- 8-9. Maclurites magnus LeSueur
Basal and top views of a cast, X0.75.
Zone I, Section F, just south of the University of Tennessee Hospital, Knoxville (T.V.A. 147-NW) Quadrangle, Tennessee.

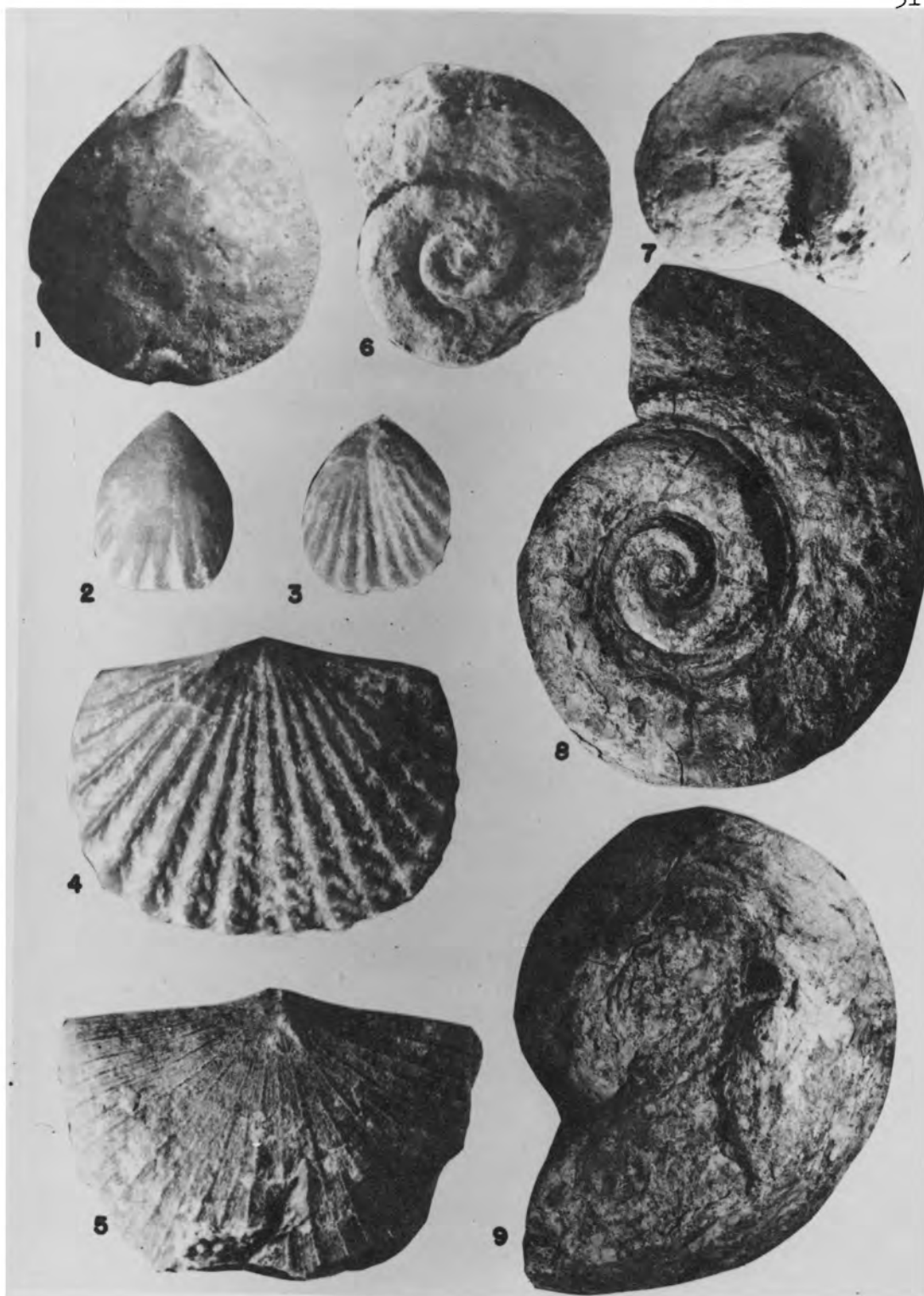


Figure 11. Fossils of the Lenoir Limestone characteristic of Zone I.

Figure 12. Fossils of the Lenoir Limestone characteristic of Zone II.

- 1-3. Pliomerops canadensis (Billings)
(1) Dorsal and (2) side view of entire specimen, X1.1.
(3) Dorsal view of a slightly coiled specimen.
Zone II, Section B, George Morton Farm, north side of
Gooseneck Road, Louisville (T.V.A. 138-SE) Quadrangle,
Tennessee.
4. Tetralichas minganensis (Billings)
Cranidium, X2.75.
Zone II, Section D, Longview Farm, Bearden (T.V.A. 138-NE)
Quadrangle, Tennessee.
5. Sponge spicules, unidentified to genus
X1.
Zone and locality same as in no. 1 above.
6. Pleurotomaria? sp.
Large high spired gastropod found in several different
zones, X0.8.
Zone II, Section F, just south of the University of Tennessee
Hospital, Knoxville (T.V.A. 147-NW) Quadrangle, Tennessee.
- 7-8. Billingsaria parva (Billings)
(7) Flat massive corallum, possibly forming incrustations,
X0.8.
(8) Close up of same specimen showing corallites, X1.1.
Zone and locality as in no. 1 above. Very common.

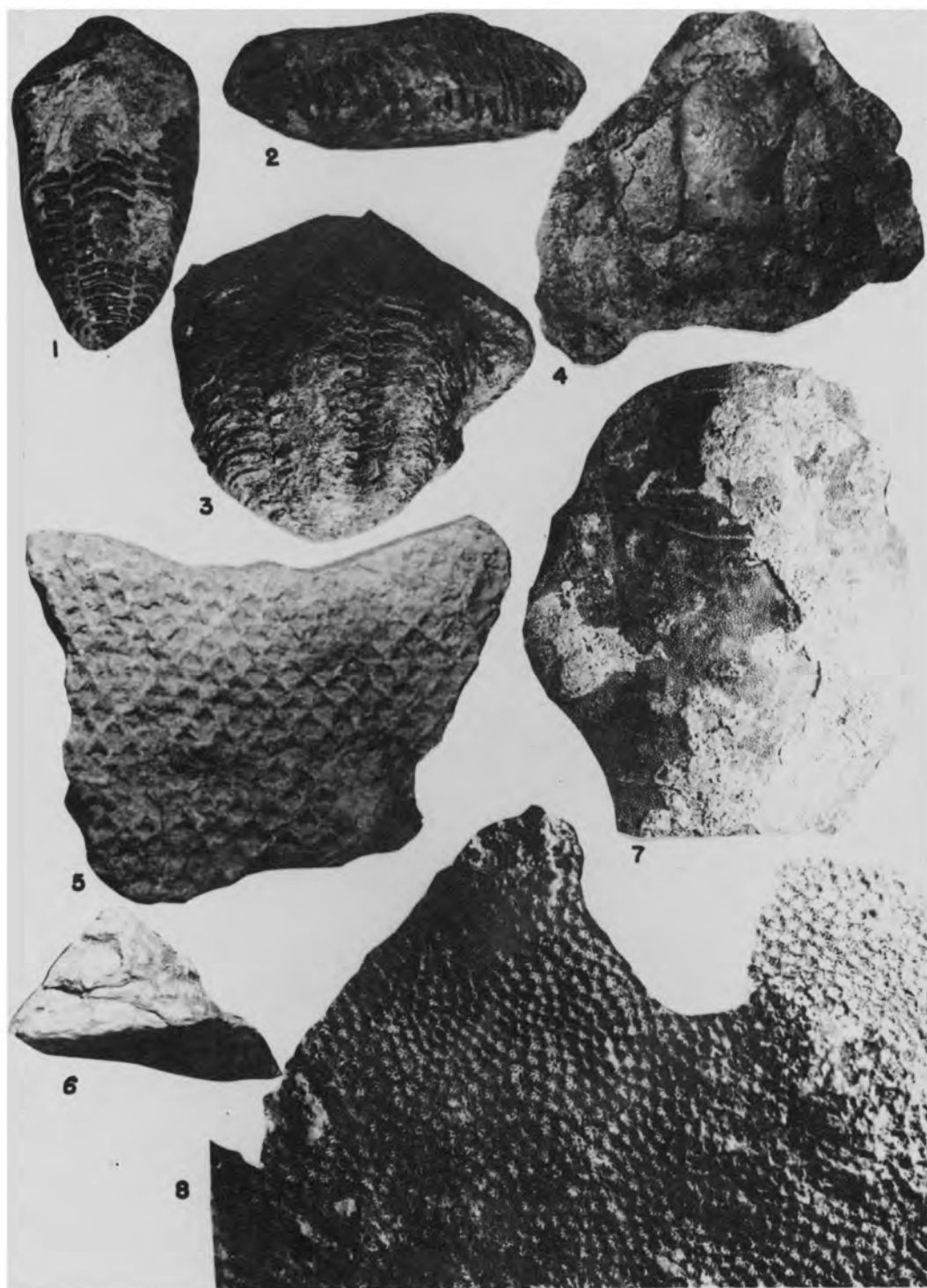


Figure 12. Fossils of the Lenoir Limestone characteristic of Zone II.

Figure 13. Fossils of the Lenoir Limestone characteristic of Zone IV.

