

To the Graduate Council:

I am submitting herewith a thesis written by Micheal R. Maitland entitled "The Paleobathymetric and Paleogeographic Distribution of Middle Ordovician Trilobites within a Portion of the Valley and Ridge of East Tennessee." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.


Kenneth R. Walker, Major Professor

We have read this thesis and
recommend its acceptance:





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THE PALEOBATHYMETRIC AND PALEOGEOGRAPHIC DISTRIBUTION
OF MIDDLE ORDOVICIAN TRILOBITES WITHIN
A PORTION OF THE VALLEY AND RIDGE
OF EAST TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
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ABSTRACT

Over 500 trilobite specimens were collected for this investigation from five stratigraphic sections within the study area (Evan's Ferry, Cedar Springs, St. Clair, Silver City and Raccoon Valley). These sections are all underlain by the post-Knox unconformity and include the part of the Middle Ordovician below the Moccasin Formation. The stratigraphic occurrences of the genera when plotted on a stratigraphic cross section of the study area, reveal distinct patterns of associations or groups (i.e., assemblages) which occur in and dominate distinct stratigraphic intervals deposited in specific depth zones.

Five distinct trilobite assemblages characterized at the generic level are present in the study area: the Illaenid, Asaphid, Pliomerid, Harpid and Raphiophorid-Remopleurid assemblages. The Illaenid Assemblage generally occurs in and dominates (with respect to total trilobite numbers) the lithologies in supratidal (+10 - +5 meters), intertidal (+5 - -5 meters), shallowest subtidal (-5 - -10 meters) and shallow subtidal (-10 - -30 meters) depth zones. Asaphid and Pliomerid assemblages dominate the deep subtidal (-30 - -50 meters) depth zone. The Harpid Assemblage dominates the shallow water depth zones (+10 - -50 meters) of the terrigenous clastic influenced platform environments. The Raphiophorid-Remopleurid Assemblage dominates the terrigenous deep water environments of the slope (-50 - -100 meters) and basin (greater than -100 meters) depth zones.

Four (Evan's Ferry, Cedar Springs, St. Clair and Silver City) of the five sections represent a transect from a shallow carbonate shelf environment to a deep terrigenous basin environment. The Evan's Ferry and Cedar Springs sections represent near shore shallow carbonate platform environments. Cedar Springs, however, was deposited in a setting closer to the shelf edge. The St. Clair and Silver City sections mainly represent environments of deposition in the slope and basin environments. The fifth section, Raccoon Valley, was deposited in an environment much like that of the Evan's Ferry section. At the beginning of the Middle Ordovician, this area was characterized by shallow carbonate shelf environments and the Illaenid Assemblage. As the basin continued to subside the Silver City and St. Clair area was characterized by deep subtidal environments. The seas began to transgress the previously exposed Knox surface to the northwest and these areas became shallow subtidal peribasinal environments. The illaenids migrated northwestward into these areas. Asaphids and pliomerids began to dominate deep subtidal environments of the Silver City and St. Clair sections. As the basin continued to subside the peribasinal shallow subtidal environments continued to shift northwestward. Finally, much of the northwestern portion of the study area was characterized by deep subtidal environments, the culmination of the northwestward transgression of the seas in the study area during the Middle Ordovician. At this time the spatial extent of the illaenids was apparently reduced in the study area because of the restriction of shallow subtidal environments which were their preferred habitat. Maximum extent of the deep subtidal assemblages (Asaphid and Pliomerid) coincided with this transgression.

An invasion by the Raphiophorid-Remopleurid Assemblage accompanied the influx of terrigenous clastics across the basin from the exposed surface to the southeast. At this time the Asaphid and Pliomerid assemblages began to shift northwestward along with the deep subtidal environments. At Cedar Springs the Raphiophorid-Remopleurid Assemblage makes a brief appearance in the Benbolt Formation. With a continued filling of the basin with clastics, the study area began to shallow. This shallowing allowed the illaenids in the northwest portion of the study area to expand southeastward into the new shallow subtidal environments. The Asaphid and Pliomerid assemblages disappeared from the study area as did the deep subtidal environments. The Harpid Assemblage began to migrate from the shallow platform clastic environments of the southeast across the basin and began to replace the Raphiophorid-Remopleurid Assemblage in the shallowing terrigenous environments. Elements of the Harpid Assemblage apparently competed with the Illaenid Assemblage in the shallow platform environments which contained increasing amounts of terrigenous sediment.

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INTRODUCTION

Purpose

Little has been understood about the distribution of the extinct class, Trilobita, in East Tennessee during the Middle Ordovician with respect to paleobathymetry and paleogeography. Most of the previous studies concerning the trilobites have analyzed other aspects, especially taxonomy.

B. N. Cooper (1953) and Raymond (1920, 1925) considered the occurrence of trilobites in East Tennessee from a taxonomic viewpoint. Other workers such as Prouty (1946) and G. A. Cooper (1956) have studied and worked with the stratigraphic aspects of the Middle Ordovician Chickamauga Group including partial lists of the trilobites. McLaughlin (1973) reviewed the biostratigraphy of the Knox County area in some detail. Recent workers under the direction of K. R. Walker have studied the paleoecology and ecostratigraphy of the Middle Ordovician Chickamauga in East Tennessee, providing a suitable framework for the present study (Walker, 1977).

The objectives of this study were to (1) identify the trilobites collected from selected sections; (2) determine the stratigraphic limits of the paleobathymetric and paleogeographic distribution of these trilobites during the Middle Ordovician within the study area; (3) define the generic level association patterns among the trilobites and (4) derive paleoecologic inferences about the occurrences of these assemblages.

Scope

The stratigraphic interval which is discussed in this report is confined to the formations which occur stratigraphically above the post-Knox unconformity and below the Moccasin Formation of the Middle Ordovician in the Valley and Ridge province of East Tennessee. This study is mainly concerned with the shelf localities. Certain aspects of the slope and basin localities are discussed, however, in order to elucidate certain aspects of trilobite assemblage interrelationships through time and space. A more detailed treatment of the deeper water trilobite assemblages of the Silver City and St. Clair sections is given by Benedict (in prep.).

CHAPTER I

HISTORICAL PERSPECTIVE

Many previous workers have studied various aspects of the Middle Ordovician Chickamauga rocks of East Tennessee, including biostratigraphy, stratigraphy, ecostratigraphy, and paleoecology.

The stratigraphy of the Chickamauga, since it was named by Hayes has been the subject of nomenclatural controversy. Prouty (1946), Rodgers (1953) and Cooper (1956) were subsequent workers in the Southern Appalachians who proposed classifications for the subdivision of the Chickamauga (see Figure 1). Cooper (1956) studied the stratigraphy of the Chickamauga and the biostratigraphy of the Brachiopoda in the Middle Ordovician of the Southern Appalachians. Bergström (1971, 1973; Bergström and Carnes, 1976) worked with the biostratigraphy of the conodonts. R. E. McLaughlin (1973) and his students concentrated their efforts on unraveling the biostratigraphy of Raccoon Valley and the Knox County area.

The research of these and other recent workers on the paleoecology and ecostratigraphy of the Chickamauga of East Tennessee have prepared the way for the research of the present study. The previous research includes Ruppel and Walker (1977), Walker (1977, and in prep.), Walker and Ferrigno (1973) and many unpublished theses and dissertations under the direction of K. R. Walker.

Previous studies on the Middle Ordovician trilobites of East Tennessee have been mainly concerned with the taxonomy and have not

Campbell 1894 Keith 1896 1901		CHICKAMAUGA LIMESTONE													
Prouty 1946		MOCCASIN		MOCCASIN		RODGERS 1953		COOPER 1956		HARRIS and Mixon 1970		McLaughlin 1973		Ulrich 1911	
WITTEN		WITTEN		MOCCASIN		CHICKAMAUGA L.S. UNIT 2		MOCCASIN		UNITS EFGH-LM		ZONE IV		MOCCASIN	
BOWEN		BOWEN		WITTEN				LOWVILLE							
WARDELL		WARDELL		MOCCASIN				WARDELL				UNIT D		UNIT C	
BENBOLT		BENBOLT		MOCCASIN		BENBOLT									
THOMPSON VALLEY		ROCKDELL		HOGSKIN		UNIT B, UNIT A		ZONE II		HOLSTON		LENOIR MOSHEIM			
LINCOLNSHIRE		EIDSON		ELWAY		TUMBEZ MARCEM									
BLACKFORD		UPPER LOWER		CHICKAMAUGA LIMESTONE UNIT 1		UNIT C		UNIT B, UNIT A		ZONE I		MOSHEIM			
MARMOR		ASHBY		PORTERFIELD		WILDERNESS									

Figure 1. Correlation of stratigraphic terminology applied to Middle Ordovician units in strike belts of the Valley and Ridge of East Tennessee (modified from Carnes, 1975).

included more than passing mention of stratigraphic relationships. Raymond (1920, 1925) and B. N. Cooper (1953) studied these ancient organisms and did much to identify the Middle Ordovician and other trilobites in the Southern Appalachians.

CHAPTER II

PROCEDURES, METHODS AND TECHNIQUES

Abundance Determination Procedure

Two types of abundance measurements are shown on the Sectional Trilobite Assemblage Distribution Diagrams (STADD's) included with the discussion of each of the five stratigraphic sections. These are (1) relative abundance of trilobite genera and (2) absolute abundance of trilobite genera within approximately 20 meter intervals of measured section.

Only rarely were whole (pygidium, thorax and cephalon articulated) trilobite remains preserved intact. Abundance data would be biased if every trilobite sample were counted as a single individual. Conceivably, the collector could count the pygidium, cephalon and thoraxial segments of one trilobite as three separate trilobites if each preserved part was counted as a whole entity. To avoid this type of possible error only the most frequently found part was counted as an individual, for each formation and section. Because the thoraxial portion was rarely found and almost always disarticulated, either the cephalon or pygidia were used for a given genus but never both.

Generic abundance, represented by bars of varying thicknesses on the Sectional Trilobite Assemblage Distribution Diagrams, was determined by (1) tabulating the total number of individual specimens of each genus in a given lithologic interval, (2) taking this total and dividing it by

the total number of all trilobite specimens in the same lithologic interval and (3) multiplying this fraction by 100 to get a percentage. This percentage is then assigned one of three categories, depending on its magnitude: (1) Abundant = greater than 25%, (2) Common = 5% to 25% and (3) Rare = less than 5%. Gaps in the bars represent nonoccurrences in parts of each section.

The absolute abundance of all trilobite specimens per given lithologic unit, represented by the abundance curve on the Sectional Trilobite Assemblage Distribution Diagrams, was calculated as follows. First the section was divided into twenty meter intervals. The total number of trilobites found within each interval was divided by twenty to determine the absolute number of specimens per meter of section. The result was then rounded to the nearest 0.1 and plotted on the diagram. All values for each section were plotted and connected to give the resulting abundance curve. As could be expected, the accuracy of the abundance bars probably increases in direct proportion with the increased value in the abundance curves.

The disadvantage of using the regular 20 meter intervals for the abundance curves is that these intervals, at times, span or cross lithologic units and formational boundaries. Relative generic abundances were determined by using lithologic changes (i.e., lithologic unit and formational boundaries) as natural breaks or subdivisions within the sections for the stratigraphic lengths of the abundance bars.

Trilobite Sample Collecting Methods

Three methods were used to collect trilobite specimens for this study: collecting in-place slabs, collecting loose material (proximity of float to its original position in outcrop was judged by lithologic and faunal similarities to nearby in-place material), and by cutting in situ specimens from the outcrop with chisels and a hammer. This third method also was used on shales and shaley limestones. Of the three methods used, most specimens were collected by the second and third techniques.

All samples were labeled with a felt tipped pen as to stratigraphic location, placed into sample bags and labeled as to section name. Later, in the lab, samples were sorted out by section, a small spot on each sample was coated with a white latex acrylic paint. This area was permanently marked with a sample number by using a rapidograph pen. Illustrated and Key reference specimens were assigned catalogue numbers for the University of Tennessee Geological Sciences Museum (UTGSM) collections. For a discussion of techniques used in the preparation of sample material, see Appendix A.

Paleobathymetry

Methods of determining absolute depths (i.e., paleobathymetry) of environments of deposition represented by intervals in the measured sections are the same as those described by Benedict and Walker (1978). In the present study, field observations of macroscopic depth indicators

were noted for each section. These indicators include three categories: (1) chemical; (2) physical and (3) biological (see Table 1). Depth of deposition can be determined more accurately by using suites of indicators than by using indicators one at a time (Benedict and Walker, 1978).

Lithologic sampling for mesoscopic identification of depth indicators was also done. When microscopic data were needed, thin sections were made on 7.6 cm. $\times$ 12.7 cm. glass slides. These were subjected to microscopic determination of presence of depth indicators. From these data depth curves were constructed on the Sectional Trilobite Assemblage Distribution Diagrams.

The paleobathymetry was subdivided into eight major depth zones. They are given below with their respective depth range values in meters. The datum point for 0 meters is Mean Sea Level. The bathymetric ranges of various depth zones used here are as follows: supratidal is +10m to +5m, intertidal is +5m to -5m, shallowest subtidal is -5m to -10m, shallow subtidal is -10m to -30m, deep subtidal is -30m to -50m, slope is -50m to -100m and basin is greater than -100m. (See Table 1 for literature references for the individual depth indicators.)

Table 1. Depth Indicators for the Depth Curves
(from Benedict and Walker, 1978).