- 1-2. Christiania subquadrata (Hall)
 - (1) Side view both valves, larger pedicle valve displaying beekite surface, X3.
 - (2) Well preserved interior of a brachial valve bearing four prominent longitudinal ridges, X3. Both specimens are silicified.
 Zone IV a., Section B, George Morton Farms, north side of Gooseneck Road, Louisville (T.V.A. 138-SE) Quadrangle, Tennessee. Abundant.
3. Palaeostrophomena sp.
 Pedicle view, X3.7.
 Zone and locality same as preceding.
- 4-5. Orthambonites sp.
 Brachial and pedicle exteriors, X3.8.
 Zone IV, Section E, U. S. Route 129, 1.5 miles south of junction with U. S. Route 11-70, Knoxville (T.V.A. 147-NW) Quadrangle, Tennessee.
6. Valcourea sp. cf. Valcourea semicarinata Cooper
 Pedicle view, X3.5.
 Zone and locality same as preceding.
7. Multicostella sp.
 Exterior of pedicle valve X2.
 Zone IV b., Section A, Friendsville, Concord (T.V.A. 138-SW) Quadrangle, Tennessee.
8. Phragmorthis buttsi Cooper
 Exterior pedicle view, X4.7.
 Zone IV b., Section B, George Morton Farm, north side of Gooseneck Road, Louisville (T.V.A. 138-SE) Quadrangle, Tennessee.
9. Schizambon sp.
 Pedicle exterior showing long foraminal slit, X4.
 Zone and locality same as preceding.
10. Rhipidomena? sp.
 Brachial exterior, X4.
 Zone and locality same as in no. 8 above.
11. Plectorthis sp. cf. P. compacta Cooper and P. transversa Cooper. Pedicle view, X4.
 Zone and locality same as in no. 7 above.

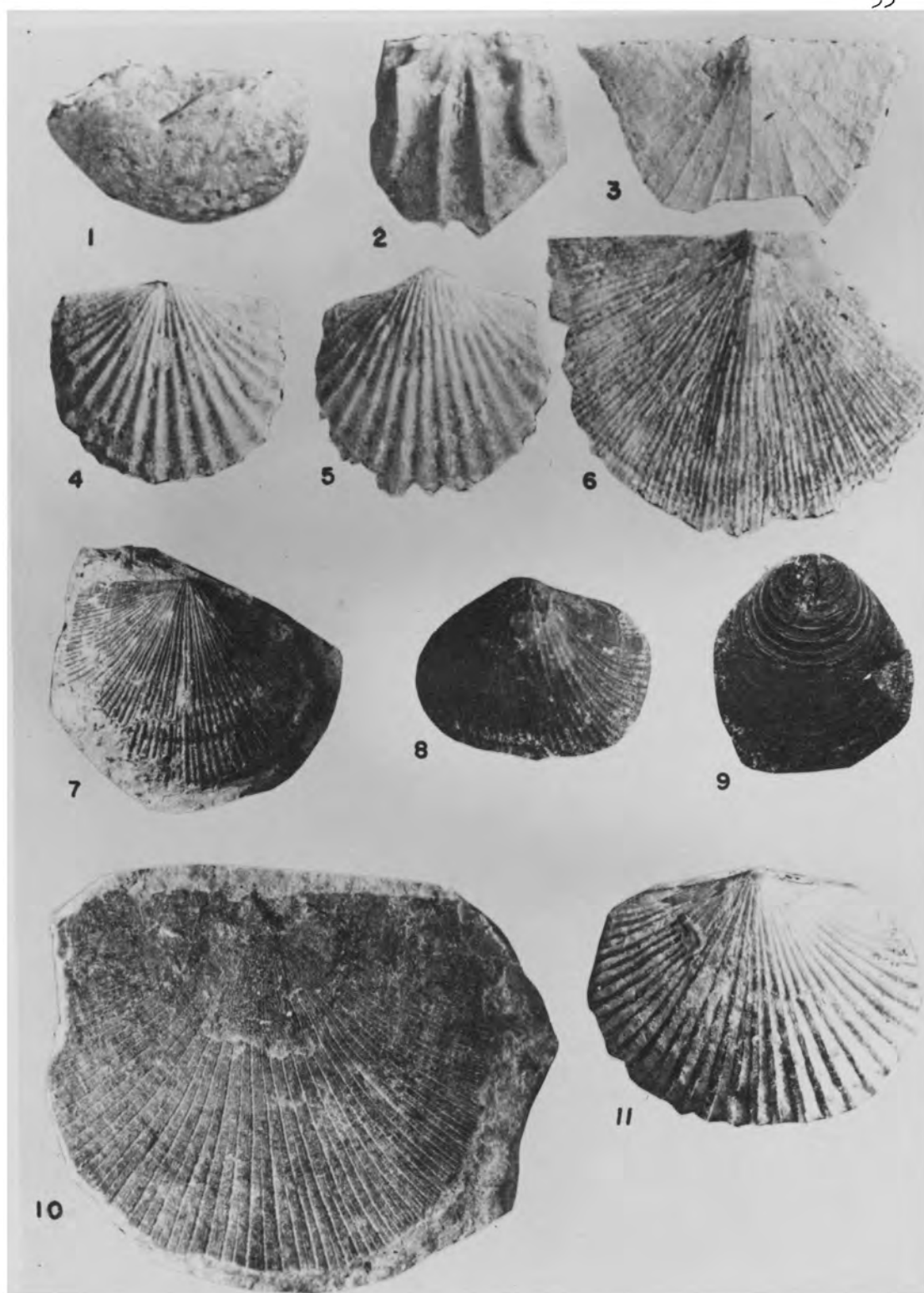


Figure 13. Fossils of the Lenoir Limestone characteristic of Zone IV.

Figure 14. Fossils of the Lenoir Limestone, Zones I, IV, and VII.

1. Orthoconic cephalopod
Naturally sectioned nautiloid showing centrally positioned siphuncle, X0.8.
Zone IV b., Section B, George Morton Farm, north side of Gooseneck Road, Louisville (T.V.A. 138-SE) Quadrangle, Tennessee.
2. Receptaculites? cf. R. oweni Hall
Flat discoid shape, with eccentric depression corresponding to narrow projecting base of attachment on under side, cell rows curve strongly as they radiate from center, X0.8.
Zone I, New Market (T.V.A. 155-SE) Quadrangle, east side of Piedmont Road in Rocky Valley.
3. Receptaculites oweni Hall
Flat probably discoidal or circular shape with funnel-shaped depression corresponding to narrow projecting base of attachment on under side, cell rows curve strongly as they radiate from center. Commonly called "sunflower coral" for its resemblance to the center of the sunflower, X1.7.
Zone IV b., 100 yards southwest of Negro cemetery. Friendsville, Concord (T.V.A. 138-SW) Quadrangle, Tennessee.
4. Ceraurus sp.
Cranidium showing glabella and one fixed cheek, X2.
Zone and locality as in no. 1 above.
- 5-6. Low coiled gastropod resembling Liospira or Raphistoma.
Similar forms common throughout the Lenoir. Side and basal views, both X1.7.
Zone VII, Section B, south side of Gooseneck Road, Louisville (T.V.A. 138-SE) Quadrangle, Tennessee.

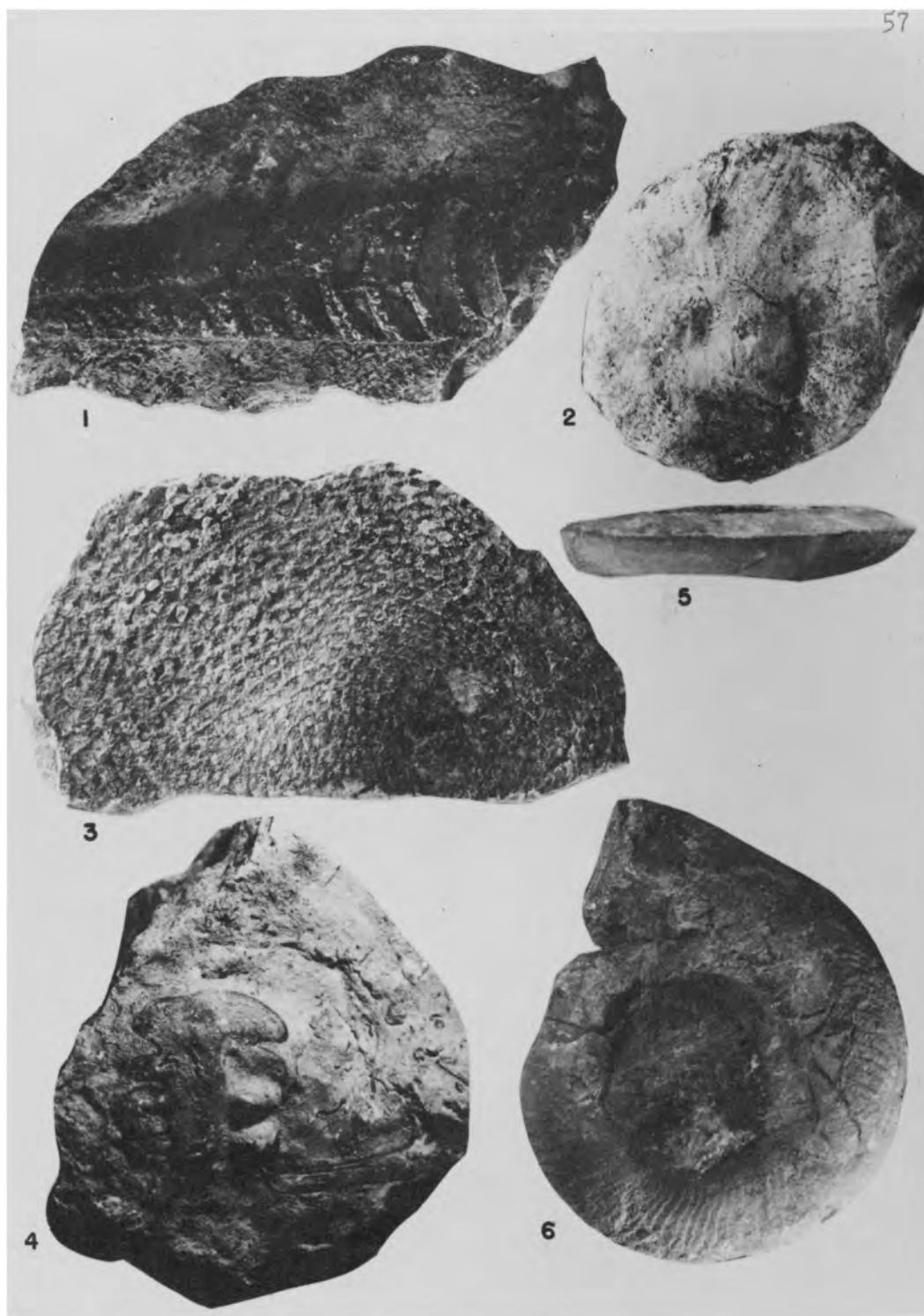


Figure 14. Fossils of the Lenoir Limestone, Zones I, IV, and VII.

Figure 15. Fossils of the Lenoir Limestone, Zones II and VI.

- 1-2. Pleurotomaria? sp.
 (1) Top view, X0.8.
 Zone V, Jenkins Ridge, 2000' south of Pumpkin Center,
 Louisville (T.V.A. 138-NE) Quadrangle, Tennessee.
 (2) Side view of a different specimen, X0.8.
 Zone II, Section D, Longview Farm, Bearden (T.V.A. 138-NE)
 Quadrangle, Tennessee.
- 3-4. Iliaenus fieldi Raymond
 (3) Dorsal view of pygidium and thorax of a coiled specimen,
 X1.
 (4) Side view of same specimen, X1.
 Zone VI, Section B, Gooseneck Road, Louisville (T.V.A.
 138-SE) Quadrangle, Tennessee.
5. Homotelus sp.
 Oblique view of the pygidium and thorax, X1.
 Zone and locality same as preceding.
- 6-7. Allosaccus prolixus Raymond and Okulitch
 (6) Convex surface with small depression in center, note
 weathering has displayed canals radiating from the center,
 X0.6.
 (7) Concave base of a different specimen, all specimens
 were found base down, X0.6.
 Zone and locality same as in no. 3 above.
8. Hudsonospongia? sp.
 Top view with silicified vertical and radiating canals,
 X0.6.
 Zone VII, marble quarry, Friendsville, Concord
 (T.V.A. 138-SW) Quadrangle, Tennessee.
9. A tarphycerid cephalopod, unidentified as to genus.
 X0.6.
 Zone and locality same as in no. 8 above.

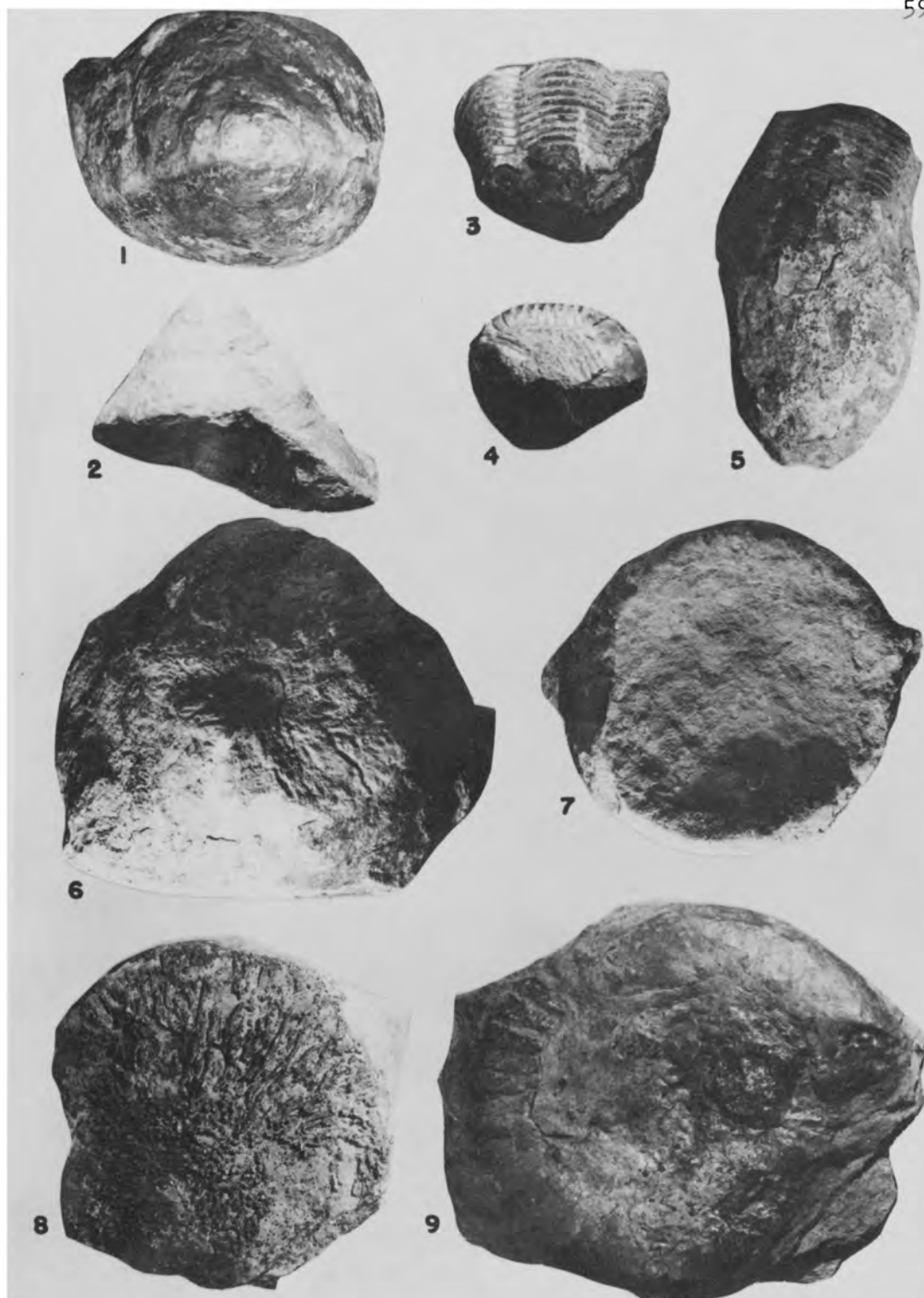


Figure 15. Fossils of the Lenoir Limestone, Zone II and VI.

Figure 16. Fossils of the Lenoir Limestone characteristic of Zone VII.

- 1-3. Cryptozoan
Top, cross section, profile cross section, X0.5.
Zone VII, Cox Farm, west of Mountain Hill, Louisville
(T.V.A. 138-SE) Quadrangle, Tennessee.
4. Macrocoelia obesa Cooper
Exterior pedicle view, X1.7.
Zone VII, Section B, south side of Gooseneck Road,
Louisville (T.V.A. 138-SE) Quadrangle, Tennessee.
5. Maclurites magnus Lesueur
Basal view of Maclurites cast with a trilobite pygidium
(Homotelus?), X0.75.
Zone and locality as in no. 4 above.
- 6-7. Maclurites sp. and encrusting algae?
(6) Gastropod cast with some trace of incrustation along
sutures, X0.8.
(7) Algae? incrusting cast, X0.8.
Zone VII, east of Mountain Hill, Louisville (T.V.A. 138-SE)
Quadrangle, Tennessee.