Indicator	Depth in Meters										Reference
	+10	0	MLW	-10	-30	-50	-100	-300	-1000	>1000	
<u>Chemical</u>											
Penecontemp. dol.	---	---	---	---	---	---	---	---	---	---	Pray & Murray 65
Evap. pseudomorphs	---	---	---	---	---	---	---	---	---	---	Pray & Murray 65
Caliche	---	---	---	---	---	---	---	---	---	---	James 72
Chamosite (tropics)	---	---	---	---	---	---	---	---	---	---	Porrenga 67
Phosphate nodules	---	---	---	---	---	---	---	---	---	---	Bromley 67
Glauconite (temp.)	---	---	---	---	---	---	---	---	---	---	Cloud 55
Glauconite (trop.)	---	---	---	---	---	---	---	---	---	---	Porrenga 67
Mn in calcite	---	---	---	---	---	---	---	---	---	---	Bencini & Turi 74
Mn nodules (hi. Mn/Fe)	---	---	---	---	---	---	---	---	---	---	Price 67
Trace element enriched	---	---	---	---	---	---	---	---	---	---	Nicholls 65
Carbonates absent	---	---	---	---	---	---	---	---	---	---	Worsely 71
Authogenic zeolites	---	---	---	---	---	---	---	---	---	---	Cronan 74
<u>Physical</u>											
Mudcracks	---	---	---	---	---	---	---	---	---	---	Reineck & Singh 73
Birdseyes	---	---	---	---	---	---	---	---	---	---	Shinn 68
Flat crenul. algal lam.	---	---	---	---	---	---	---	---	---	---	Logan et al. 64
Domate algal laminae	---	---	---	---	---	---	---	---	---	---	Logan et al. 64
Herringbone cross bed.	---	---	---	---	---	---	---	---	---	---	Reineck & Singh 73
Coarse grns. abund.	---	---	---	---	---	---	---	---	---	---	Allen 67
Vertical burrows	---	---	---	---	---	---	---	---	---	---	Rhoads 74
Flasher bedding	---	---	---	---	---	---	---	---	---	---	Reineck & Singh 73
Flat algal laminae	---	---	---	---	---	---	---	---	---	---	Logan et al. 64
Megaripples	---	---	---	---	---	---	---	---	---	---	Reineck & Singh 73
Algal oncolites	---	---	---	---	---	---	---	---	---	---	Logan et al. 64
Ooliths	---	---	---	---	---	---	---	---	---	---	Bathurst 75

Pray & Murray 65
 Pray & Murray 65
 James 72
 Porrenga 67
 Bromley 67
 Cloud 55
 Porrenga 67
 Bencini & Turi 74
 Price 67
 Nicholls 65
 Worsely 71
 Cronan 74
 Reineck & Singh 73
 Shinn 68
 Logan et al. 64
 Logan et al. 64
 Reineck & Singh 73
 Allen 67
 Rhoads 74
 Reineck & Singh 73
 Logan et al. 64
 Reineck & Singh 73
 Logan et al. 64
 Bathurst 75

Table 1. (continued)

Indicator	Depth in Meters										Reference
	+10	0	MLW	-10	-30	-50	-100	-300	-1000	>1000	
<u>Physical (continued)</u>											
Aggregate grains	---	---	---	---	---	---	---	---	---	---	Bathurst 67
Fine grns. abundant	---	---	---	---	---	---	---	---	---	---	Allen 67
Soft-sed. deformation	---	---	---	---	---	---	---	---	---	---	Walker 74
Flat, thin laminae	---	---	---	---	---	---	---	---	---	---	Reineck & Singh 73
Horizontal burrows	---	---	---	---	---	---	---	---	---	---	Rhoads 74
Turbidite sequences	---	---	---	---	---	---	---	---	---	---	Kuenen 67
<u>Biological</u>											
Arthrop. + mollusc	---	---	---	---	---	---	---	---	---	---	Elias 37
Encrusting bryozoa	---	---	---	---	---	---	---	---	---	---	Schopf 69
Green algae	---	---	---	---	---	---	---	---	---	---	Riding 75
Filter feed. dominant	---	---	---	---	---	---	---	---	---	---	Lewis 65
Boring algae	---	---	---	---	---	---	---	---	---	---	Golubic et al. 75
Pelmatozoa	---	---	---	---	---	---	---	---	---	---	Fell 66
Red algae	---	---	---	---	---	---	---	---	---	---	Riding 75
Arborescent bryozoa	---	---	---	---	---	---	---	---	---	---	Schopf 69
Art. brachiopods	---	---	---	---	---	---	---	---	---	---	Rudwick 70
Trilobites with eyes	---	---	---	---	---	---	---	---	---	---	Whittington 66
Boring fungi	---	---	---	---	---	---	---	---	---	---	Golubic et al. 75
Inart. brachiopods	---	---	---	---	---	---	---	---	---	---	Rudwick 70
Depos. feed. dominant	---	---	---	---	---	---	---	---	---	---	Lewis 65
Graptolites	---	---	---	---	---	---	---	---	---	---	Elias 37
Eyeless trilobites	---	---	---	---	---	---	---	---	---	---	Clarkson 67
Tintinnines	---	---	---	---	---	---	---	---	---	---	Loeblich et al. 68

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Clarkson 67
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CHAPTER III

LOCALITY

The study area (see Figure 2) is located in East Tennessee within the Valley and Ridge province of the APPALACHIAN HIGHLANDS major division (Fenneman, 1928). The study area is characterized by thrust sheets of Paleozoic sedimentary rocks (Cambrian-Mississippian), which strike roughly northeast to southwest. The repetition of sequence of strata produced by these folded-fault structures allows for a lateral comparison of the same Middle Ordovician strata (see Figures 3 and 4) which are exposed in numerous localities within the study area.

Two separate transects (i.e., a series of stratigraphic columnar sections) were chosen for the present research within the study area (see Figures 5 and 6). A total of five sections comprise these transects used for this study. The northernmost transect contains four of these sections. These are the Evan's Ferry, Cedar Springs, St. Clair and Silver City sections. The southernmost transect contains the remaining section which is Raccoon Valley (see Table B-1, Appendix B, for precise geographic localities of the five sections).

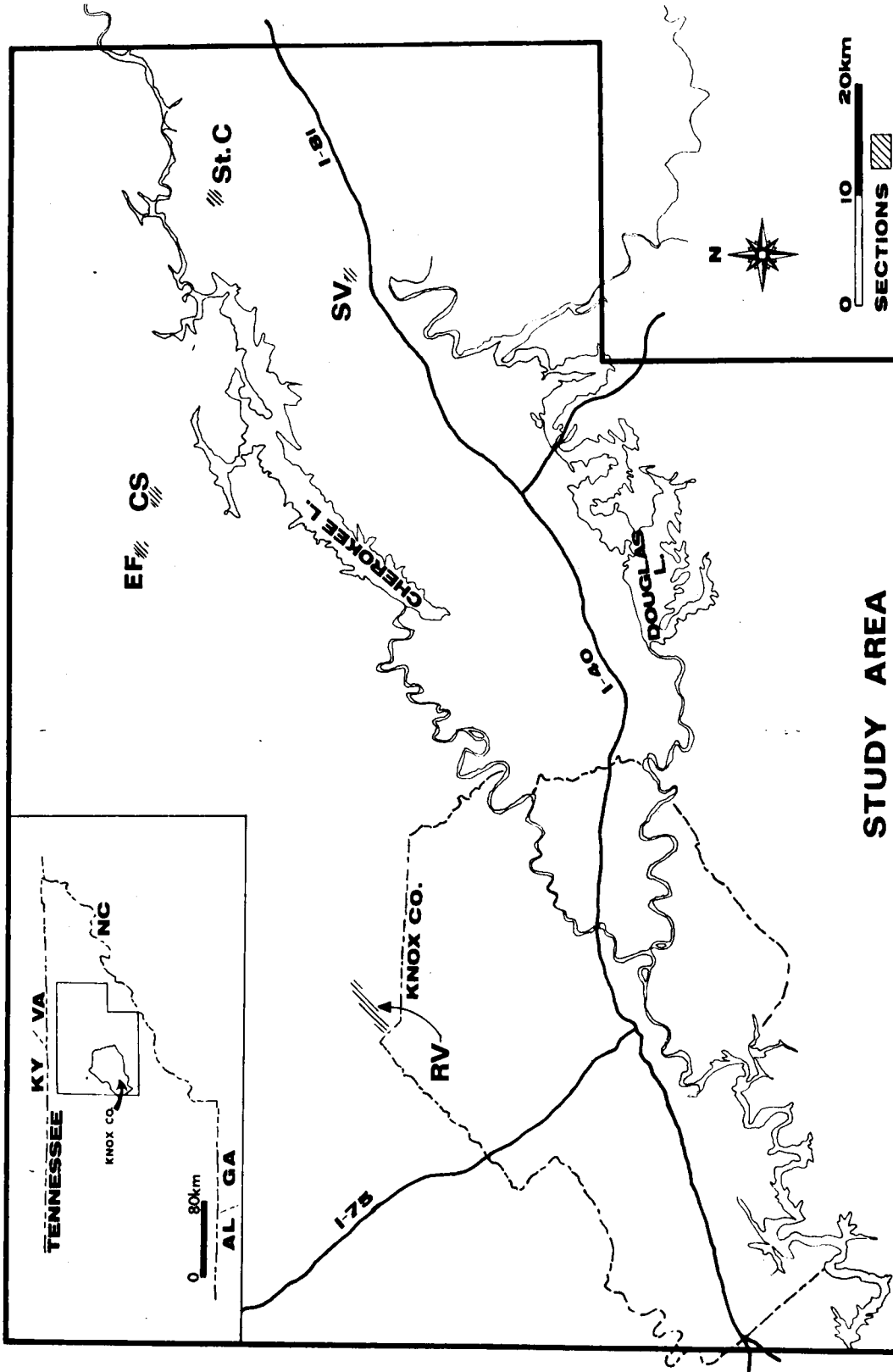


Figure 2. Thesis study area. EF = Evan's Ferry, CS = Cedar Springs, St. C. = St. Clair, SV = Silver City, RV = Raccoon Valley. These are the five sections analyzed in this study.

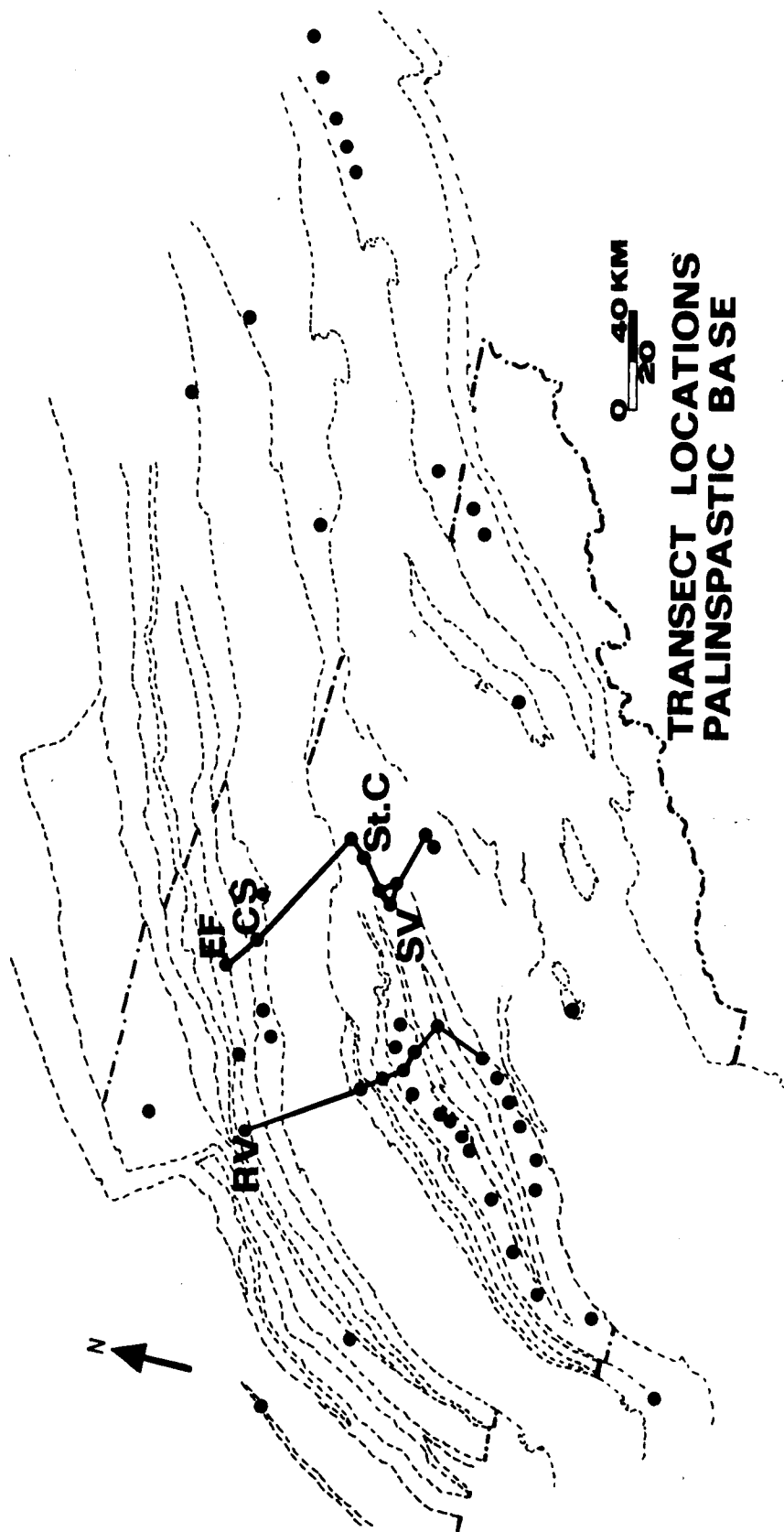


Figure 4. Palinspastic base section locality map. EF = Evan's Ferry, CS = Cedar Springs, St. C. = St. Clair, SV = Silver City, RV = Raccoon Valley. (Palinspastic base map after Roeder and Witherspoon, 1978.)

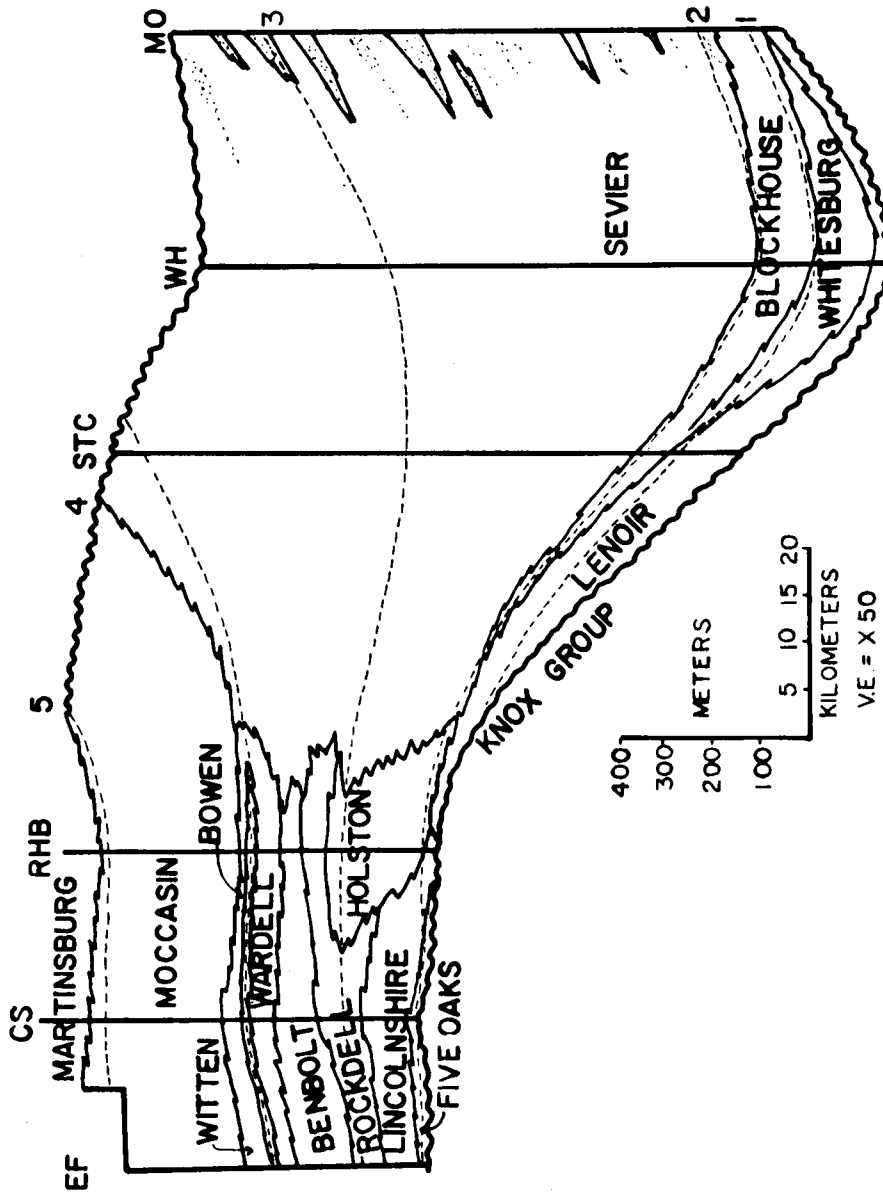


Figure 5. Northern transect stratigraphic cross section (see Figure 2 for geographic locations). Vertical exaggeration (V.E.) = 50. Note difference in V.E. of Figure 6 in which the V.E. = 40 (after Ruppel, 1979).

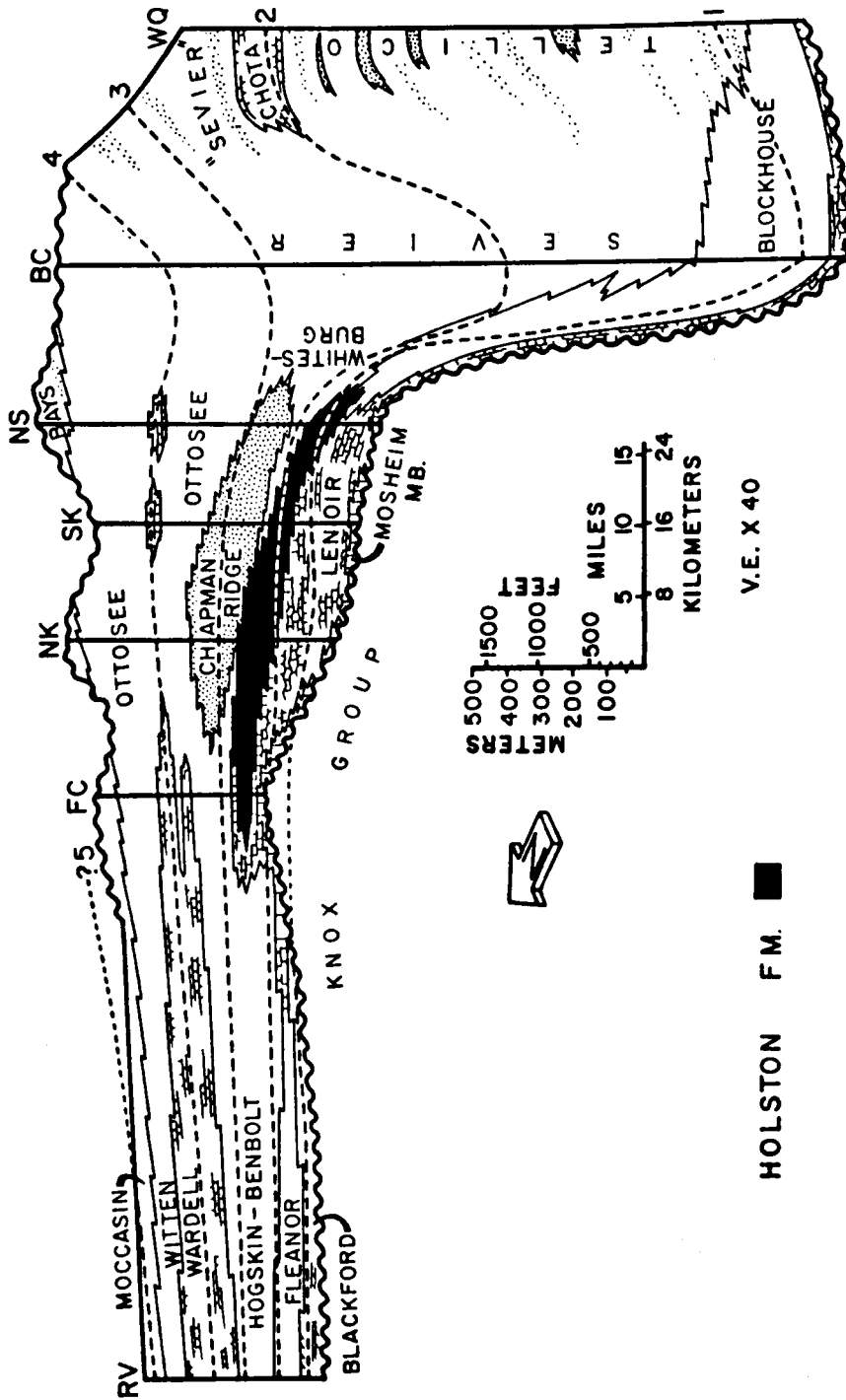


Figure 6. Southern transect stratigraphic cross section (see Figure 2 for geographic locations). (From Walker, 1977.)

CHAPTER IV

SUMMARY OF TAXA STUDIED

The full taxonomic treatment of the trilobites encountered in the course of this study is given in Appendix C. A summary of the taxonomic position of these organisms is given in Table 2. A reconstruction of the most important genera is shown in Figures 7 and 8.

Table 2. Systematic Listing of All Trilobite
Genera Analyzed in This Report.

TRILOBITA:

Order: Ptychopariida:

Family: Remopleurididae:

Genus: (1) Robergia

Family: Asaphidae:

Genera: (1) Isotelus, (2) Homotelus, (3) Isoteloides.

Family: Illaenidae:

Genera: (1) Illaenus, (2) Nanillaenus, (3) Bumastus.

Family: Harpidae:

Genera: (1) Dolichoharpes, (2) Paraharpes.

Family: Raphiophoridae:

Genera: (1) Ampyx, (2) Ampyxina, (3) Lonchodomas.

Order: Phacopida:

Family: Cheiruridae:

Genera: (1) Ceraurinella, (2) Ceraurus, (3) Sphaeroxochus.

Family: Pliomeridae:

Genera: (1) Pliomerops, (2) Pilekia.

Family: Encrinuridae:

Genera: (1) Encrinurus, (2) Cybeloides.

Family: Pterygometopidae:

Genera: (1) Calyptaulax, (2) Eomonorachis.

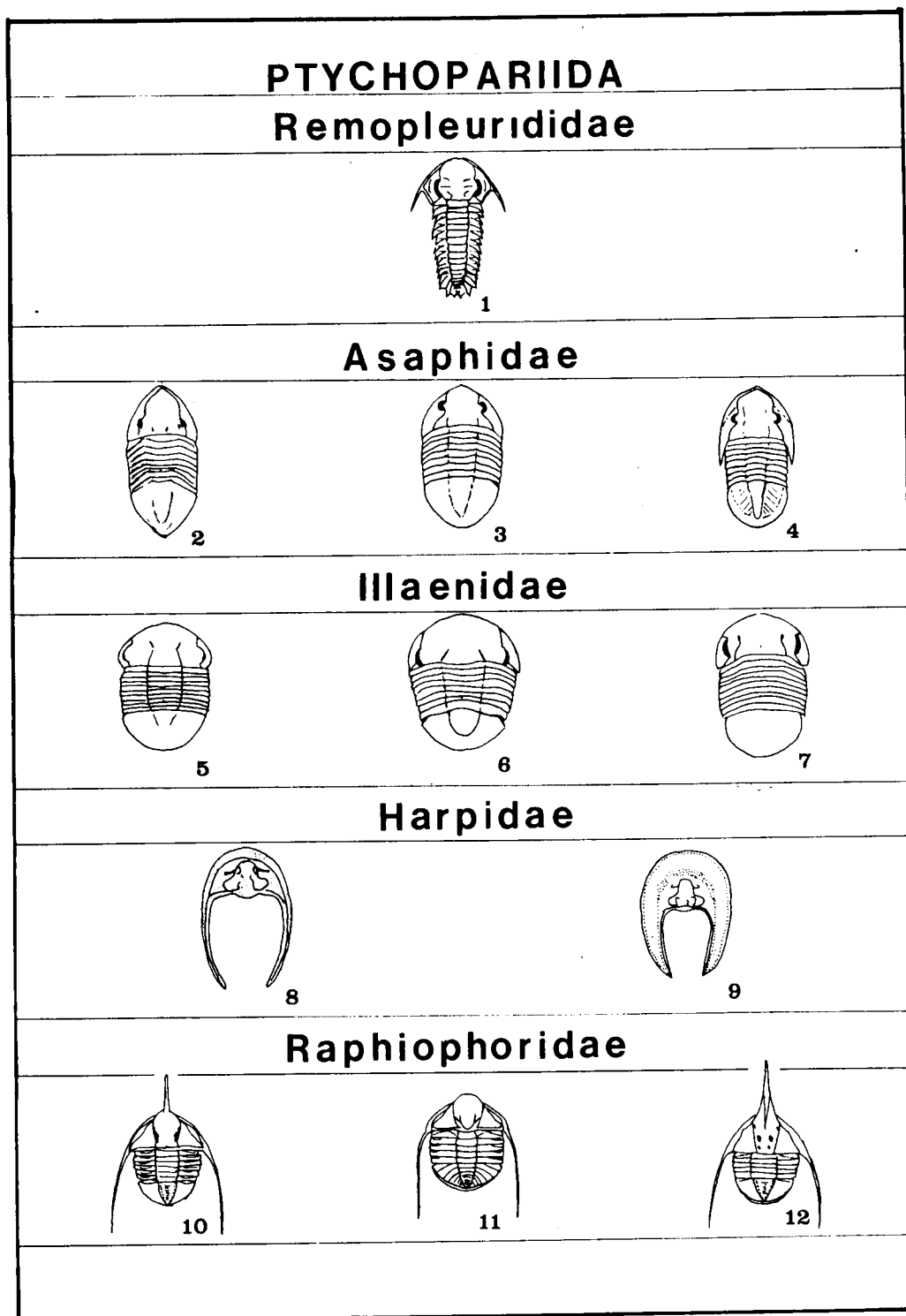
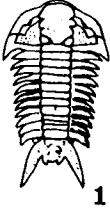


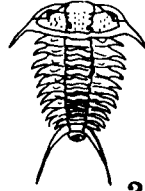
Figure 7. Members of the Order Ptychopariida: (1) Robergia, (2) Isotelus, (3) Homotelus, (4) Isoteloides, (5) Illaenus, (6) Nanillaenus, (7) Bumastus, (8) Dolichoharpes, (9) Paraharpes, (10) Ampyx, (11) Ampyxina, (12) Lonchodomas.

PHACOPIDA

Cheiruridae



1

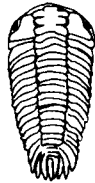


2

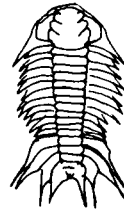


3

Pliomeridae



4



5

Encrinuridae

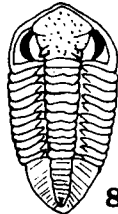


6

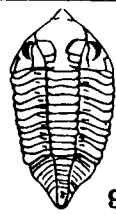


7

Pterygometopidae



8



9

Figure 8. Members of the Order Phacopida: (1) Ceraurinella, (2) Ceraurus, (3) Sphaerexochus, (4) Pliomerops, (5) Pilekia, (6) Encrinurus, (7) Cybeloides, (8) Calyptaulax, (9) Eomonorachis.

CHAPTER V

DESCRIPTION AND ANALYSIS OF THE SECTIONS

Introduction

This chapter consists of two main subdivisions. In the first subdivision, each of the five studied sections is discussed in turn. Various aspects pertaining to the respective Sectional Trilobite Assemblage Distribution Diagram (STADD) of each section are explained and analyzed. For each section, these are: (1) a brief discussion of the abundance curve; (2) interformational and intraformational unconformities in the section used for the purpose of displaying abundance relationships of the trilobites; (3) determination of trilobite assemblages and their respective generic members; (4) stratigraphic distribution of these assemblages; (5) construction of depth curves and (6) the relationships of these assemblages to their inferred paleobathymetric distribution.

The second subdivision of this chapter discusses the interrelationships among the five studied sections. These interrelationships are then analyzed and interpretations are presented. These interrelationships center around three aspects: (1) paleogeographic distribution of the trilobite assemblages through time; (2) overlapping and gradational paleobathymetric relationships of these assemblages and (3) paleoecological characteristics of specific trilobite genera with

respect to limiting factors which may have controlled their paleodistribution within the study area.

Analysis of Individual Sections

Evan's Ferry

Abundance curve. The average calculated value for Evan's Ferry (see Figure 9) is 0.52. This value, the calculation of which is explained in Chapter II, means that on the average approximately one trilobite specimen was collected for every two meters of section. The detailed abundance curve, however, shows that absolute abundance of trilobites decreases up section, except for the initial low abundance at the base of the section. This apparent decrease in absolute abundance up section could be the result of some induced bias, or it might actually represent a real diminishing in the trilobite numbers originally present.

There are four possible sources of bias which may cause an apparent decrease in abundance. These are (1) unequal exposure of the outcrop, (2) differing weathering characteristics of the lithologies present, (3) preferential collecting by the author or previous collectors of this section. These sources of bias are explored below.

The relative amount of exposure does not appear to be a factor; all formations are equally well exposed in this section. The weathering characteristics do not appear to be a major factor either. The Rockdell Formation is a massively bedded packstone to grainstone (classification of Dunham, 1962). This type of lithology usually makes fossil collecting

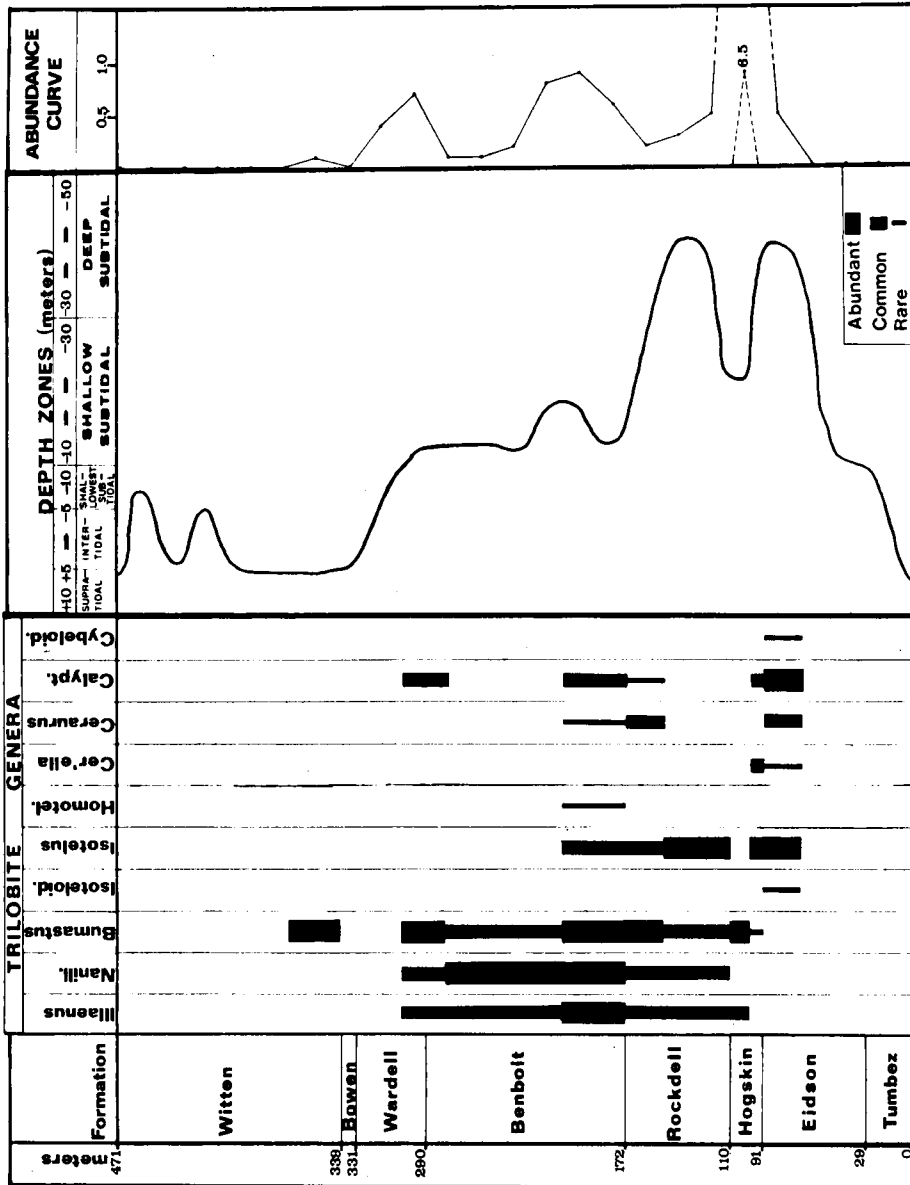


Figure 9. Evan's Ferry trilobite assemblage distribution. Abundant = more than 25% of the total trilobite fauna. Common = 5% to 25% of the total trilobite fauna. Rare = more than 0% and up to 5% of the total trilobite fauna. Nonoccurrence = a break in the bar. The Abundance Curve is calculated by dividing the total number of all specimens of all genera found within a 20 meter interval by 20 and rounded to the nearest tenth (0.1). Diagonally striped areas of the bars indicate that no trilobite specimens were collected from that interval within the bar.

difficult because of its resistance to weathering and lack of bedding plane exposures. This unit was well exposed and only composed a small interval within the section. It is not believed by the author that this is related to the systematic decrease in abundance up section.