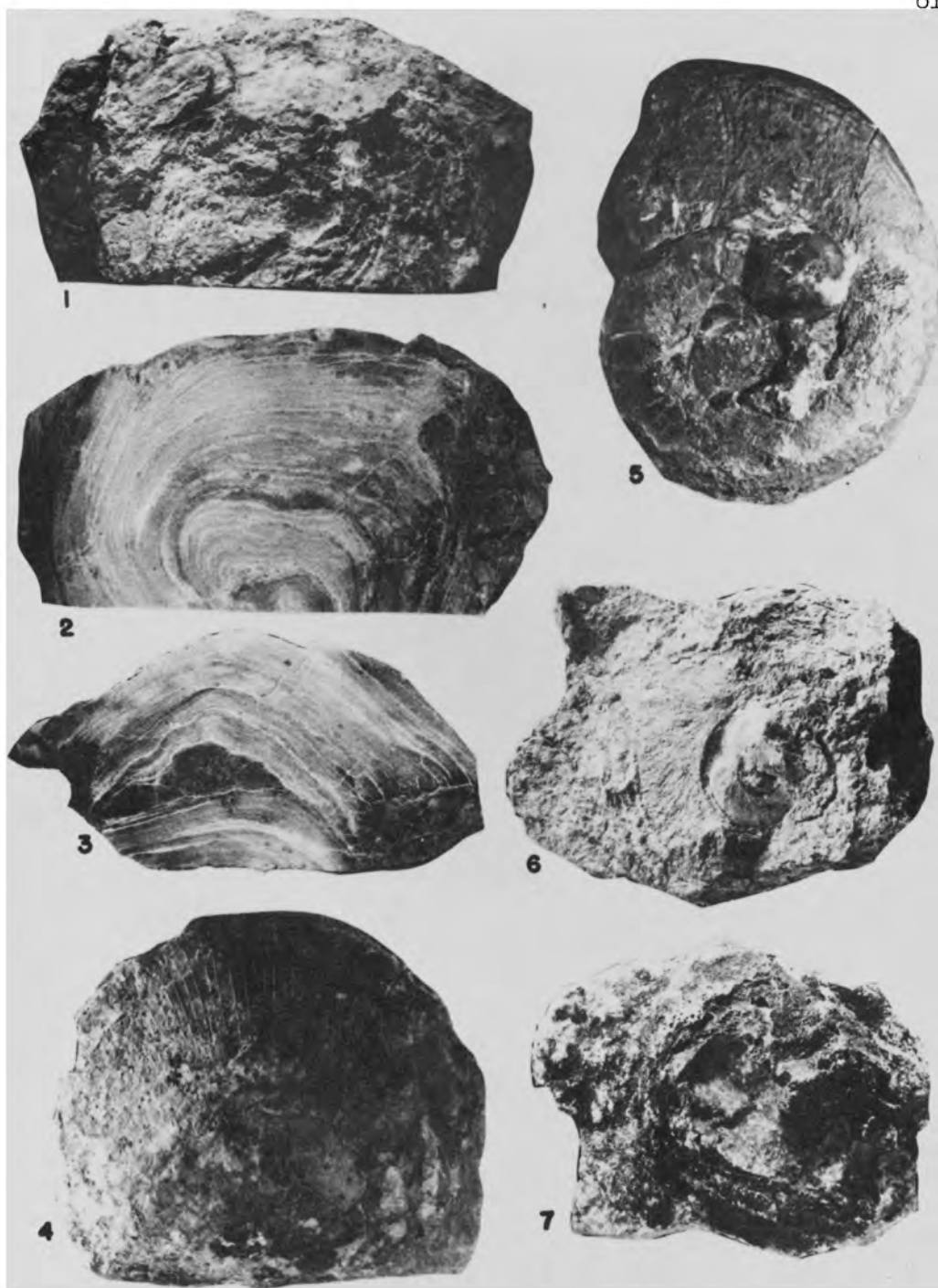


Figure 16. Fossils of the Lenoir Limestone characteristic of Zone VII.

Paleoecology

Introduction

The main body of the Lenoir in the study area, as previously noted, can be divided into a sequence of seven zones. The underlying Mosheim, given member status by recent stratigraphers, is not included in the sequence of numerical designations. Additional study could lead to inclusion of this unit but is beyond the scope of the present study. The lithologic and paleontologic differences and similarities of the zones in the typical Lenoir, it is believed, are a reflection of environment and are therefore ecological.

The fossil record was examined in each zone in regard to vertical and lateral distribution of components, associations, manner of preservation, and relationship to the sediment. From these observations a number of basic deductions have been made which may lead to a clearer stratigraphic interpretation of the Lenoir.

It has been noted that the general characteristic of zones in the lower half of the formation are repeated in the upper portion. This may indicate some relationship between the similar zones at least to conditions under which they were developed.

Zone I

In the Friendsville area, Zone I is composed of two lithologies: a typical argillaceous limestone, and a more coarsely crystalline limestone somewhat resembling marble. In the southern portion of the

thesis area the fauna consists of numerous small brachiopods, bryozoans, and crinoid fragments with occasional, small, low-spired gastropods. It should be noted that one large Maclurites specimen was found. To the north, for example in the Blue Grass section and farther, the zone contains larger fossils as a more argillaceous lithology becomes dominant. The major components there are Maclurites magnus Lesueur, Allosaccus prolixus Raymond and Okulitch, and cryptozoans. These are all large types and their occurrence and ecologic implication is duplicated in Zone VII. A nearshore, shallow water, high energy environment is suggested.

Large Maclurites are abundant (Figure 17) and although exceptions occur, the majority assume an orientation with their flat, basal side down. The abundance of these large gastropods in a restricted fauna seems contrary to the natural habitat of the organism. It would be expected to be found associated with numerous other organisms. The absence of Maclurites opercula seems also to be significant. With the large number of shells at least some opercula would be expected. A highly probable inference to be drawn is that the gastropod conchs, once free from the fleshy part of the organism after death, drifted some distance before eddies and currents concentrated them. This would account for the missing opercula, an orientation likely to be a stable one in a high energy environment, and, possibly, a mechanical sorting by currents to account for the similarity in size.



Figure 17. Maclurites-dominated Zone I. This photograph illustrates the large size and abundance of Maclurites casts in Zone I. T.G.C. are 618,600 N. and 2,726,350 E.

This is not to say that living large-shelled gastropods were not endemic to this zone. As a matter of fact, large size would have survival value in a high energy zone.

Sponges are also indicative of a high energy type of environment as implied in Zone I. In form they are hemispherical and of low relief. Modern forms living in areas affected by strong changing currents have similar or encrusting forms. The circulation of the water by currents would be beneficial to the sponges which thrive in shallow, near shore water.

The cryptozoans indicate shallow water and possess an adaptive form similar to that of the sponges, low bowl-shaped masses.

Zone I in the Friendsville area has a large and varied brachiopod population indicating a lower energy environment. Both valves of the small brachiopods are present and long segments of little altered branching bryozoans are common. Shells in this part of Zone I are located normally on bedding surfaces and appear to be little disturbed. A similar assemblage is found above the Mosheim where it is present.

The Mosheim presents a separate problem that was not attacked in any detail in this study. The lithology seems to indicate an environment of deposition quite dissimilar to that of the typical Lenoir. It is a relatively pure limestone while the main body of Lenoir is highly impure. The Mosheim has been recorded as sparingly fossiliferous to unfossiliferous but detailed study is required to

support this assumption. The fossils observed were mainly large gastropods and ostracods. As previously mentioned, the Mosheim is nearly continuous in the thesis area.

One inescapable conclusion concerning the Mosheim in reference to its high calcium carbonate content is that little contamination by clastic deposition occurred during the formation of the limestone. This implies a restricted site of deposition.

Zone II

Six different phyla are represented in Zone II. There are a number of homeomorphic forms present in the Lenoir and especially in this zone. For this reason the classification of some specimens is still in doubt. At any rate there is a multitude of fossil types in comparison to most other zones. The assemblage consists of brachiopods, bryozoans, cephalopods, crinoids, gastropods, sponges, trilobites, corals, and questionable stromatoporoids. This indicates an environment ideally suited for a large and varied population. The components of the fauna suggest shallow, clean, near shore water, possibly of warm temperature.

The fossils appear to be evenly distributed. The major types in this zone have been found from the southern to the northern extremities of the study area. The fauna is composed of both fragmented and complete fossils and many well preserved specimens were collected. Two nearly complete specimens of the trilobite Pliomerops canadensis

were collected from one location along with several rock slabs displaying sponge spicules in original orientation. Low energy conditions appear to be indicated. Crinoid and bryozoan fragments are common but these more delicate types might be expected to become disassembled and fragmented.

One of the most abundant types in this zone are small, low-spired gastropods, in this case appearing to be native to the zone, as do the less common orthoconic cephalopods, and not drifting shells. All fossils seem to be deposited roughly parallel to bedding and randomly scattered. Both large and small forms are present. Large blocks containing Billingsaria parva (Billings) are common, along with Allosaccus prolixus, which ranges from common to dominant. In the latter case, this zone resembles Zone VI which is dominated by this sponge form. A few large gastropods resembling Maclurites magnus Lesueur are the large forms present. The remainder of the fauna is normally small.

Zone III

Zone III is not continuously well exposed in the thesis area but where outcrops were observed they were sparingly fossiliferous to barren. The lower portion of the zone (Figures 18 and 19) generally contains shale and chert and resembles Zone II while blocks exposed in the upper portion resemble Zone IV. Although few fossils were observed, in one exposure at the head of Cox Creek embayment just



Figure 18. Shaly, chert-bearing, unfossiliferous beds of Zone III, Section C. This exposure is located approximately 2 miles northeast of Friendsville. T.G.C. are 511,300 N. and 2,559,190 E.



Figure 19. Porous, yellow-brown chert nodules weathered out of beds in Zone III, Section C. Chert of this type is common in both the lower and upper portions of the Lenoir. T.G.C. are 511,300 N. and 2,559,190 E.

west of Louisville in presumed Zone III beds (structural involvement makes identification speculative) there are abundant large orthoconic cephalopods. Similar forms have previously been mentioned in Zone III strata of Section C. Such concentration of these conchs is highly suggestive of drifting. The large cephalopods were undoubtedly benthonic. After the death and removal of the organism, the empty shells must have drifted widely and were locally concentrated by eddies or currents. Although such occurrences can yield little paleoecological information, the floating conchs might possibly serve as a horizon marker, cutting across environmental zonation.

The lack of a large fossil fauna which might be considered in situ is characteristic of this zone. The only conclusions to be drawn from this feature are that environmental conditions were not amenable to the development of a large fauna, or, if conditions were suitable for populations to flourish, all traces of them have been obliterated. The latter seems least likely.

Zone IV

This zone has been divided for discussion purposes into two parts based largely on certain paleontologic and lithologic distinctions which are not sufficient, however, to warrant separation into particular zones.

Subzone A is somewhat lithologically distinctive in that the wavy irregular clay partings exhibited elsewhere in the formation are

accented to create a nodular or cobbly appearance of the massive outcropping blocks and ledges (Figure 20). At no place were these blocks observed to weather into nodular rubble and loose fragments or small blocks common to much of the formation. An unusual deep orange-red soil is developed in vertical channels to depths of 6 to 8 feet or more.