The preservational aspect may have affected the curve to some slight degree in the upper Eidson Formation. Here silicification has preserved many excellent trilobite specimens. The process of chertification, however, has probably destroyed and hidden as many faunal elements within the chert layers as it has preserved on the surface of the chert layers.

The author does not believe that collecting biases have caused the general trend of decreasing abundance up section. These possible collecting biases are (1) preferential collecting by the author of the better preserved and larger specimens and (2) unrecorded collecting by other persons previously.

Numerous hours were spent by the author to collect all exposed specimens for the present research, including the poorest and smallest specimens. Unscientific collecting by previous persons such as "amateur fossil collectors" is ruled out because the Eidson and Benbolt formations still contain many excellent specimens. Obviously these would not be there if the more aesthetic specimens had been collected. The only major research at Evan's Ferry within the past few years was done by Sickafoose (unpublished thesis, 1979). I have included all of the trilobite specimens collected by Sickafoose in this study.

Two factors which may have caused an actual decrease in the trilobite fauna up section are (1) correspondence of the studied time interval with a period of low trilobite diversity and density and (2) deposition of the units in question in environments lacking trilobite niches.

One possibility is that there were not any or there were only a very few trilobites present in the area near or at the beginning and close of the Middle Ordovician. Elsewhere however, according to various authors no such reductions are apparent. In fact, the trilobites as a group were very abundant before, during and after this geological time period (Butts, 1940; Cooper, 1953; Moore, 1959; Raymond, 1920, 1925; Shaw and Fortey, 1977).

Another possibility is that restricted availability of ecological niches suitable for trilobite habitation in this area was a controlling factor in the reduction of the trilobites during these times. These niches may have become progressively fewer in number through the time represented by this section. It appears that the case of progressive ecological exclusion (i.e., decreasing availability of suitable niches) is the better explanation to account for the initial low trilobite abundance at the base of the section and progressive lowering of the trilobite abundance up section. A progressive diminishing in available niches could have resulted from the filling of the Sevier Basin by clastics from the south and southeast (Benedict and Walker, 1978; Shanmugam, unpublished dissertation, 1979; Walker, 1977).

Interformational and intraformational units. The Evan's Ferry section was divided into formations using the terminology of Cooper (1956) mainly on the basis of lithologic changes and partly on the basis of faunal changes (Sickafoose, 1979). The formations were further divided on the basis of other minor lithologic and faunal changes where necessary for more detail in the abundance curve construction. Calculation of trilobite abundances was based on intervals determined between the selected interformational and intraformational boundaries. These boundaries are discussed below. It was not necessary to subdivide the Tumbez because it did not display any internal abrupt lithologic changes and yielded no trilobite fauna.

The Eidson was divided into upper and lower intervals. The lower Eidson contains only small amounts of chert and almost no trilobites except for some unidentifiable debris. This formation is also characterized by numerous algae and intertidal to supratidal depth indicators. These indicators will be discussed later under the section labeled Depth curve. The upper Eidson is characterized by abundant chert nodules and bedded chert. It also yields fewer algae of all types. This interval shows a dramatic increase in the diversity of identifiable fauna in numbers and species; this is especially true of the trilobites.

The Hogskin was divided into upper and lower intervals also. The lower interval is characterized by numerous medium bedded grainstones and an abrupt increase in number and variety of algae. The upper Hogskin shows a decrease in the algal diversity, a decrease in the abundance of grainstones, and a change in the types of trilobite fauna present.

The Rockdell was divided into upper and lower intervals also. The lower Rockdell shows a dominance of massive packstone and grainstone lithologies and a decrease in trilobite abundance. The upper Rockdell shows an increase in algal, trilobite and other faunal abundance; it becomes less massive and cobbly weathering increases up section in this formation.

The Benbolt and Wardell together were divided into four intervals: lower Benbolt, upper Benbolt, uppermost Benbolt/lowermost Wardell and upper Wardell. The lower Benbolt becomes extremely cobbly upon weathering, yields a dense and diverse fauna and has a great diversity of algae, especially green algae such as Receptaculites. The upper Benbolt becomes less cobbly upon weathering, contains a less diverse fauna and its features indicate a shallowing of water depths (see depth curve of Figure 9). The uppermost Benbolt/lowermost Wardell contains birdseye structures and occasional mudcracks. These features plus the presence of numerous algal oncolites and an abrupt decrease in the diversity of fauna indicate a continued shallowing event. The upper Wardell contains numerous mudcracks, birdseyes, vertical burrows and absence or near absence of most biota except articulate strophomenid brachiopods.

The Bowen contains only a few vertical burrows, mudcracks and birdseyes. It is apparently abiotic, varies in color from maroon to green to gray and has an increase in the percentage of terrigenous clastics.

The Witten was divided into upper and lower parts. The lower Witten has numerous vertical burrows, clastics are reduced to a small quantity and mudcracks are absent, and the formation contains only a few birdseyes and rare trilobites. The upper Witten becomes more thickly bedded towards the top and contains a few brachiopods and ostracodes. Birdseyes and mudcracks are absent below the upper two or three meters of section where the Witten interfingers with the Moccasin Formation.

Trilobite assemblages. The trilobites were collected systematically from the section as previously described in Chapter II. The specimens were then arranged stratigraphically and identified. Table 3 shows the stratigraphic positions of trilobite genera at Evan's Ferry.

The positions of specimens assigned University of Tennessee Geological Sciences Museum (UTGSM) numbers are also shown. Numbered units determined by Sickafoose (1979) who measured the section, basing unit thicknesses upon mesoscopic lithologic changes, faunal changes and outcrop exposures, were used by the present author. (For a discussion of these units see Sickafoose, 1979.)

Upon close inspection of the positions of the trilobite genera, it appeared that certain intervals were characterized by different numerically dominant genera and generic associations. The lower part of the section appears to be characterized by trilobites belonging to the Asaphidae (approximately 35% to 45% of the total trilobites). The asaphids are represented by the genera Isotelus and Isoteloides. Although the pygidium of Isoteloides in the adult stage closely resembles

Table 3. Unit Positions of Genera at Evan's Ferry.

EVAN'S FERRY											
INTERVAL	UNIT	G E N E R A									
		ILLAENUS	NANILLAENUS	BUNASTUS	ISOTILOIDES	ISOTILUS	HONOTILUS	CERATINELLA	CERATUS	CALYPTALAX	CYBELOIDES
L WITTEN	30		(1)								
U WARDELL	26									(2)	
	25		(1)							(1)	
WARDELL / BENBOLT	24					(1)					
		10017	10018, 20			10002				10026	
	23	(3)	(6)	(7)		(2)				(1)	
U BENBOLT	22	(2)	(1)	(1)							
	21		(1)								
	20		(2)	(1)							
L BENBOLT			10019								
	19	(3)	(3)	(13)		(6)					
		10015, 16				10003			10021		
	18	(6)	(5)	(11)		(4)	(1)		(1)	(1)	
U ROCKDELL	17			(1)		(3)					
L ROCKDELL	14		10012	10013		10001			(1)	(1)	
			(2)	(4)		(2)					
	13		10009- 11	(3)	(3)	(1)					
U HOGSKIN	6			(2)		(1)					
	5	(2)		(1)		(1)					
	4			(1)							
L HOGSKIN	3			(3)							
	2			(2)		(1)		(1)		(1)	
	1			(1)		(1)					
U EIDSON	0				(2)	10004- 08 (41)	10022- 23 (2)		10027- 37 (8)	10024- 25 (70)	10026- 25 (3)

Numbers in () indicate total specimens of genus collected from unit, whereas five digit numbers are University of Tennessee Geological Science Museum catalogue numbers.

the pygidium of Isotelus in the meraspid stage, both genera appear to be present in this part of the section.

The only other trilobite family well represented in this portion of the section is Pterygometopidae, which comprises about 50% of the total number of trilobites. The dominant genus from this family here is Calyptaulax; only rare specimens of genera of other families are present here (e.g., Ceraurinella, Ceraurus and Cybeloides). Initially the author chose the name Asaphid-Pterygometopid Assemblage for this group of trilobites as an appropriate name. Later, when it became clear that Calyptaulax was widespread stratigraphically and not a characteristic faunal element for any one assemblage, the name Asaphid Assemblage was adopted.

One other group or assemblage of trilobites occurs in the upper part of the Evan's Ferry section. This group consists characteristically of genera belonging to the Illaenidae. The three generic representatives of this family are Illaenus, Nanillaenus and Bumastus, which comprise nearly 75% of the total number of trilobites. The genus Calyptaulax is present and makes up about 15% of the total. Rarely specimens of Isotelus, Homotelus and Ceraurus also occur in the upper interval. The name Illaenid Assemblage was chosen for this group of trilobites.

Stratigraphic ranges. The Asaphid Assemblage is mostly restricted to the upper Eidson Formation. The Hogskin and Rockdell formations record a transition from the Asaphid Assemblage to the Illaenid Assemblage (they appear to be intermixed in the Rockdell). The upper Rockdell

through lower Witten interval contains specimens mainly from the Illaenid Assemblage. No trilobites were found in the Tumbez, lower Eidson, upper Wardell, Bowen and upper Witten.

Depth curve. The depth curve at Evan's Ferry was constructed by using many of the depth indicators discussed in Benedict and Walker (1978). The position of the occurrence of the depth indicators used in this curve is presented in Table 4.

The bathymetric curve shown on the Evan's Ferry STADD (see page 24) shows a transgressive-regressive sequence. The Tumbez to lower Rockdell records a major transgression or paleobathymetric deepening. The only exception is in the Hogskin which shows a brief marked shallowing event. This is in part supported by a great increase in species and numbers of red and green algae.

The upper Rockdell begins a major shallowing event which continues into the upper Witten. The uppermost part of the upper Witten becomes slightly deeper, possibly shallowest subtidal, in depth for a brief interval. Then, however, a change back to littoral conditions is recorded in the lithology at the Witten-Moccasin contact at the top of this section.

Paleobathymetry of assemblages. By comparing the depth curve to the locations of the trilobite assemblages, one can readily see the relationships between the two. The Asaphid Assemblage corresponds to the upper Eidson which is interpreted as being deep subtidal. Where the curve shows a shallowing in the Hogskin, the Asaphid Assemblage ends

Table 4. Position of Depth Indicators
in Evan's Ferry.

FORMATION	PALEOBATHYMETRIC INDICATOR (PRESENCE = X)*																							
	PENECONTEMP. DOL.	MUDCRACKS	BIRDSEYES	FLAT CREN. ALGAL LAM.	VERTICAL BURROWS	FLAT ALGAL LAMINAE	ALGAL ONCOLITES	OOOLITHS	FINE GRAINS ABUNDANT	COARSE GRNS. ABUND.	SOFT-SED. DEFORM.	FLAT THIN LAMINAE	HORIZONTAL BURROWS	ARTHROPOD & MOLLUSC	ENCRUSTING BRYOZOA	GREEN ALGAE	FILTER FEEDERS DOM.	BORING ALGAE	PELMATOZOA	RED ALGAE	ARBORESCENT BRYOZOA	ARTICULATE BRACH.	INARTICULATE BRACH.	DEPOSIT FEEDERS DOM.
U WITTEN			X		X								X									X		X
L WITTEN	X	X	X		X	X																		
BOWEN	X	X	X		X				X															
U WARDELL	X	X	X		X																		X	
L WARDELL/U BEN							X		X				X									X		
U BENBOLT					X								X					X	X					
L BENBOLT										X				X	X	X		X	X	X				
U ROCKDELL									X					X	X			X	X					
L ROCKDELL								X				X							X					X
U HOGSKIN										X			X	X	X				X					
L HOGSKIN											X		X	X	X				X	X	X			
U EIDSON								X	X	X	X								X		X			X
L EIDSON			X		X					X								X					X	
TUMBEZ	X	X	X	X			X					X	X										X	

*Presence noted only when indicator dominated lithology of unit often.

rather abruptly and the Illaenid Assemblage becomes the important constituent. Both assemblages are present in the Rockdell. Here the depth curve deepens and then shallows again. This constantly changing paleobathymetry suggests rather unstable environmental conditions.

The Rockdell, Benbolt and Wardell are dominated by a shallow subtidal depth curve. Most of the Bowen and Witten depth indicators support an intertidal to supratidal environment of deposition with respect paleobathymetry.

With changing depth, the temperature and salinity also are likely to change (Kinne, 1963). If the Asaphid Assemblage was in fact a deep subtidal assemblage as a whole it was probably adapted to more constant environmental parameters such as temperature and salinity. The instability in the environmental parameters could have helped bring about the gradual exclusion of this assemblage. If gradual exclusion did take place, as is likely, previously existing niches were probably vacated. The vacating of such niches would allow for occupation of these niches by new organisms which were better adapted to a wider range of variation in the environmental parameters. Such a wider range of environmental parameters is more characteristic of the shallow subtidal and littoral zones than it is of the deep subtidal zone.

The exclusion of the previous organisms would allow for the gradual occupation of both vacated and new niches by a group of shallow subtidal trilobites such as the Illaenid Assemblage. This appears to be the case in the area of the section interpreted as being shallow subtidal.

In places where the paleobathymetry has been inferred to be either intertidal or supratidal, the trilobites become either extremely rare or are absent. Since the great majority of trilobites were probably normal marine organisms (Moore, 1959, page 0 172), this exclusion from the latter two types of environments was probably related to the development of too wide a range in environmental parameters such as salinity and temperature in the littoral zone (Hutchins, 1947; Kinne, 1963).

In summary, the Asaphid Assemblage is interpreted to be a deep subtidal or deep shelf assemblage. The Illaenid Assemblage is interpreted as being a shallow subtidal or shallow shelf assemblage.

Cedar Springs

Abundance curve. The average value calculated for the Cedar Springs abundance curve is 0.25 (see Figure 10). This value means that on the average one trilobite specimen was collected from every four meters of section. The abundance curve is easily divisible into two parts or stratigraphic intervals. In the lower interval, trilobite specimens were rarely found and collected in comparison to the upper interval. The boundary between the two intervals occurs at the Rockdell-Benbolt contact.