The fauna of this subzone is basically simple. It is comprised essentially of one species of brachiopod, Christiania subquadrata (Figure 20). Specimens are concentrated in layers in the upper portion of the subzone and occur in great numbers when present. In the layers, the specimens are not particularly oriented but are found randomly in any and all positions, some along the irregular surfaces with the clay partings, others with no relationship to bedding.

Because of silicification, another feature of the subzone, the fossils stand out in weathering relief and are abundant in the thick residuum. Both valves are in contact except where physically separated and internal features are well preserved. Beekite is often developed on valve surfaces. In the thesis area, an example of the extraordinary abundance of specimens in the residuum can be found in the Negro cemetery in the northwest part of Friendsville community where they literally cover the ground.

As pointed out above, the distribution of Christiania in this subzone is not uniform but concentrated in the upper portions.

A.



B.



Figure 20. "Christiania Beds," Subzone IV a., Section B.
A. Massive, resistant ledges with typical nodular or cobbly appearance. Note the development of residuum which is distinctive and typical of this subzone. B. Concentration of Christiania subquadrata. T.G.C. are 507,100 N. and 2,557,825 E.

The continuity of the lateral distribution of this species at approximately the same horizon is beyond question in the thesis area. Observation of this by others has accorded Christiania a major role in recent correlation of Middle Ordovician rocks in East Tennessee by some authors. Consequently, more discussion and emphasis has been centered on Christiania than any other Lenoir fossil. This matter will be discussed in a later chapter.

Aside from the correlation question, occurrence of the Christiania has various environmental implications. One significant feature mentioned previously is that both valves of the shell are present and in contact, showing little separation and breakage. A low energy environment is indicated permitting the small shells to be buried in situ. The thick clay partings characteristic of the matrix lithology in this subzone suggests that the organism was adapted to a muddy environment, and one that persisted for long periods of time as reflected by the massiveness of the subzone. The lack of a record of other organisms would appear to suggest that conditions were unsuitable for them but ideal for Christiania.

Subzone b is a brachiopod-dominated portion of Zone IV. It has been separated from the lower division of the zone because of certain lithologic and paleontologic differences. While the lithology is very much the same, the large massive blocks (Figure 21) may be observed to break into small nodular or slabby blocks with weathering (Figure 22) unlike the lower zone which maintains its

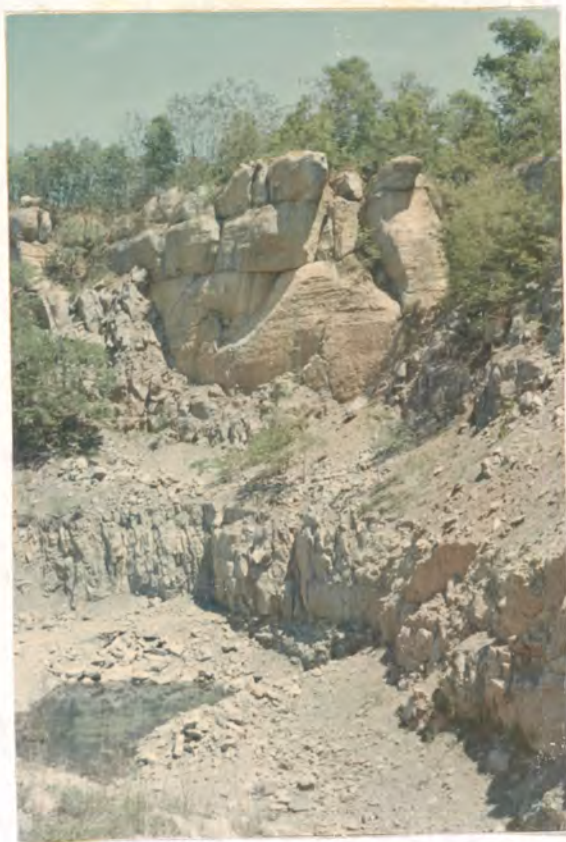


Figure 21. Quarry in Zone IV. This photograph illustrates the massiveness of the zone. This is a former Blount County quarry just recently abandoned. T.G.C. are 518,400 N. and 2,577,400 E.



Figure 22. Weathered exposure of Subzone IV b., Section B. This view illustrates the rubbly surfaces of small slabby blocks and chips formed by this subzone in contrast to Subzone IV a. which retains its massive appearance. T.G.C. are 506,680 N. and 2,557,825 E.

massive appearance. The fossils are silicified but to a lesser degree than in the lower zone. The most important distinction is the variety of brachiopods and other organisms. Trilobites, sponges, bryozoans, and orthoconic cephalopods are all common and small gastropods are found occasionally, but the significance of these members is dwarfed by the abundance of brachiopods. Unfortunately, brachiopods do not indicate any special set of environmental conditions. The presence of a Lingula-type (Lingulella) brachiopod does appear to indicate a definite zone, the littoral or shore zone. The same conclusion would have been inferred from the fauna even in absence of the Lingula-type. The brachiopods apparently flourished with numerous associated organisms. Christiania subquadrata is still present and abundant and this points out that the subzone does not merit individual zonal designation. The continued presence of Christiania indicates that the changes in conditions were not drastic. The environmental changes that did occur apparently were not great enough to affect the Christiania but of enough consequence to encourage a more luxuriant population.

The brachiopods and other members of the fauna appear to be evenly distributed in this zone and the zone is consistent in position and composition in the study area. The brachiopods are often found forming a fossil hash with bryozoan, crinoid, and trilobite fragments. Often one shell is found encrusted on another. The brachiopods are partially silicified. They occasionally weather completely free of

the matrix but usually are found well exhibited on the weathered slabby or nodular blocks. Usually the valves are separated but many specimens still possess both valves and in either case the shells show little wear or breakage. The entire fauna seems to be normally deposited with expected orientation of the shells along bedding plane surfaces appearing relatively undisturbed.

The other components on a whole indicate shallow near shore water. Bryozoans prefer shallow seas, and many live fairly close to shore. They seem to prefer clear water rather than turbid, muddy water so they may be cited as another point in favor of a more desirable environment compared to the suspected muddy environment of the Christiania. The trilobites suggest no special set of conditions since it is believed that they were not confined to any single environment and most could live under a variety of conditions. The sponges indicate clean, near shore, shallow water and the cephalopods, if in place, would probably indicate a shallow water environment where other organisms were plentiful.

In summary, this subzone denotes a change in environmental conditions from those of Subzone IV a. to conditions more suitable to a less restricted and more diversified population. Conditions were certainly more advantageous to life. Shallow water, low energy environment is indicated by the assemblage.

Zone V

Zone V is sparingly fossiliferous to barren. It is gradational with the bordering zones and, therefore, some elements from adjacent faunas are included such as brachiopods in the lower portion and sponges in the upper portion. However, the major portion of this zone is sterile. The lithologic characteristics of this zone are similar to the rest of the formation except that it is somewhat more impure with a higher silt fraction.

This zone represents a major change in conditions from those prevailing during the deposition of Subzone b of Zone IV where life was abundant and varied. Apparently, there was a gradual shift in environment to which the brachiopods and associates could not adjust. It seems reasonable to assume that an increase in mud or other physical and chemical alterations of environmental conditions eliminated the majority of niches formerly occupied. Less likely is the removal of all trace of former inhabitants subsequent to death. Perhaps this zone reflects deeper water deposition or a high energy environment unsuitable for survival of most organisms.

It is noteworthy that many similarities between this zone and Zone III exist. It is possible that a return to those earlier conditions is reflected in Zone V.

Zone VI

The fauna of Zone VI is very restricted. The dominant form is the sponge Allosaccus prolixus Raymond and Okulitch. There are

some brachiopods, trilobites, and orthoconic cephalopods, but their presence is greatly obscured by the preponderant occurrence of Allosaccus.

The form and presence of Allosaccus appear to have several ecological implications. First, as previously noted, hemispherical, low shape is very characteristic of modern forms living in strong, often changing, currents. The presence of sponges would appear to indicate a near shore shallow environment, the water relatively low in clay and silt yet freely circulating. The Lenoir is argillaceous but perhaps currents prevented the settling of much fine material during times of abundance and, later, the silt and clay were responsible for restriction of sponge growth.

This sponge-dominated zone may indicate the fore flank of a reef environment. The sponges are composed of the same or nearly the same material as the host limestone and are intimately related to the enclosing matrix. They appear to be oriented with their base along bedding, the most stable position with respect to currents.

When extremely abundant, the sponges appear to be partially responsible for some of the nodular or cobbly weathered appearance of the Lenoir (Figure 23). On flat surfaces or gentle slopes they retain their approximate original positions with a concave bottom directed downward and a shallowly depressed upper surface with canals seen radiating from the center if preserved.



Figure 23. Zone VI, Section A. Sponges are often abundant in this zone and as illustrated by this photograph they may be partially responsible for the nodular or cobbly weathered appearance. T.G.C. are 501,710 N. and 2,553,090 E.

Weathering in this zone usually produces short, narrowly elongate blocks with pseudo-conchoidal surfaces as compared with more equidimensional or nodular weathering products seen in other zones.

The brachiopods and trilobites in this zone reflect less vigorous conditions, perhaps nearby localized biohermal development. The orthoconic cephalopods appear to have random distribution in the zone and may have been related to this zone in life. The apparently physical concentration of such shells seen in other zones was not observed.

Zone VII

The fauna of Zone VII is well defined. It is consistent wherever the zone has been recognized throughout the thesis area. The basically simple fauna is composed of Maclurites magnus LeSueur, Allosaccus prolixus Raymond and Okulitch, Macrocoelia obesa Cooper, medium to large orthoconic cephalopods, and cryptozoans or other stromatolites. Specimens of all of these components tend toward large size although individual large specimens may occur in other zones, for example in Zone I. Excepting the varied brachiopod fauna not present in Zone VII, many characteristics of this zone compare favorably with Zone I, especially in the central to northern part of the thesis area. This is particularly true of the mutual dominance of Maclurites, Allosaccus, and cryptozoan stromatolites in places in both zones.

The fauna of Zone VII is discussed in the following paragraphs in terms of its five major elements, gastropod, sponge, stromatolite, cephalopod, and brachiopod, etc., element.

Gastropod element. Most marine gastropods today are benthonic but some are pelagic. The vast majority live in comparatively shallow water. The gastropod of this zone is Maclurites and as mentioned under Zone I, these large specimens generally are found with the flat side (base) of the shell down. This appears to be the preferred orientation although exceptions have been observed. It is noteworthy that there is a lack of Maclurites opercula (as in Zone I) which would be expected among the numerous shells found.

The abundance of large gastropods in this zone appears to be out of balance with what would be expected in a natural environment. Marine snails are benthonic carnivores or herbivores today, although a few strain mud for food. The size and numerical strength of these snails imply a dependence on a nutritional base of larger dimension than that represented by their fossil associates. The suggestion is made, as in Zone I, that these were originally empty conchs floated to the site of deposition while buoyant and preserved in a foreign thanatocoenose. The orientation of the shell mentioned previously appears to be a natural position of rest following the activity of transporting currents. During or following movement and settling, the shells were swept full of sediment by the currents. Maclurites

casts have been found in some cases to contain fossil fragments such as brachiopod valves as shell fillings and commonly the matrix of the cast, the typical fossil type, is very similar to that of the enclosing limestone. Following death and before transport, opercula must have been separated from the shell which would account for their absence, a point raised in describing Zone I.

The concentration of the Maclurites fossils in this zone is consistent from one mile south of Friendsville to the Keller Bluff peninsula area, a distance of at least nine or ten miles. The characteristics of Zone VII, on the whole, do not indicate environmental conditions under which an abundant population could flourish but rather an environment of high energy and rigorous conditions tolerated by only specially adapted types and forms. The Zone II association for gastropods such as Maclurites seems a more natural one.

Sponge element. The sponge, Allosaccus prolixus, is commonly very abundant in this zone. A number of specimens measured ranged from 4 to 15 cm. in base diameter and 2 to 6 cm. in height. They are invariably oriented with their greatest diameter, across the base, parallel or approximately parallel to bedding and apparently in living position. It should be noted that this could be the most stable position following current orientation. This raises a question as to whether the Zone VII sponges may represent a physical concentration peripheral to Zone VI where they are the chief if not exclusive faunal element.

As in Zone VI, sponges appear to be responsible for some of the nodular or cobbly appearance of most weathered surfaces. The fossils take on the appearance of the enclosing matrix but are slightly more resistant to weathering with some silicification displayed.

Sponges of the modern sea displaying a subhemispherical form comparable to Allosaccus grow under conditions of strong currents which frequently change direction. In more placid waters, they are associated with a varied fauna, none of which is present in Zone VII.

Although distributed throughout the Lenoir, Allosaccus is concentrated in certain zones as previously noted but the concentrations are themselves variable. In Zones V and VI they may be dominant or nearly so and they occur without association with large gastropods and orthoconic cephalopods. The latter, on the other hand, is particularly the case in Zone VII and in Zone I. It is believed that this latter association is due to high energy conditions responsible for physical concentration of some elements or marginal biological conditions to which only special forms were adapted.

Cryptozoan-Stromatolite element. This element is a reliable index to Zone VII which, in this respect along with other features, resembles Zone I. Mainly they are fairly symmetrical, if uncompressed, concentric masses often with laminae in relief due to silification. Undoubtedly, many of these forms are referable to the algal cryptozoans

believed to be ancient cyanophytes. Others, similar in form but less convincing, are referred to the general term, stromatolite. All these forms occur in the same zones and appear to be in the natural position.

The size of these forms range from a few inches to a foot or more in diameter. They served to entrap particles of detritus around which they developed curving laminae. Some apparently are partially dolomitized but this feature has not been investigated to any degree as yet.

The distribution of these forms parallels that of Maclurites consistently (Figure 24) and they are found often encrusting upon the gastropod shells. Close inspection of some weathered specimens of the latter shows markings left by the incrustation.

During the time of development of these forms, a shallow depth of less than 30 meters is assured. Beyond this the light necessary for photosynthetic organisms does not penetrate.

Cephalopod element. Orthoconic cephalopods are common in this zone, yet not particularly concentrated in great numbers in any one place in the thesis area. They are subcircular to lenticular in cross section, and of moderate length up to a foot. Operating in life close to the bottom, these animals released the heavy shells upon death and these may have been contributed directly to the bottom sediment close at hand. Remaining afloat, however, the conchs could have drifted great distances. It is not improbable that these fairly



Figure 24. Close association of Maclurites and cryptozoans in Zone VII. The large cryptozoan in this photograph is flanked by casts of Maclurites indicated by the circles on the outcrop. In this same location cryptozoans were found encrusted on casts of the gastropod. T.G.C. for this location are 529,435 N. and 2,570,875 E.

robust forms were well adapted to the high energy environment implied by other elements in this zone. The environmental significance of these forms, however, remains in doubt.

Brachiopod and other elements. A large, strophomenid brachiopod, Macrocoelia (Rafinesquina) obesa Cooper, is common in the zone. Specimens are found upon the bedding planes and may be partially silicified with beekite on valve surfaces. They are evenly distributed in the zone and are found consistently where outcrops of the zone occur. They permit only limited ecological or association inferences other than that they are large brachiopods found with other large fossils. If this zone does indicate high energy conditions, as previously suggested, it is logical to assume that the possession of a large and heavier shell might have survival value. This argument coincides with the presence of large trilobites such as Illaenus among others in the zone. A limited number of other brachiopods and some bryozoans, however, add little support to this view except that at times they are fragmented.

CHAPTER IV

THE CORRELATION PROBLEM

Introduction

In an earlier chapter, the controversy concerning Middle Ordovician correlation was introduced as a justification for reexamination of the formations and faunas involved and, in particular, the Lenoir Formation in central East Tennessee where many of the conflicting opinions have their source.

In this chapter, the views of the principal advocates of the contrasting interpretations will be examined in closer detail and these opinions will be judged in the light of evidence gathered in the development of the present thesis.

Stage and Inter-formational Correlation

G. A. Cooper (1956) correlated his restricted Lenoir Limestone with the Crown Point and Valcour Formations of the New York Champlain Valley section. In this view, the brachiopods, Onychoplectra and Valcourea characterize the Crown Point while Hesperorthis and Titanambonites link the Lenoir with the Valcour. Species of Mimella may be related to either of the two formations.

Cooper states that the most important brachiopods in his Arline Formation, the Upper Lenoir representative in the Friendsville area, are: Bimuria, Christiania, Eremotoechia, Isophragma, Palaeostrophomena,

Phragmorthis, Platymena, and Titanambonites. These fossils have a wide geographic distribution. Cooper relates the elements of this assemblage at least in part to the following formation: the Little Oak and Pratt Ferry of Alabama; the Botetourt, Effna, and Edinburg of Virginia; the Shippensburg of Maryland and Pennsylvania; and the Benbolt and Tellico of Tennessee. Cooper also compares the Arline closely to the Stinchar-Balclatchi assemblage of the Girvan district of Scotland. It is noteworthy that all of the formations with related brachiopods are post-Chazyan according to the correlation chart of Twenhofel, et al. (1954).

Raymond (1928) identified 21 species of brachiopods from the Lenoir. His specimens were collected from three widely spaced localities: the Knoxville vicinity, Bluff City, Tennessee, and the Catawba Valley, north of Salem, Virginia. Raymond notes that 9 of the 21 species were originally described from the Chazy thus giving the Lenoir a strong Chazyan appearance. He felt that the Lenoir represented Middle Chazy but noted that the presence of Christiania and Plectambonites were non-Chazyan elements of the fauna. He concludes that an admixture of the two main elements, both European in origin, is indicated. Raymond noted also that the Athens, Holston, and Ottosee all contain some elements of the Chazy. Raymond further stressed the close relationship between the brachiopod genera of the American Middle Ordovician with the faunas in Scotland.

The "Christiania Beds"

Central to the problem of correlation is the time-stratigraphic significance of the Christiania-bearing beds in the Lenoir. Unlike most of the brachiopod genera listed in the preceding section, specimens tend to be concentrated in great numbers and well-preserved; and they dominate a portion of the sequence exclusively. Hence they have been chosen by some authors as an index to relative age interpretation of the formation.

At the type section in Athens, the Athens Shale rests upon a thin layer of Lenoir Limestone, overlain by a thin bed of impure limestone abounding in Christiania (G. A. Cooper, 1956). The whole of the Athens then interfingers laterally with Lenoir. Tracing the units northward the percentage of limestone increases while the shale percentage decreases until at Friendsville shale is no longer present.

Christiania is missing in the type Chazy in New York and the lower boundary of its geologic range has been drawn at the top of the Chazy stage. Based on the presence of Christiania roughly in the middle portion of the Lenoir in the Friendsville area, and the fact that they are missing from the type locality at Lenoir City, Tennessee, Cooper (1956) considered the upper Lenoir to be a "restricted Lenoir" which he named the Arline Formation. Christiania is present in the lower portions of the Arline and is diagnostic of the formation. The Arline is regarded, therefore, as younger than all of the Lenoir at the type locality in Lenoir City. Since both the type Lenoir and the

renamed Arline both are overlain by the Holston Formation, the Holston beds are not considered equivalent. Thereupon, the Athens Shale is considered to be a facies equivalent of the Arline Formation portion of the undivided Lenoir.