As at Evan's Ferry, this marked change from scarce to abundant trilobite specimens could be induced by some bias or biases or it might be an actual change in original trilobite abundance brought about by change in the paleoenvironmental parameters. Of the four possible sources of introduced bias as discussed for the Evan's Ferry section,

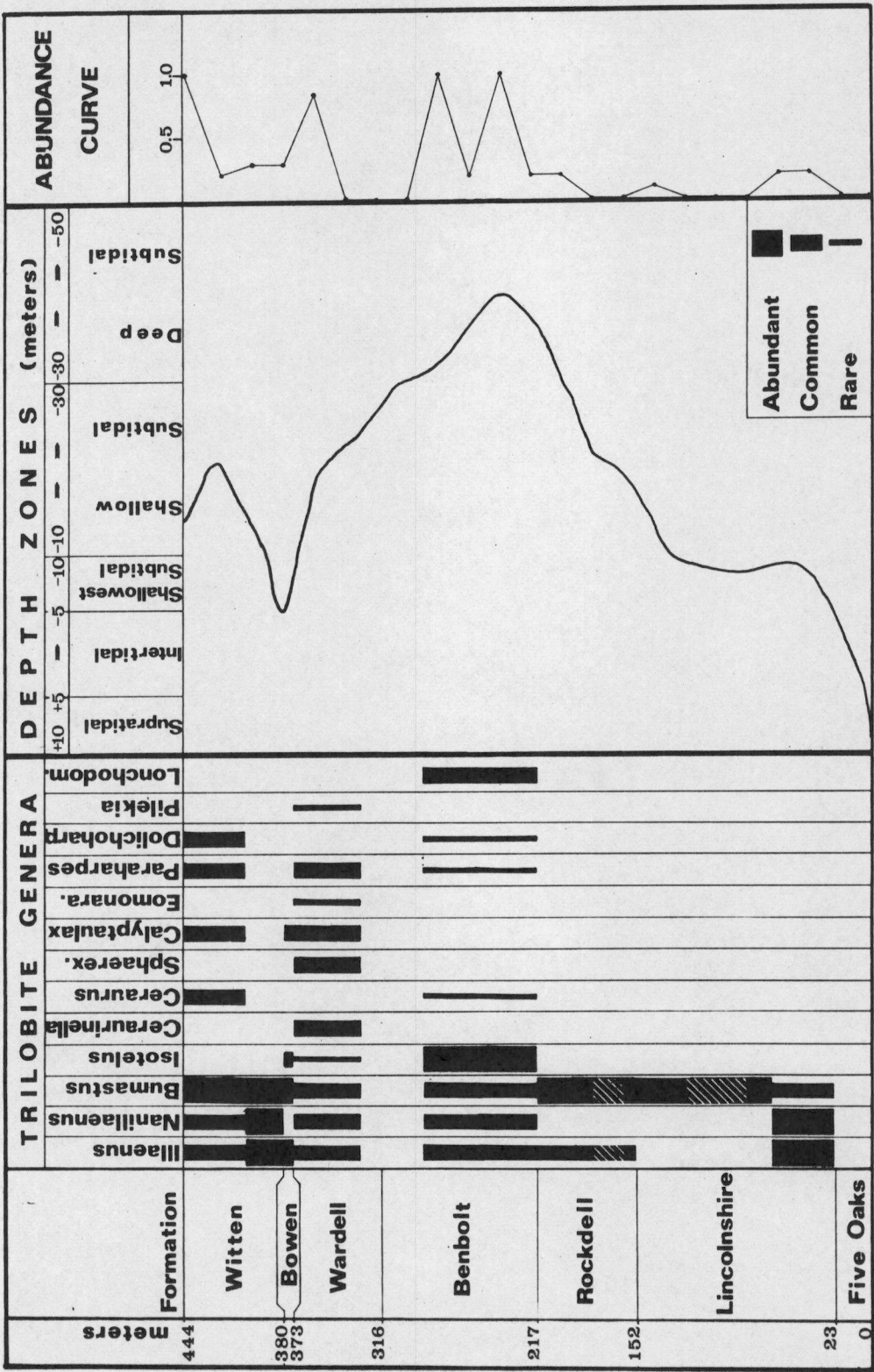


Figure 10. Cedar Springs trilobite assemblage distribution. Abundant = more than 25% of the total trilobite fauna. Common = 5% to 25% of the total trilobite fauna. Rare = more than 0% and up to 5% of the total trilobite fauna. Nonoccurrence = a break in the bar. The Abundance Curve is calculated by dividing the total number of all the specimens of all genera found within a 20 meter interval by 20 and rounded to the nearest tenth (0.1). Diagonally striped areas of the bars indicate that no trilobite specimens were collected from that interval within the bar.

see pages 23-27, which might affect the abundance values in the Cedar Springs section. It appears that the differing weathering characteristics of the lithologies present is partly the key.

The Rockdell is an extremely massive grainstone at Cedar Springs. This lithology is very much like portions of the Holston reef flank deposits described by Walker and Ferrigno (1973), being composed of white to light pink pelmatozoan-bryozoan grainstones. The only trilobite samples obtained from this lithology were collected by splitting Rockdell samples using a hammer and chisel. The Rockdell comprises almost 15% of the total section and, therefore, the rarity of trilobites in this section has a noticeable effect upon the abundance curve.

The overlying Benbolt formation, which shows a marked increase in the absolute abundance of trilobites, is composed of quite different lithologies. The Benbolt is a thin to medium bedded packstone to wackestone, with some shale partings present between calcareous layers. This allows for excellent exposure of the trilobites due to weathering. The Wardell and Witten have similar lithologies. The difference in lithologies and the resultant preservation of trilobites between the Rockdell (which makes up a significant part of the lower interval) and the Benbolt-Wardell (much of the upper interval) may help explain in part the increase in abundance from the lower to the upper interval.

On the other hand, the Lincolnshire of the lower interval is a cobbly weathering wackestone similar to the formations of the upper interval. It, however, yields comparatively few trilobites as does the Five Oaks Formation at the base of the section. The weathering

characteristics for these formations is not believed to be a contributing bias factor.

The above indicates that the change in abundance in part at least must have been an original faunal characteristic during the deposition of the Lincolnshire and Five Oaks formations. Once again the availability of the environmental niches was probably the main contributing factor. A discussion of the probable controls of trilobite distribution will be presented under the heading of Paleobathymetry of assemblages.

Interformational and intraformational units. The Cedar Springs section was divided into formations following the terminology of Cooper (1956), in part on the basis of lithologic changes and also on the basis of changes in the biota (Ruppel, 1979). The present author further subdivided the formations on the basis of smaller scale changes in lithology and biota. This was necessary for a more detailed presentation of the trilobite abundance data which is shown diagrammatically (Figure 10) in relationship to these interformational and intraformational units. The subdivisions recognizable in the Cedar Springs section are as follows. The Five Oaks Formation was divided into upper and lower intervals based on physical changes. The upper differs from the lower in that it (1) is devoid of Knox chert clasts and green chert clasts, (2) has much fewer birdseyes and (3) shows a change from predominantly vertical burrows to predominantly horizontal burrows. Ostracods, although common in the lower Five Oaks, are greatly reduced in number in the upper part.

The Lincolnshire was also divided into lower and upper intervals. The lower interval shows an abrupt increase in the diversity of all biota present over the Five Oaks. Green algae, pelmatozoan debris and bifoliate ectoprocts are particularly numerous. Large oncolites of five to seven centimeters in diameter are present as are numerous algally bored grains. The upper interval shows a decrease in green algae and an increase in the abundance of pelmatozoan debris. The ratio of encrusting to arborescent bryozoa increases noticeably also in the interval.

The Rockdell was left undivided because of the apparent lack of lithologic and biologic change within the formation. Compared to the wackestone lithology of the Lincolnshire stratigraphically below, the Rockdell is a massively bedded grainstone. The Rockdell shows an increase in pelmatozoan, debris, bifoliate, ectoprocts, molluscs and arthropods from the underlying units. The green and red algae are diverse and abundant. Contexta, Vermiporella and Spongiostroma are present for the first time (Ruppel, 1977).

The Benbolt was divided into lower and upper units. In the lower unit algae are absent except for the green alga, Receptaculites. Pelmatozoan debris arborescent ectoprocts and encrusting ectoprocts are abundant in the lower unit. Trilobites as well as molluscs become very abundant. The lithology changes from a grainstone in the Rockdell to a packstone-wackestone in the lower Benbolt and weathering becomes more cobbly upwards. The upper Benbolt yields no algae and only unidentifiable trilobite debris is present. Pelmatozoan debris as well as encrusting ectoprocts become more abundant. The upper Benbolt shows a change back to the Rockdell type massively bedded grainstones.

The Wardell was subdivided into lower and upper units also. The biota increases in diversity; not in equitability but in types present. The green alga Receptaculites is present once again. Bryozoa and pelmatozoan debris are present but rare. Horizontal burrows are very abundant. The lithology ranges from a mudstone to a wackestone. The upper Wardell has abundant ostracodes and trilobites, and ectoprocts are common to rare. Dolomite rhombs and terrigenous clastics are a noticeable constituent of the lithology.

The Bowen was not divided, but shows a dramatic increase in terrigenous clastics and dolomite. Biota are rare and mudcracks are present.

The Witten was divided into lower and upper intervals. In the lower interval dolomitic intraclasts, pelets, Girvanella oncolites and strophomenid brachiopods become very abundant. The lower Witten is a packstone to wackestone. The upper Witten shows a general increase in faunal diversity. Pelmatozoa, arborescent ectoprocts and trilobites become common to abundant.

Trilobite assemblages. Table 5 shows the unit positions of the trilobite genera at Cedar Springs and the unit positions of the specimens, which were assigned UTGSM numbers. The above mentioned units were defined by Ruppel (1979) who originally measured this section, basing the units upon mesoscopic and microscopic lithologic and faunal changes.

At Cedar Springs it appeared that certain intervals were characterized by specific groups or assemblages of trilobites. A total

Table 5. Unit Positions of Genera at Cedar Springs.

CEDAR SPRINGS												
INTERVAL	UNIT	G E N E R A										
		ILLAEUS	NANILLAENUS	BUPASTUS	ISOTELUS	CERATINELLA	CERAEUS	CALYPTALAX	LOUCHODOMAS	PASPIARPES	DOLICHORARPES	PISCEIA
U WITTEN	64			10042 52 (2)								
	62	(3)	(2)	10051 (9)			(1)	(2)		10043 (1)	10041 (1)	
L WITTEN	60	(1)	(1)	(1)								
BOWEN	59	(4)		(2)				(2)				10040 (2)
	58	(1)	(1)	(1)	(1)		(1)	(5)		10045 47 (3)	10044 (1)	10046 (1)
	56		(1)									
U WARDELL	55	(5)	(2)	(1)	(1)	10039 (1)						
	51	(3)		(2)	(1)							
	50	(3)	(2)	(3)					(2)	(2)	10048 (1)	
	49		(1)	(1)			(1)		(3)			
	48	(3)		(2)								
L BENBOLT	45	(4)	(8)	(4)	(16)					10050 (1)		
ROCKDELL	42	(1)		(3)								
U LINCOLNSHIRE	38			(1)								
L LINCOLNSHIRE	22	(7)	(4)	(1)								

Numbers in () indicate total specimens of genus collected from unit, whereas five digit numbers are University of Tennessee Geological Science Museum catalogue numbers.

of four such assemblages were recognized at Cedar Springs, two of which (Illaenid, Asaphid) were also encountered at Evan's Ferry. The Illaenid Assemblage is represented by Illaenus, Nanillaenus and Bumastus. The Asaphid Assemblage is represented only by Isotelus (this assemblage contains Isotelus, Homotelus and Isoteloides at Evan's Ferry).

The two other assemblages present are the Harpid Assemblage and the Raphiophorid-Remopleurid Assemblage. The Harpid Assemblage is represented by the genera Dolichoharpes and Paraharpes. The Raphiophorid-Remopleurid Assemblage is represented only by the genus Lonchodomas. These two assemblages will be discussed later in this and other sections. The two families Cheiruridae and Pterygometopidae are present but appear in several areas and with all of the assemblages; they are not considered to be characteristic elements of any one assemblage. Their rare occurrence does not justify definition of an additional assemblage. In the Cedar Springs section they appear to be present in greater numbers in the shallow subtidal areas. Cheiruridae is represented by Ceraurus, Ceraurinella and Sphaerexochus. The Pterygometopidae is represented by Calyptaulax and Eomonarachus. One specimen of Pilekia of the Pliomeridae was collected.

Stratigraphic ranges. The Lincolnshire and Rockdell specimens are all of the Illaenid Assemblage; the lower Benbolt contains a very diverse trilobite fauna. The illaenids comprise about 54% of the total; whereas the asaphids make up 26% of the total. These assemblages overlap slightly in this interval. The Raphiophorid-Remopleurid Assemblage and

Harpid Assemblage each make up 8% of the total. Here the Asaphid assemblage reaches its most abundant interval or hyperbole in the section.

The greatest diversity in genera occurs in the upper Wardell. The Illaenid Assemblage, in its lowest percentage in the Cedar Springs section, makes up 33% of the total. The asaphids comprise only 5% as do the pliomerids. The Harpid Assemblage reaches its maximum abundance with 14% of the total. The cheirurids and pterygometopids reach their maximum percentages in the Cedar Springs section with 24% and 19%, respectively. In the Wardell, the assemblages previously defined from the Evan's Ferry section overlap to a certain extent. Stratigraphic intervals within the upper Wardell, however, yield trilobites mostly from one assemblage.

The Bowen is dominated by the Illaenid Assemblage with 67% of the total. The Asaphid Assemblage makes up 11% of the total and the pterygometopids 22% of the total.

The lower Witten is represented only by the illaenids. The upper Witten trilobites become much more diverse in general. The illaenids are dominant in this interval with 79% of the total number of trilobites. The harpids make up 11% and the pterygometopids 5% of the total.

No trilobites were found in the lower and upper Five Oaks, upper Benbolt or lower Wardell intervals.

Depth curve. The depth curve was constructed by using those indicators discussed in Benedict and Walker (1978). The indicators used

and their stratigraphic positions are shown in Table 6. The curve shown on the Cedar Springs STADD shows a transgressive-regressive sequence. The Five Oaks to Lower Benbolt interval shows a major transgression or paleobathymetric deepening event. The upper Lincolnshire, however, is interpreted as being slightly shallower than the lower Lincolnshire. The upper Benbolt to Bowen interval shows a regressive event. The lower Witten becomes slightly deeper but then shallows again in the upper Witten near the Witten-Moccasin contact.

Paleobathymetry of assemblages. Comparison of stratigraphic ranges of the trilobite assemblages to the position of the depth curve, shows that given assemblages make up greater percentages of the total number of trilobites found within certain depth zones.

The Illaenid Assemblage is present throughout the entire section. It is the only assemblage found in the Lincolnshire and Rockdell formations. These formations are interpreted as being low intertidal to shallow subtidal environments. The Illaenid Assemblage decreases in percent of total trilobites present in the Benbolt and Wardell formations which constitute the part of the section deposited in the deepest water. In the Bowen and Witten, formations which represent the culmination of the regressive sequence and a return to shallowest subtidal and intertidal conditions, the Illaenid Assemblage regains its dominance as determined by numbers of specimens present.

The Asaphid Assemblage makes up an important portion of the total trilobites present only in the lower Benbolt which is inferred to

Table 6. Position of Depth Indicators
in Cedar Springs.

FORMATION		PALEOBATHYMETRIC INDICATOR (PRESENCE = X) *															
		PENECONTEMP. DOLO.	MUDCRACKS	BIRDSEYES	VERTICAL BURROWS	ALGAL ONCOLITES	HORIZONTAL BURROWS	ARTHROPOD & MOLLUSC	ENCRUSTING BRYOZOA	GREEN ALGAL	FILTER FEEDERS DOM.	PELMATOZOA	RED ALGAL	ARBORESCENT BRYOZOA	DEPOSIT FEEDERS DOM.	SOFT-SED. DEFORM.	FLASER BEDDING
U	WITTEN		X		X				X					X			X
L	WITTEN	X			X							X		X			
	BOWEN	X	X		X		X										
U	WARDELL	X					X							X	X		
L	WARDELL				X		X			X					X		
U	BENBOLT							X			X	X		X			
L	BENBOLT							X		X				X			
	ROCKDELL							X	X	X		X	X	X			
U	LINCOLNSHIRE				X						X	X	X				
L	LINCOLNSHIRE					X	X	X		X			X	X	X		
U	FIVE OAKS	X			X		X									X	
L	FIVE OAKS	X		X	X			X									

*Presence noted only when indicator dominated lithology of unit often.

represent deep subtidal conditions. The asaphids occur in the Wardell and Bowen but only rarely. The genus Lonchodomas, from the Raphiophorid-Remopleurid Assemblage, is common in the lower Benbolt where it makes up nearly 10% of the total trilobites collected. It becomes much more important in the St. Clair and Silver City sections which will be discussed later. This assemblage is thought by the author to be a part of the migration of biota from the south and southeast accompanying the filling of the Sevier Basin. The filling of the Sevier Basin is discussed in Benedict and Walker (1978) and Shanmugam (1977, unpublished dissertation, 1979).