Rodgers (1952, 1953) stated that the contact between the underlying Lenoir and the Athens is gradational and that the Athens is laterally equivalent to the Lenoir as a whole and not to just the restricted "Upper Lenoir," or Arline Formation of Cooper. He believed that the units of the Knoxville-Friendsville belt correspond exactly to the units of the standard belt of the Lenoir type locality and suggested that the Christiania fauna is restricted to the shaly limestone facies. He believed that this facies invaded the area under consideration at an earlier time during Lenoir deposition than it did in the standard belt to the northwest where the Christiania fauna first appears in the lower part of the Ottosee or equivalent rocks. Rodgers (in Twenhofel et al., 1954) has suggested, therefore, that the restrictions set for Christiania are too rigid and that facies implications have been overlooked. He states:

The lateral gradation of the Lenoir limestone (not just the "Upper Lenoir") into the Christiania-bearing Athens suggests that Christiania ranges even lower than shown on the chart, into equivalents of the Chazy. Probably it is excluded from rocks commonly classed as Chazy by facies differences.

In the course of establishing regional familiarity with the Lenoir, outcrops were examined between the Knoxville-Friendsville area and the type locality in the standard belt. To the south of

Friendsville in Monroe County, Christiania were found to occur within 30 feet of the Knox contact in the Craighead Limestone Company quarry (T.G.C. 442,500 N., 2,483,300 E.). The Lenoir exposed is a nodular shaly limestone. This evidence appears to challenge the use of Christiania as a specific time marker. Furthermore, its use in subdividing a formation constructed on lithologic grounds without time connotation is a questionable procedure. It is admitted that the Christiania beds do have a somewhat distinctive appearance but, as indicated in the previous chapter, typical rubbly "Lower Lenoir" lithology follows the Christiania beds and much of the lower fauna including Christiania repeats itself. The lithology with dominant Christiania (Zone IV) is an accentuation of the typical Lenoir with thicker clay partings producing a cobbly or nodular weathered effect. These "Upper Lenoir" beds are also chert producing, a lithologic distinction used by Cooper (1956) to characterize "Lower Lenoir." The Maclurites-bearing beds in the lower portion is an apparent repetition of conditions. This reoccurrence of Maclurites also appears in the belt of the type locality.

In the portion of the belt examined, the measured sections revealed that the Christiania beds are higher in the section to the north and lower in the south with respect to upper and lower contacts. This again suggests that they appear lower and lower in the section in a southward direction toward Athens.

It seems likely that the Christiania fauna is facies controlled and transgresses northward and westward. If this is true, the Christiania horizon at Athens is the age equivalent of the lower Lenoir in the Friendsville area and is probably Chazyan. This would require revision downward of the presently established range for Christiania (Twenhofel et al., 1954).

Conclusions Regarding Correlation

The weight of evidence derived from the present study supports the view of Rodgers (1953). The Christiania facies apparently invaded the Lenoir to the east and did not reach the area of deposition of the Lenoir type locality until a later time during which the Ottosee was being deposited. The movement of Christiania up the column from Athens to Knoxville indicates that this is the case.

Detailed field inspection revealed no suggestion of unconformity in the Lenoir immediately below the Christiania beds. This, in the view of the writer, further weakens the argument for subdivision. Age relationships between Friendsville area and Lenoir City Holston are beyond the scope of the present investigation.

CHAPTER V

SUMMARY AND CONCLUSIONS

Knoxville-Friendsville Lenoir

The Lenoir Limestone in the thesis area consists of a separately distinct lower Mosheim Member and the main body of Lenoir. The Mosheim is a dove- to dark-gray, massive, cryptocrystalline limestone, with such distinctive features as birds-eye calcite and a conchoidal fracture. In the study area the Mosheim occurs almost continuously, normally with an erosional surface separating it from the main body of the Lenoir, as well as the more familiar one separating it from the Knox below. The major portion of the Lenoir is an impure limestone with a rubbly or nodular weathered appearance. The formation contains several lithologic variations but for the most part it is a medium- to dark-gray, finely crystalline limestone with clay partings along irregular surfaces. Coarsely crystalline limestone occurs in both the Mosheim and the Lenoir. The Lenoir is overlain by either the Holston Formation or the Chapman Ridge Sandstone. Lenoir-type lithology is found above Holston-type lithology in places. Some "marble-ized" Mosheim has also been seen.

In the Friendsville vicinity and elsewhere in the study area, analysis of measured sections and close inspection of faunal elements has revealed that the Lenoir Formation can be subdivided into a number of zones based on general lithologic and paleontologic criteria. The

lithologic and paleontologic differences and similarities of the zones appear to be a reflection of environment. Examination of the fauna characteristic of each zone makes it possible to draw inferences which may lead to a better understanding of these rocks. It was noted that the general characteristics of the lower three zones were repeated in the upper portion of the formation indicating perhaps a return to former environmental conditions. These zones and their faunal assemblages were traced where exposed throughout the thesis area and were found to be persistent. The results of this investigation strongly suggest that further study of this nature may resolve several points of controversy introduced by previous workers who have attempted to subdivide and correlate these rocks in the past.

Recent workers have used brachiopods to subdivide and correlate the Lenoir, and, in particular, one genus, Christiania, has been given a chief role in the matter of subdivision and correlation. Evidence produced by the present study challenges this position and appears to support the contention of Rodgers (1954, Twenhofel et al.) that the restrictions placed on the stratigraphic range of Christiania are too rigid and that the Christiania "zone" is environmental rather than temporal. No wide spread unconformity was found below the Christiania beds to further weaken the argument for subdivision.

In contrast with most previous studies, the present investigation sought to examine the total fauna with respect to its organization into environmental associations, each governed in its distribution by implied

environmental conditions. Fossil species endemic to a particular zone along with exotic elements whose presence appears to be sedimentological in origin collectively represent various expressions of energy intensity, it is believed, and provide a basis for establishing paleogeographic boundaries.

In the local situation, for example, it seems reasonable to assume that faunal and other characteristics of Zones I through III imply a continuous reduction in turbulence or other high energy conditions and consequent biological adaptations and sedimentological variations. Following the development of Zone IV with its brachiopod assemblages including Christiania, an orderly return to the previous conditions is believed to be reflected by Zones V through VII. Therefore, it is concluded that correct interpretation of these beds and their faunas in the past has been complicated by shifting facies. Use of specific elements out of the context of such dynamic implications can be challenged.

Regional Implications

Perhaps the most significant achievement of this investigation is the division of the Lenoir into recognizable zones which should prove valuable in deciphering the geologic history of the formation. It was found through reconnaissance of outcrops outside the study area that zonal characteristics are persistent and predictable. Some success along these lines has been achieved in the Mascot and Boyds Creek areas of Lenoir exposure.

One striking discovery is the sequence in which the zones occur. The symmetry of the sequence seems to have more significance than mere coincidence. This sequence, if lateral, would suggest Zone IV (Christiania beds) as a central core with similar conditions existing on the limbs with three zones on each side of the core. The sequence, however, is vertical. The major differences that occur are mainly in the fossil types included in the respective faunal assemblages. These changes have been interpreted as ecologic rather than evolutionary and indicate changing environments. The latter must have taken place rapidly or abruptly since, paleontologically, the zones are quite distinctive with rather sharp boundaries. A few types such as the sponge Allosaccus are found throughout the formation but for the most part the faunas appear to be well restricted.

In short, the rocks in the Knoxville-Friendsville Lenoir belt are believed to represent a sectional view of shifting environments, transgressive in nature, during the interval of time represented. With the local sample of the Lenoir formation better understood, it is tempting to place the vertical section of rocks described into a regional setting.

In the view of the writer, Figure 25 diagrammatically illustrates a possible regional interpretation which could serve as a working hypothesis against which the results of further investigation of these rocks could be compared.

As shown in the diagram, individual zones might rise higher in the section along strike of the formation. Of special interest in this

regard is the evidence discussed previously that Christiania, characteristic of Zone IV in the thesis area, and used as a stratigraphic marker by some authors, is known to occur lower in the section to the south. It is tempting to speculate that faunal elements characteristic of other zones similarly vary in position in the section as illustrated.

The lithologic aspects of the Lenoir sequence represented in the thesis area quite obviously bear on the problem of local and regional interpretation. The whole Middle Ordovician interval in this section of the Valley and Ridge province appears to reflect the interfingering of clastic and non-clastic lithosomes. The typical impure limestone lithology with a high percentage of argillaceous material is remarkably consistent in spite of local variations. While this lithologic type may be related tectonically to an unstable shelf, changes appear not to have been drastic over long periods of time.

The nodular or cobbly appearance of some zones, regarded as typical of the Lenoir by most students of these rocks, is derived from the concentration of argillaceous material along undulating surfaces (Figure 26). This may be produced by organic remains on occasion but in the main it remains a curious phenomenon. Contrasting clay-silt versus calcitic settling velocities possibly accounts for the rhythmic nature of this lithology. Fairly constant agitation placed these components into temporary suspension from which they settled. In Zone IV, where this feature is well developed, agitation may have accounted



Figure 26. Argillaceous partings in the Lenoir Limestone. These clay stringers are very common throughout the Lenoir. They are especially well developed in Subzone IV a., the "Christiania beds." The partings probably play an important role in the development of soil and the Lenoir's characteristic weathered appearance.

for sorting of the uniformly-sized Christiania at one extreme and the concentration of brachiopod shell mixtures at the other.