The Harpid Assemblage occurs rarely in the Benbolt Formation but more commonly is found in the Wardell and Witten formations. This assemblage also is thought by the author to represent a portion of the migrating trilobites from the south and southeast. This assemblage, however, is associated with the shallow shelf environments and the terrigenous clastics influx from the southeast.

Generic representatives of the Cheiruridae and Pterygometopidae occur commonly in the upper portion of the Cedar Springs section from the Benbolt through the Witten formations. The only genus representing the pliomeridae in the upper Wardell Formation is Pilekia.

The gradual deepening during the deposition of the Benbolt is probably responsible for the introduction of the genus Lonchodomas from the deeper water environments such as the slope and basinal environments located to the south and southeast. The deepening also probably created niches suitable for the introduction of the Asaphid Assemblage. If in

fact the Illaenid Assemblage was a shallow subtidal assemblage, it was probably better adapted to the widely fluctuating environmental parameters of the shallow shelf and proliferated there partly because of the lack of competition from the other deeper water assemblages. The harpids were introduced onto the carbonate platform along with the clastics from the south and southeast and were probably better adapted to the presence of the clastics. They, therefore, probably provided much competition for the niche occupation during the deposition of the Wardell and Witten formations. The harpid-clastics association will be discussed further in the summary of this chapter.

Environmental parameters such as temperature, salinity and substrate have limited the assemblages in their paleobathymetric distribution. The Illaenid Assemblage and Harpid Assemblage are interpreted as characteristic of the shallow subtidal environments. The Asaphid Assemblage is interpreted as representing deep subtidal environments. The Raphiophorid-Remopleurid Assemblage, which only makes a brief appearance in the Cedar Springs section, is associated with the deeper water types of trilobites such as the asaphids.

St. Clair

Abundance curve. The average value calculated for the St. Clair section is 0.22 (see Figure 11). This value means that on the average one trilobite specimen was found for every 4.5 meters of section. This abundance curve is easily divisible into two major intervals. The lower interval, which includes the Mosheim Member, Asbury Member and basal

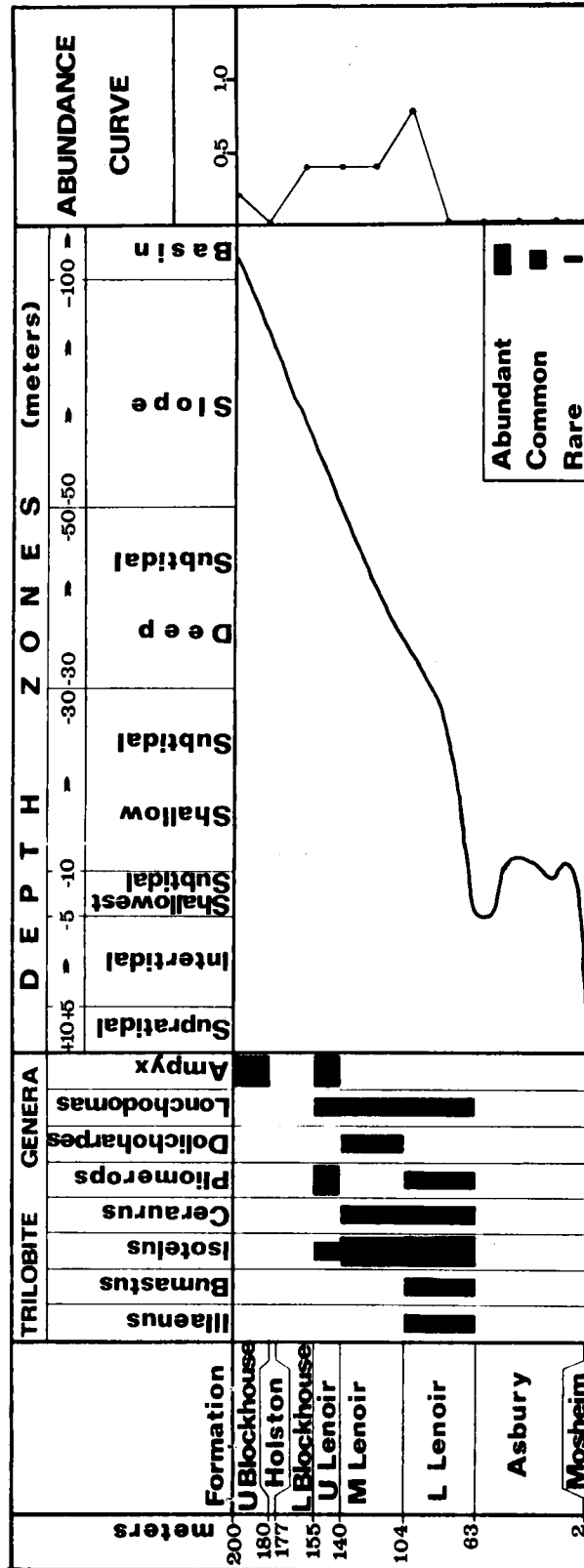


Figure 11. St. Clair trilobite assemblage distribution. Abundant = more than 25% of the total trilobite fauna. Common = 5% to 25% of the total trilobite fauna. Rare = more than 0% and up to 5% of the total trilobite fauna. Nonoccurrence = a break in the bar. The Abundance Curve is calculated by dividing the total number of all the specimens of all genera found within a 20 meter interval by 20 and rounded to the nearest tenth (0.1). Diagonally striped areas of the bars indicate that no trilobite specimens were collected from that interval within the bar.

half of the lower Lenoir, contains no identifiable trilobites. Less than one dozen minute (2-3 mm.) trilobite fragments were found. The upper interval, which includes the top portion of the lower Lenoir, the middle and upper Lenoir, lower Blockhouse, Holston and upper Blockhouse intervals however, yielded all of the identifiable trilobite specimens from this section. The peculiarity shown on the trilobite abundance curve could represent either an actual shift in the paleoenvironment of deposition and its environmental parameters or be due to an induced bias. Possible biases have been enumerated in the discussion of the Evan's Ferry Section.

The scarcity of trilobite specimens for this section as a whole may have been caused by earlier collection of workers from The University of Tennessee and elsewhere. Such previous collecting, however, should not have caused the marked change in abundance from the lower interval to the upper interval of the St. Clair section. Therefore, the marked change in abundance must have been caused by the environmental parameters shifting during deposition. This author believes that the environment during deposition of the Asbury Formation of the lower interval was probably not suitable for habitation by trilobites, partly because of unusually low diversity of many other biota present in this interval as well. Algal oncolites, such as the type present in this interval, are formed in constantly turbulent marine water. The turbulence of the water allows for the coating of a nucleus or grain on all sides by an alga such as Girvanella, and algal oncolites characteristically form in the intertidal to shallowest subtidal areas. Rarely has the author noted

any trilobite material in oncolitic lithologies among the Ordovician rocks in the study area or outside it, except for occasional trilobite debris or rare identifiable specimen.

There are two obvious ecologic reasons for absence of trilobites in oncolitic intervals. First, the turbulence itself may have been a limiting factor to the presence of shallow water trilobites, many of which are inferred to have been vagrant-benthic. Second, many of these vagrant-benthic trilobites as well as some of the nekto-benthic trilobites were probably deposit feeders. This is suggested by some of the ichnofossils which are thought to be the feeding trails of some of the trilobites. The deposit feeder hypothesis is also supported by the fact that in many genera the hypostoma, which was a cover or shield over the mouth region, was fixed and immobile or at least was restricted by a tegument which may have caused partial or complete symphysis (Moore, 1959, page 0 58). The turbulent environment would not allow for the deposition of much of the organic material. The mobile trilobites too would have had a difficult time resting and remaining upright.

The paleoecology, including substrate mobility relationships of many of the trilobite genera is explained in detail in the last subdivision of this chapter, which is concerned with interrelationships of the five studied sections.

In addition to purely ecological reasons for the scarcity of trilobites in oncolitic intervals, trilobite skeletons may have been removed by transportation (i.e., a taphonomic bias). Organic matter has a density less than that of inorganic matter, and the usually platy and

rod shaped portions of trilobite exoskeletons might tend to be sorted out and carried away. Postmortem transport of exoskeletons could cause abrasive removal such as discussed for recent environments by Driscoll and Weltin (1973).

The absence of trilobite remains in the Mosheim Member may be explained by the wide range of variability in intertidal environments such as inferred for the deposition of this member, of environmental parameters such as salinity, temperature and nutritional factors. Such an unstable environment would tend to inhibit normal marine organisms such as many of the trilobites. Here, too, the turbulence of the littoral zone results in postmortem transport and abrasion of the remains of biota.

The abundance curve shows a more abundant trilobite fauna for the rest of the Lenoir Formation. The lower Blockhouse and Holston formations however, did not yield any trilobites, in fact the lower interval of the Blockhouse was apparently abiotic. Possibly the rapid and great paleobathymetric deepening did not allow sufficient time for the inhabitation of any benthic organisms due to what must have been rapidly changing environmental parameters such as temperature and reduction in light availability in the environment. The Holston formation, on the other hand, is a very fossiliferous, massive packstone to grainstone which does not show the cobbly weathering feature of the Lenoir. This weathering characteristic may have been partly responsible for the lack of trilobite specimens taken from this interval. The upper Blockhouse contains a few specimens but the diversity (equitability) is low as are the numbers of species (personal communication, Benedict,

1979). Because the Blockhouse has many well formed bedding planes, the lack of abundant trilobites is probably due to the unfavorable environmental conditions.

Interformational and intraformational units. The St. Clair section was originally measured and divided into formations by Benedict (in prep.) and Ruppel (1979). These formational boundaries are based upon lithologic and faunal changes within the section. The present author further separated this section into smaller intervals based upon lithologic and faunal changes on a smaller scale. These intervals allow for a more detailed representation of the abundance data. These intervals and their boundaries are discussed below.

The Lenoir, Holston and Blockhouse formations were recognized as being present at the St. Clair section by both Benedict and Ruppel cited above. They subdivided the Lenoir into the Mosheim Member, Asbury Member and the main body of the Lenoir. The present author further divided the Lenoir into lower, middle and upper main body of the Lenoir. The Holston was not divided further. The Blockhouse Formation occurs in two separate and distinct stratigraphic intervals.

The Mosheim Member contains fenestral birdseyes, flat crenulated algal laminations and penecontemporaneous dolomite. The Mosheim Member appears to be abiotic except for the occurrence of ostracodes. The Asbury Member is characterized by gastropods such as Maclurites and numerous arthropods, trilobites and ostracods. Bryozoans and pelmatozoan debris rarely occur in this interval. The sponge, Allosaccus, is found

in the basal portion within this interval and Girvanella oncolites are common. Soft-sediment deformational features are also common. The lower main body of the Lenoir is characterized by green algae such as Receptaculites and sponges which occur abundantly; the oncolites are not present. Cephalopods, ostracodes trilobites, ectoprocts and pelmatozoan debris are abundant and diverse in variety and equitability. All biotic elements are robust, especially toward the top of this interval. Vertical and horizontal burrows are common in this interval and soft-sediment deformational features continue to be present. The middle main body of the Lenoir is very similar to the lower main body of the Lenoir. However, all biotas decrease in diversity and abundance except for the sponges which remain diverse, abundant and robust. The upper main body of the Lenoir contains only a few sponges. The biota continues to decrease in diversity and numbers and completely disappears in the uppermost part of this interval.

The lower interval of the Blockhouse Formation is abiotic. The lithology changes from a clayey silt to clay shale, and is characterized by flat, thin laminae. Terrigenous clastics dominate this unit.

The Holston consists of grainstones and boundstones. Some trilobite debris was noted but no identifiable specimens could be collected. Pelmatozoan debris and ectoprocts are the most abundant biotic elements in this interval. Coarse grains dominate the lithology.

The upper interval of the Blockhouse is very similar in lithology to the lower interval of the Blockhouse. Graptolites are present for the first time in this section, and trilobites are also present although comparatively they are rare.

Trilobite assemblages. The trilobites were collected from this section employing the methods used in the sections previously discussed. Table 7 shows the stratigraphic positions of the trilobite genera collected.

All five recognized assemblages are present in this section. They are the (1) Asaphid Assemblage, (2) Raphiophorid-Remopleurid Assemblage, (3) Pliomerid Assemblage, (4) Illaenid Assemblage and (5) Harpid Assemblage. Most of the trilobites collected in this section belong to the first three assemblages.

The Asaphid Assemblage is represented only by the genus Isotelus. The Raphiophorid-Remopleurid Assemblage is represented by Lonchodomas and Ampyx. The Pliomerid Assemblage is represented by Pliomerops. Illaenus and Bumastus represent the Illaenid Assemblage. Ceraurus (Cheiruridae) also occurs here but it has not been assigned to an assemblage, because it is represented by only a minor percentage of the total number of trilobites and occurs in most assemblages.

Stratigraphic ranges. The Asaphid Assemblage constitutes 56% of the total trilobites in the lower main body of the Lenoir with most of the specimens occurring in the upper ten meters of this interval. In the main body of the Lenoir Formation the Asaphid Assemblage reaches its greatest percentage of the total number of trilobites present, with over 64% of the total. The highest stratigraphic occurrence of the asaphids is in this section in the upper main body of the Lenoir, where they constitute slightly over 12% of the total.

Table 7. Unit Positions of Genera at St. Clair.

S T . C L A I R									
INTERVAL	UNIT	G E N E R A							
		ILLAENUS	BUMASTUS	ISOTELUS	GERAURUS	PLIOEROPS	LONGHODONAS	ANTYX	DOLICHOPARPES
U BLOCKHOUSE	180 - 200							(4)	
U LENOIR	135 - 155			(1)		(3)	(1)	(3)	
	120 - 130			(5)					
M LENOIR	100 - 120			(2)	(2)		(2)		(1)
L LENOIR	90 - 100	(1)	(1)	(9)	(1)	(1)	(3)		

Numbers in () indicate total specimens of genus collected from unit.

The Raphiophorid-Remopleurid Assemblage makes up approximately 18% of the total number of trilobites present in the lower main body of the Lenoir. All the representatives of this assemblage are found within the upper ten meters of the lower Lenoir, and the assemblage decreases slightly with respect to percentage of total number of trilobites in the middle main body of the Lenoir, with just over 14% of the total. In the upper main body of the Lenoir, the Raphiophorid-Remopleurid Assemblage constitutes only 12% of the total number of trilobites present.

The Pliomerid Assemblage makes up just over 6% of the total number of trilobites in the lower main body of the Lenoir. In the upper main body of the Lenoir, however, the assemblage constitutes over 37% of the total.

The Illaenid Assemblage constitutes 12% of the total number of trilobites collected from the lower main body of the Lenoir. Some illaenid fragments were also noted higher in the section but they were unidentifiable at the generic level.

The Harpid Assemblage occurs only within the middle main body of the Lenoir where it makes up about 7% of the total number of trilobites collected from this interval.

Ceraurus occurs in the lower main body of the Lenoir and constitutes 6% of the total. This genus also occurs in the middle main body of the Lenoir and makes up approximately 14% of the total. No trilobites were found in the Mosheim Member, Asbury Member, lower interval of the Blockhouse or Holston Formation.

Depth curve. The depth curve at St. Clair was constructed using the depth indicators discussed in Benedict and Walker (1978). The occurrence of the indicators used in this section are shown in Table 8. [Refer to the meter values of the depth zones given on page 9 and Table 1 (see page 10) for the bathymetric ranges of the indicators used.]

Paleobathymetry of assemblages. By comparing the stratigraphic occurrences of the trilobite assemblages with the depth curve for the St. Clair section it may be seen that certain bathymetric ranges are characterized by specific assemblages. The Asaphid Assemblage occurs mainly within the deep subtidal interval. Even its appearance in the lower interval of the main body of the Lenoir is restricted to the uppermost portion where the paleobathymetry has been interpreted to be on the border between shallow subtidal and deep subtidal.

The Pliomerid Assemblage which has also been interpreted to be associated with the deep subtidal occurs mostly within the upper interval of the main body of the Lenoir Formation which has been inferred as having been deposited in a deep subtidal environment.

The Raphiophorid-Remopleurid Assemblage occurs mainly within the deep subtidal to lower slope bathymetric range. Ampyx is thought to be a lower slope genus, whereas Lonchodomas is believed to have been a deep subtidal to upper slope genus (Benedict, personal communication).

The Illaenid Assemblage occurs in the lower interval of the main body of the Lenoir. This interval has been interpreted as being shallow subtidal except for the upper ten meters.

Table 8. Position of Depth Indicators
in St. Clair.

FORMATION	PALEOBATHYMETRIC INDICATOR																	
	(PRESENCE = X)*																	
	PENECON. DOLO.	BIRDSEYES	FLAT CREN. ALGAL LAM.	VERTICAL BURROWS	ALGAL ONCOLITES	FINE GRAINS ABUND.	SOFT-SED. DEFORM.	PELMATOOZOA	HORIZONTAL BURROWS	ARTHROPODS & MOLLUSCS	ENCRUSTING BRYOZOA	GREEN ALGAE	ARBORESCENT BRYOZOA	GRAPTOLITES	FLAT THIN LAM.	COARSE GRNS. ABUND.	TURBIDITE SEQUENCES	INARTICULATE BRACH.
U BLOCKHOUSE						X								X	X		X	
HOLSTON								X			X		X			X		
L BLOCKHOUSE						X									X			
U LENOIR						X	X		X									X
M LENOIR						X	X		X		X							
L LENOIR				X			X		X			X	X					
ASBURY MEMBER				X	X		X		X	X		X						
MOSHEIM MEMBER	X	X	X															

*Presence noted only when indicator dominated lithology of unit often.

The only appearance of the Harpid Assemblage is the rare occurrence in the middle interval of the main body of the Lenoir. This interval has been interpreted as deep subtidal. The Harpid Assemblage has, however, been interpreted as being a shallow subtidal assemblage. No explanation of this conflicting interpretation is offered at this time except to note that this occurrence is supported by one specimen only which is certainly not statistically meaningful.

Silver City

Abundance curve. There is no trilobite abundance curve in this report for the Silver City section. An abundance curve for trilobites in this stratigraphic section is being prepared by Benedict (in preparation). Reference to trilobite abundances for the Silver City section in the present report applies to relative abundances among genera and not absolute abundances. The relative abundances are based upon data obtained from Benedict (personal communication, 1979).

Interformational and intraformational units. The Silver City section was originally measured and divided into the intervals shown in Figure 12 by Benedict (in preparation). These subdivisions which are discussed below, are based upon lithologic and biologic changes.

The Lenoir Formation was divided into three intervals. These are the (1) Mosheim Member, (2) Asbury Member and (3) main body of the Lenoir. The Mosheim Member is characterized by fenestral birdseyes, flat crenulated algal laminations, soft-sediment deformational features

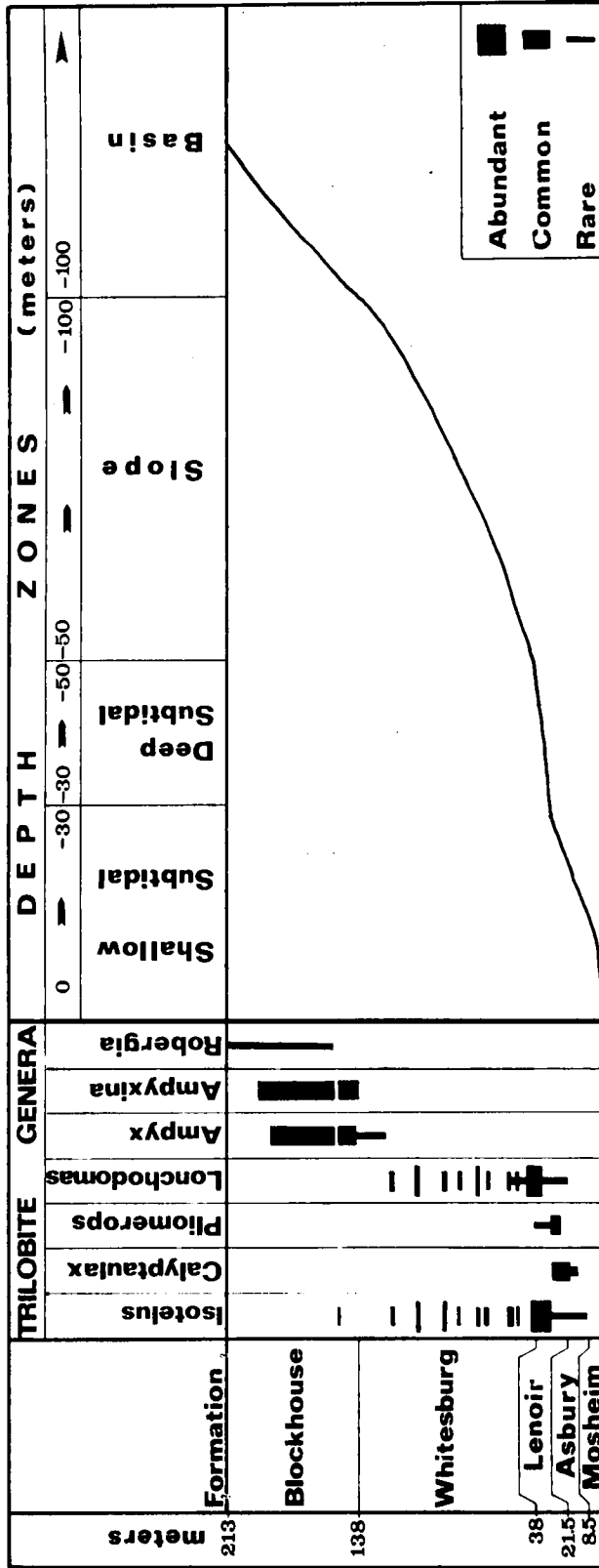


Figure 12. Silver City trilobite assemblage distribution. Abundant = more than 25% of the total trilobite fauna. Common = 5% to 25% of the total trilobite fauna. Rare = more than 0% and up to 5% of the total trilobite fauna. Nonoccurrence = a break in the bar. The Abundance Curve is calculated by dividing the total number of all the specimens of all genera found within a 20 meter interval by 20 and rounded to the nearest tenth (0.1). Diagonally striped areas of the bars indicate that no trilobite specimens were collected from that interval within the bar. [No abundance curve was plotted for this section (see Benedict, in prep., for abundance values).]

and penecontemporaneous dolomite. Gastropods and ostracodes occur commonly, but no trilobites were found in this interval at Silver City.

The Asbury Member contains penecontemporaneous dolomite and almost no birdseyes. Vertical and horizontal burrows are numerous. Features attributable to soft-sediment deformation occur abundantly throughout this interval. The Asbury Member is characterized by numerous algal oncolites; green algae are abundant and diverse. Some trilobites, bryozoans and gastropods were noted in this interval. Biotic diversity increases with respect to equitability and variety through this interval up section.

Within the main body of the Lenoir Formation biotic diversity continues to increase although algae begin to decrease in number and variety. Algal oncolites are not present in this interval. Encrusting and arborescent ectoprocts increase in number. Horizontal burrows increase in number, whereas the vertical burrows decrease in number. Penecontemporaneous dolomite is no longer present.

The Whitesburg Formation is characterized by slab bedded, fine-grained limestone interbedded with shales. The ratio of shale to limestone increases upward in the section. Only a few trilobites were noted at the base of the formation. Most of the trilobites found in the Whitesburg Formation occur within the limestone layers. Contourites are found in the lower half of the Whitesburg and decrease in number up section (Benedict, in preparation). Faunal diversity and abundances decrease up section. No algae, ectoprocts or molluscs appear to be present, but graptolites are present for the first time in the section

and increase upward in the formation. At the Whitesburg-Blockhouse contact, the trilobite genera present change abruptly.

The Blockhouse Formation consists of thinly laminated shales which are abiogenic except for an occasional inarticulate linguloid brachiopod and graptolites. The shales were deposited as clay pelagites with rare terrigenous silty turbidites (Shanmugam, 1979). The trilobite elements present continue to change in generic composition gradually upward in the section.

Trilobite assemblages. The trilobites were collected from this section using the methods previously described. Three assemblages were recognized as being present.

The Asaphid Assemblage, represented solely by the genus Isotelus, was the only assemblage found within the Asbury Member. Calyptaulax was also collected from that interval. The Pliomerid Assemblage, represented here by Pliomerops, and the pterygometopid Calyptaulax, make up over half of the total number of trilobites collected in this interval. The asaphid Isotelus, and the raphiophorid Lonchodomas, make up the remaining trilobites of this interval.

The Whitesburg Formation is characterized by Isotelus and Lonchodomas which decrease in absolute numbers up section. Also, rarely, Ampyx of the Raphiophorid-Remopleurid Assemblage was collected from the top of the Whitesburg.

The Blockhouse Formation contains only genera of the Raphiophorid-Remopleurid Assemblage except for one thin limestone bed that contains

Isotelus. The genera of the Raphiophorid-Remopleurid Assemblage present in the Blockhouse are Ampyx, Ampyxina and Robergia.

Stratigraphic ranges. The Asaphid Assemblage occurs chiefly within the main body of the Lenoir Formation, but is also found rarely in the Asbury Member, Whitesburg Formation and Blockhouse Formation. The Pliomerid Assemblage occurs only within the main body of the Lenoir. The Raphiophorid-Remopleurid Assemblage is found commonly in the main body of the Lenoir, Whitesburg Formation and Blockhouse Formation.

Depth curve. The depth curve at Silver City was constructed using the depth indicators described in Benedict and Walker (1978). The position of the indicators used in this section are given in Table 9. Meter values of the depth zones are given on page 9. Bathymetric ranges of the indicators used are shown on page 10 in Table 1.

Paleobathymetry of assemblages. The Asaphid Assemblage and Pliomerid Assemblage continue to be present mainly in the interval which has been interpreted as deep subtidal. They are present mostly within the main body of the Lenoir. The asaphids are present in the Whitesburg only within the calcareous layers. The Whitesburg has been interpreted as a series of slope deposits. A plausible explanation for the occurrence of this assemblage in the upper slope material is that the asaphid trilobites in the Whitesburg represent allocthonous material that has been transported down slope from the shallower environment where they actually lived. Fortey (1975) and Fortey and Barnes (1977)

have noted a similar type of deposit in Spitzbergen limestones involving Early Ordovician trilobite communities.

The Raphiophorid-Remopleurid Assemblage has been interpreted as being an upper slope to basinal assemblage. This is a transitional assemblage as noted elsewhere in this report and in Benedict (in preparation). The slope environments were occupied by the raphiophorid trilobites Lonchodomas, Ampyx and Ampyxina. As the basinal deposits are approached stratigraphically up section, the remopleurids gradually become the dominant trilobites. Finally in the basinal deposits of the upper Blockhouse Formation the remopleurids (i.e., Roergia) are the only trilobites present. Lonchodomas is present mainly on the upper slope and overlaps some with the Asaphid Assemblage in the deepest subtidal interval represented by the Lenoir Formation. Lonchodomas is also found in the allocthonous deposits which occur within the calcareous layer in the Whitesburg Formation. The numbers of Lonchodomas decrease upward, as does the limestone to shale ratio, in the Whitesburg Formation.

Ampyx and Ampyxina become the dominant genera in the lower slope material of the basal half of the Blockhouse Formation. These raphiophorids decrease in numbers up section into the upper Blockhouse Formation which is interpreted as being formed of basinal deposits. The remopleurid Roergia becomes the dominant trilobite taxon and finally the only one present in the upper part of the Blockhouse.

At Silver City very little supratidal to shallow subtidal lithology exists (less than 15% of the total section). The remainder of the section appears to reflect sudden subsidence with the creation of the

Sevier Basin. According to Benedict and Walker (1978), the subsidence was not followed by an immediate influx of sediment. Rather there was a lag time during which the basin gradually increased in depth. Sediment later poured in from the south and southeast (Shanmugam, 1977; Walker, 1977).

The asaphids flourished in the deep subtidal environment of the main body of the Lenoir. When the water deepened, however, they began to be displaced by the raphiophorids which were migrating from the south and southeast with the closing of the Proto-Atlantic (Whittington and Hughes, 1972). As the basin continued to deepen, the upper slope raphiophorid genus Lonchodomas was replaced by the lower slope raphiophorid genera Ampyx and Ampyxina. Finally the remopleurid Robergia began to occupy the deeper water niches of the Blockhouse depositional environment.

As a rule, the faunal diversity among the trilobites decreases with increasing depth at Silver City. A decrease in numbers per species population has been noted in the modern environment by Bretsky and Lorenz (1969).

Raccoon Valley

Abundance curve. The average value calculated from the Raccoon Valley abundance curve is 0.38 (see Figure 13). This value means that on the average approximately one trilobite specimen was collected for every 3 meters of section.