Suggestions for Further Investigation

During the course of this study a number of related and intimately associated problems were uncovered. Since the purpose of the present study required concentration of interest on the main body of the Lenoir Formation, some of the more important of these problems are listed below for the purpose of emphasizing the need for further studies in the area.

A continuing study of the Lenoir is a necessity before any concrete regional interpretations can be made. Zones identified in the study area should be traced to the north and south in the same belt to determine their extent and facies relationships with other regional units. This should lead to study of adjacent belts in the same manner.

More detailed fossil collections and measured sections are needed. Only the grosser aspects of the former have been presented in this study, and the range in thickness of the zones must be investigated. Specific fossil types, in particular Maclurites, abound in the Lenoir and offer excellent opportunities for study of large populations.

The Mosheim or lower "member" of the Lenoir presents a number of interesting problems. The lithology is quite distinctive in

comparison to the Lenoir. This in itself indicates a different set of environmental conditions and sedimentological controls. The stratigraphic occurrence of the Mosheim is also of interest. While the Mosheim usually occurs at the base of the Lenoir, it was pointed out in this thesis that it may occur above typical Lenoir lithology. The fauna of the Mosheim, the origin of the curious birds-eye calcite, and the extent of an apparent erosional surface developed on it, all pose interesting questions. It has been noted that a Mosheim lithology occurs in the Ottosee locally.

The relationship between the Lenoir and the Holston is very puzzling. There is some question, at least in the mind of the writer, as to whether the contact between the two formations is abrupt or gradational. The presence of Lenoir-type lithology in and above the Holston needs further examination, as does Holston-type lithology in the Mosheim, Ottosee, and Chapman Ridge. Faunal links among all of these are suspected and stratigraphic distinction may be more apparent than real.

The close resemblance of the Ottosee to the Lenoir even to the inclusion of Mosheim-type limestone mentioned earlier is of considerable interest. A repeated transgression of the Lenoir facies at a later time or the deposition of somewhat similar sediments and the existence of a similar fauna all under similar conditions may be represented. In this and all the problems discussed above, it is abundantly clear that no single unit can be treated separately out of context with the entire Middle Ordovician sequence in this area.

An interesting footnote to the present study has been uncovered in the literature. Recently, Banks and Johnson (1957) have observed the abundant occurrence of Girvanella (algae) and Maclurites in close association in the Ordovician Gordon River Limestone of Tasmania. The Maclurites are reported to occur usually with the flat side downward and, in many cases, seem to be encrusted by a stromatoporoid. Other fossils are not as common but include strophomenid brachiopods, orthoconic cephalopods, and sponges. Thus, the Lenoir environmental association appears to be a widespread phenomena of Ordovician seas.

BIBLIOGRAPHY

BIBLIOGRAPHY

- Ager, D. V., 1963, Principles of Paleocology: McGraw-Hill Book Co., Inc., New York, 371 pp.
- Banks, M. R., and Johnson, J. H., 1957, Maclurites and Girvanella in the Gordon River limestone (Ordovician) of Tasmania: Jour. Paleontology, v. 31, p. 632-640.
- Bassler, R. S., 1932, The stratigraphy of the Central Basin of Tennessee: Tenn. Depart. of Education, Div. of Geology, Bull. 38.
- Bridge, Josiah, 1956, The stratigraphy of the Mascot-Jefferson City zinc district: U. S. Geol. Survey Prof. Pap. no. 277.
- Butts, Charles, 1926, The Paleozoic rocks, in Geology of Alabama: Alabama Geol. Survey Special Rept. 14.
- _____, 1940, Geology of the Appalachian Valley in Virginia: Va. Geol. Survey Bull. 52.
- Cattermole, J. M., 1955, Geology of the Shooks Gap quadrangle, Tenn.: U. S. Geol. Survey Geol. Quad. Map QQ 76.
- _____, 1958, Geology of the Knoxville quadrangle, Tenn.: U. S. Geol. Survey Geol. Quad. Map QQ 115.
- _____, 1960, Geology of the Bearden quadrangle, Tenn.: U. S. Geol. Survey Geol. Quad. Map QQ 126.
- Cloud, P. E., Jr., 1942, Notes on Stromatolites: Am. Jour. Science, v. 240, p. 366-379.
- Cooper, B. N., 1953, Trilobites from the Lower Champlainian formations of the Appalachian Valley: Geol. Soc. America Mem. 55.
- _____, and Cooper, G. A., 1946, Lower Middle Ordovician stratigraphy of the Shenandoah Valley, Va.: Geol. Soc. America Bull., v. 57, p. 35-114.
- Cooper, G. A., 1956, Chazy and related Brachiopoda: Smithsonian Misc. Coll., v. 127, pt. 1 text, pt. 2 plates.
- ^{ed.} Gordon, C. H., et al., 1924, Marble deposits of east Tennessee: Dept. of Education, Div. of Geology Bull. 28, p. 15-86.

- Hayes, C. W., 1891, The overthrust faults of the southern Appalachians: Geol. Soc. America Bull., v. 2, p. 141-154.
- _____, 1895, U. S. Geol. Survey Geol. Atlas, Cleveland folio (no. 20).
- Hedgepeth, J. W. (ed.), 1957, Treatise on marine ecology and paleoecology, v. 1--Ecology: Geol. Soc. America Mem. 67.
- Hershey, R. E. and Maher, S. W., 1963, Limestones and dolomite resources of Tennessee: Tenn. Dept. of Conserv., Div. of Geology Bull. 63.
- Hofman, H. J., 1963, Ordovician Chazy Group in southern Quebec: A.A. P.G. Bull., v. 47, pp. 270-301.
- Johnson, J. H., 1954, An introduction to the study of rock building algae and algal limestone: Quart. Col. School of Mines, v. 49, no. 2, pp. 1-117.
- Keith, Arthur, 1895, U. S. Geol. Survey Geol. Atlas, Cleveland folio (no. 20).
- _____, 1896, U. S. Geol. Survey Geol. Atlas, Loudon folio (no. 20).
- Ladd, H. S. (ed.), 1957, Treatise on marine ecology and paleoecology, v. 2--Paleoecology: Geol. Soc. America Mem. 67.
- Moore, R. C. (ed.), 1953, Treatise on invertebrate paleontology, Part G--Bryozoa: Geol. Soc. America and Univ. of Kansas Press, 253 pp.
- _____, 1955, Treatise on invertebrate paleontology, Part E--Archaeocyatha and Porifera: Geol. Soc. America and Univ. of Kansas Press, 122 pp.
- _____, 1956, Treatise on invertebrate paleontology, Part F--Coelenterata: Geol. Soc. America and Univ. of Kansas Press, 498 pp.
- _____, 1959, Treatise on invertebrate paleontology, Part O--Arthropoda 1: Geol. Soc. America and Univ. of Kansas Press, 560 pp.
- _____, 1960, Treatise on invertebrate paleontology, Part I--Mollusca 1: Geol. Soc. America and Univ. of Kansas Press, 351 pp.
- _____, 1964, Treatise on invertebrate paleontology, Part K--Mollusca 3: Geol. Soc. America and Univ. of Kansas Press, 519 pp.
- Neuman, R. B., 1955, Middle Ordovician rocks of the Tellico-Sevier Belt Eastern Tennessee: U. S. Geol. Survey Prof. Pap. no. 274-F.

- Raymond, P. E., 1908, Gastropoda of the Chazy Formation, *Annals of Carnegie Mus.*, v. 3, p. 168-225.
- _____, 1925, Some trilobites of the lower Middle Ordovician of Eastern North America, *Harvard Univ. Mus. Comp. Zool. Bull.*, v. 67, p. 1-180.
- _____, 1928, The brachiopods of the Lenoir and Athens Formations of Tennessee and Virginia: *Harvard Univ. Mus. Comp. Zool. Bull.*, v. 68, p. 292-312.
- _____ and Okulitch, V. J., 1940, Some Chazyan sponges: *Harvard Univ. Mus. Comp. Zool. Bull.*, v. 86, p. 197-214.
- Rodgers, John, 1952, Geology of the Athens quadrangle, Tenn.: U. S. Geol. Survey Geol. Quad. Map.
- _____, 1953, Geologic map of East Tennessee: *Tenn. Dept. of Conserv., Div. of Geology Bull.* 58.
- Safford, J. M., 1869, Geology of Tennessee, State of Tennessee, Nashville.
- _____ and Killebrew, J. M., 1876, The elements of the geology of Tennessee: Nashville.
- Shimer, H. W. and Schrock, R. R., 1944, Index fossils of North America: Wiley and Sons, Inc., New York, 837 pp.
- Twenhofel, W. H., et al., 1935-1936, Report of the committee on paleoecology: *National Research Council, Washington, D. C.*, 64 pp.
- _____, et al., 1936-1937, Report of the committee on paleoecology: *National Research Council, Washington, D. C.*, 63 pp.
- _____, et al., 1954, Correlation of the Ordovician formations of North America: *Geol. Soc. America Bull.*, V. 65, p. 247-298.
- Ulrich, E. O., 1911, Revision of the Paleozoic systems: *Geol. Soc. America Bull.*, v. 22, p. 281-680.
- Wilmarth, M. G., 1938, Lexicon of geologic names of the United States: *U. S. Geol. Survey Bull.* 896.
- Wilson, Charles W., Jr., 1948, The geology of Nashville, Tennessee: *Tennessee Division of Geology Bull.* 53.