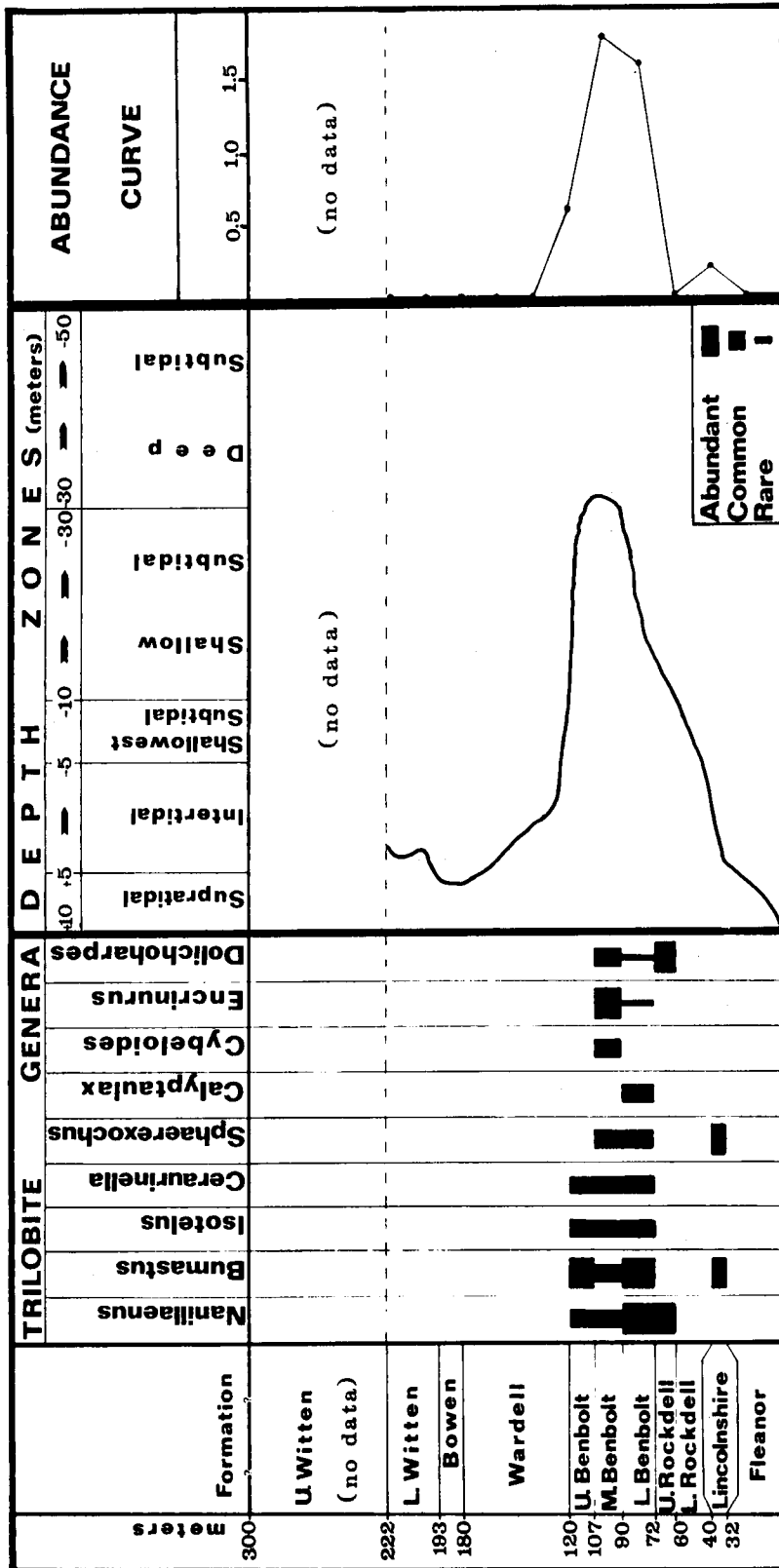


Figure 13. Raccoon Valley trilobite assemblage distribution. Abundant = more than 25% of the total trilobite fauna. Common = 5% to 25% of the total trilobite fauna. Rare = more than 0% and up to 5% of the total trilobite fauna. Nonoccurrence = a break in the bar. The Abundance Curve is calculated by dividing the total number of all the specimens of all genera found within a 20 meter interval by 20 and rounded to the nearest tenth (0.1). Diagonally striped areas of the bars indicate that no trilobite specimens were collected from that interval within the bar.

This abundance curve may be divided into three distinct intervals; upper, middle and lower. The lower one third of the total abundance curve has an average abundance value of 0.07 which indicates that approximately one trilobite individual was collected from every 15 meters of section. The middle one third of the total abundance curve has an average abundance value of 1.33 which means that one trilobite specimen was collected for every 0.8 meters of section. Because no trilobites were collected from the upper interval the abundance value is shown as 0.0.

The marked contrast among these three intervals may have been caused either by some induced bias or an actual change in the trilobite numbers brought about by some change in the diversity and availability of suitable ecologic niches. These possibilities are explored below.

The low abundance value for the lower interval, which consists of the Fleanor, Lincolnshire and lower Rockdell formations, may be due to two main factors: (1) the lithologic weathering characteristics and (2) niche availability. The lower Rockdell is a massively bedded grainstone to wackestone, which provides few bedding plane exposures. The limited bedding plane exposure is probably the major contributing factor to the low trilobite abundance in this interval. Most of the remaining portion of the lower interval consists of the Fleanor Formation. This formation appears to represent supratidal to intertidal environments of deposition in which environmental parameters such as salinity, temperature, substrate and nutrient availability probably tended to have a wider range of variability. Over 90% of the trilobite specimens found

within the study area were collected from rocks deposited in shallow subtidal or deeper water bathymetric zones. Some trilobites, however, have been collected from supratidal and intertidal lithologies elsewhere (Walker, 1972). Suitable niches, the availability of which is partially controlled by the variance of the environmental parameters, were probably limited to a greater extent in supratidal to intertidal environment such as represented by the Fleanor. Trilobite abundance is also consequently limited. The Lincolnshire Formation is also interpreted as having been deposited in a shallow water environment, perhaps intertidal to shallowest subtidal, with oncolites occurring mainly near the top. In general, trilobite specimens have been found only rarely within lithologies which contain algal oncolites. Even if this type of environment were suitable for trilobite habitation, the effect of the turbulent waters might tend to remove the highly organic trilobite specimens after death and abrade the exoskeletons.

The middle interval which includes the upper Rockdell and Benbolt formations has the highest abundance value for the entire abundance curve. This is, in part, because none of the discussed factors tending to limit the abundance of trilobites in the lower and upper intervals, have reduced the occurrence or hindered the collecting of trilobites in the middle interval. In this interval the formations are well exposed, easily accessible, representative of subtidal environments of deposition and show cobbly weathering which enhances the collection of trilobite specimens.

The upper interval consists of the Wardell, Bowen and lower Witten formations. The collecting of trilobite specimens within this interval was limited by one or more of the following factors: (1) limited amount of exposed outcrop; (2) previous collection of fossils by other workers; (3) low availability of suitable niches for trilobite habitation. Limited exposure mainly affected collecting in the Wardell and Bowen formations. In the Raccoon Valley section examined these two formations were exposed only along a small creek bed which cut these formations along the dip direction in an otherwise wooded and grass covered area. This restricted exposure allowed only very limited collecting of trilobite specimens. The lower Witten was well exposed in the abandoned quarry in this Raccoon Valley section.

Previous collecting of specimens from the upper interval has possibly affected the lower Witten only. This portion of the upper interval is exposed in the abandoned quarry mentioned earlier. Numerous students from The University of Tennessee have visited this quarry previously during course field trips. Collecting would probably account for the lack of any apparent trilobite specimens in this interval because many of the rocks contain trilobite fragments. Trilobite debris was noted rarely in the Wardell and not at all in the Bowen.

The third and final possible cause for the low abundance in the upper interval of the Raccoon Valley section is the limited availability of suitable niches for trilobite habitation in the paleoenvironments represented by the lithologies. The paleobathymetry of the Wardell, Bowen and lower Witten formations is interpreted as having been largely

intertidal. Some trilobite genera (e.g., Bathyrurus) have been noted in the intertidal lithologies elsewhere (Walker, 1972); however, the great majority of them are considered to have been normal marine organisms (Moore, 1959, page 0 172). In the littoral zone, the limiting factors which affect survival, reproduction and nutrient availability such as salinity, temperature and the presence of sufficient organic particulate matter have a wide range of variance. In this type of environment, only the most eurytopic organisms can survive. The lack of numerous available and suitable ecologic niches, therefore, was probably a major contributing factor in the rarity of trilobites in these formations.

Interformational and intraformational units. The Raccoon Valley section (at the Stanley Cemetery in Raccoon Valley) was originally measured and divided into formations by T. W. Broadhead and the present author using the stratigraphic terminology of Cooper (1956). These divisions for the most part were based on lithologic changes. The author further divided the formations based upon lithologic and faunal changes on a smaller scale for the elucidation of trilobite abundance data in greater detail. These subdivisions are discussed below.

The Fleanor Formation was left undivided. This formation consists mainly of finely laminated calcareous red and yellow mudstones with varying amounts of terrigenous clastic debris. Mudcracks are common in this formation. Gastropods and ostracodes along with some trilobite debris (possibly illaenid), constitute the only biota noted as being present.

The Lincolnshire Formation, which is characterized by soft-sediment deformational features, was also left undivided. Oncolites occur mainly toward the top of this formation. Vertical burrows are common while horizontal burrows were only rarely noted. Gastropods and ostracodes are also present.

The Rockdell was divided into upper and lower intervals. The lower Rockdell is a massively bedded grainstone to wackestone. Pellets are common in the grainstone. Soft-sediment deformation evidenced by very irregular bedding is only very rarely noted in this interval. The wackestones are characterized by numerous vertical burrows, gastropods and articulate brachiopods. Pelmatozoan debris is common in the packstones and grainstones as are ectoprocts. The upper Rockdell becomes much less massive, and soft-sediment deformational features increase upward. The upper interval contains thickly bedded wackestones and mudstones. Encrusting ectoprocts and gastropods are abundant, whereas vertical burrows are rare.

The Benbolt was divided into lower, middle and upper intervals. The lower Benbolt is medium to thinly bedded with abundant irregular bedding. Green algae such as Receptaculites are common in this interval, and horizontal burrows are rare to common. The middle Benbolt is characterized by some soft-sediment deformational features and common horizontal burrows. Pelmatozoans are abundant while green algae are rare. Sponges are common with the larger specimens up to 10 centimeters in diameter. One specimen of Nidulites was noted toward the top of this interval. The upper Benbolt contains Receptaculites and numerous algal

oncolites. At some horizons the oncolites dominate the lithology, making up as much as 60% to 70% of the total volume. Large arborescent ectoprocts continue to be common but encrusting ectoprocts are rarely present. One large encrusting colony was 25 to 30 centimeters in diameter and 10 centimeters thick at its crest. Articulate brachiopods are very abundant, but pelmatozoans and vertical burrows are generally rare.

The Wardell was not subdivided because of poor exposure and homogeneous lithology. The Wardell is a medium to thin bedded wackestone interbedded with discontinuous layers or lenses of grainstone. Vertical burrows are abundant while horizontal burrows are rare. Soft-sediment deformational features are present but less common than in the Benbolt. Mudcracks, birdseyes and penecontemporaneous dolomite are present but uncommon. Ostracodes and gastropods are common in the wackestone layers, whereas pelmatozoans, ectoprocts and articulate brachiopods are common in the grainstone lenses.

The Bowen Formation was also left undivided. It is a red and yellow calcareous mudstone with varying amounts of terrigenous clastics present. This mudstone is characterized by numerous mudcracks and rare cross laminations.

The Witten was divided into lower and upper intervals. The lower interval is characterized by vertical burrows, but horizontal burrows and soft-sediment deformational features are occasionally present. Mudcracks and cross laminations are rarely present. Gastropods, ostracodes and articulate brachiopods are common in the lower interval.

The upper interval was not studied in any detail, but it appears to be devoid of mudcracks and is more thickly bedded. Grainstones tend to increase in number and in percent of total lithologic volume, whereas soft sediment deformational features decrease in abundance up section in this interval.

Trilobite assemblages. The trilobites were collected, arranged and identified from this section using the same methods as those which were used in the previous sections.

Table 10 shows the unit positions of the trilobite genera at Raccoon Valley. Three of the previously recognized assemblages were found to be present at this section. These are the Illaenid Assemblage, the Asaphid Assemblage and the Harpid Assemblage. The Illaenid Assemblage is represented by Nanillaenus and Bumastus. The Asaphid Assemblage is represented only by Isotelus with other closely associated genera such as Ceraurinella and Cybeloides. The latter two genera are also closely associated with the asaphids at Evan's Ferry. The Harpid Assemblage is represented solely by the genus Dolichoharpes. Other genera are present but have not been assigned to an assemblage mainly because of their sporadic and irregular occurrence with many assemblages. These are Calyptraulax and, to a lesser extent, Sphaerexochus and Encrinurus.

Stratigraphic ranges. The Illaenid Assemblage is found in the Raccoon Valley section in the Lincolnshire Formation and through the entire Benbolt Formation. This assemblage makes up 67% of the total trilobites present in the Lincolnshire and decreases to 50% of the total

Table 10. Unit Positions of Genera
at Racoon Valley.

RACCOON VALLEY										
	G E N E R A									
INTERVAL	UNIT	NANTILAEUS	BURASTUS	ISOTELUS	CERAURINELLA	SPHAEREXOCHIUS	CALYPTACLAX	CYBELOIDES	ENCERERUS	DOLICHOMARPES
U BENBOLT	110 - 120	(1)	(4)	(1)	(1)					
M BENBOLT	90 - 110	(2)	(1)	(3)	(1)	(2)		(1)	(3)	(1)
L BENBOLT	70 - 90	(15)	(18)	(5)	(5)	(9)	(3)		(2)	(2)
U ROCKDELL	60 - 70		(1)							(1)
LINCOLNSHIRE	30 - 40		(2)			(1)				

Numbers in () indicate total specimens of genus collected from unit, whereas five digit numbers are University of Tennessee Geological Science Museum catalogue numbers.

trilobites collected from the upper Rockdell. The illaenids constitute nearly 65% of the total in the lower Benbolt and decrease to just over 20% of the total trilobites taken from the middle Benbolt. The illaenids increase in abundance again to comprise over 57% of the total trilobites collected from the upper Benbolt.

The Asaphid Assemblage is found in the Benbolt only. The asaphids constitute just over 8% of the total trilobites from the lower Benbolt and increase to nearly 25% of the total trilobites present in the middle Benbolt. The asaphids decrease again in abundance to about 14% in the upper Benbolt.

The Harpid Assemblage ranges from the upper Rockdell to the middle Benbolt. In the upper Rockdell, the harpids, represented only by Dolichoharpes, constitute 50% of the total trilobites collected from this interval and decrease in percent of total abundance in the lower Benbolt Formation to almost 4%. In the middle Benbolt, the harpids constitute just over 7% of the total trilobites collected.

Depth curve. The depth curve for the Raccoon Valley section was again constructed by using the depth indicators discussed previously. The indicators used and their stratigraphic positions are shown in Table 11. The positions are listed with respect to the interformational and intraformational units discussed previously for the Raccoon Valley section. Depth zones are given on page 9 and the bathymetric range values of the indicators used here are shown in Table 1 (page 10).

Table 11. Position of Depth Indicators
in Raccoon Valley.

FORMATION	PALEOBATHYMETRIC INDICATOR															
	(PRESENCE = X)*															
	PENECONTEMP. DOLO.	MUDCRACKS	BIRDSEYES	VERTICAL BURROWS	ALGAL ONCOLITES	FINE GRAINS ABUNDANT	COARSE GRNS. ABUND.	SOFT-SED. DEFORM.	FLAT THIN LAM.	HORIZONTAL BURROWS	ARTHROPOD & MOLLUSCS	ENCRUSTING BRYOZOA	GREEN ALGAE	PELMATOZOA	ARBORESCENT BRYOZOA	ARTICULATE BRACH.
L WITTEN				X				X		X	X					
BOWEN	X	X				X										
WARDELL	X	X	X	X				X			X					X
U BENBOLT					X					X		X	X	X		X
M BENBOLT								X		X				X	X	
L BENBOLT				X				X		X			X	X	X	
U ROCKDELL											X	X	X	X	X	
L ROCKDELL						X				X		X	X	X	X	X
LINCOLNSHIRE				X	X			X								
FLEANOR		X				X			X	X						

*Presence noted only when indicator dominated lithology of unit often.

The Raccoon Valley section graphically depicts a transgressive-regressive sequence. The Fleanor to middle Benbolt formations record a major transgressive or paleobathymetric deepening event. Beginning in the upper Benbolt and continuing into the lower Witten Formation a regressive event is recorded in the lithologies.

Paleobathymetry of assemblages. Comparison of the Raccoon Valley depth curve to the stratigraphic distribution of trilobite genera, shows the Illaenid Assemblage dominating the Lincolnshire and lower and upper Benbolt formations, interpreted as representing intertidal to shallow subtidal environments of deposition. Where the environment becomes deep subtidal, represented by the middle Benbolt Formation, dominance is assumed by the Asaphid Assemblage. The dominance of the Illaenid Assemblage in shallow subtidal environments was noted in the other stratigraphic sections, whereas the Asaphid Assemblage has been interpreted as being characteristic of the deep subtidal lithologies. The Harpid Assemblage, which is thought to be part of a faunal migration from the south and southeast, represents the shelf counterpart of the Raphiophorid-Remopleurid Assemblage which is found mainly in the slope and basin lithologies of the Sevier Basin.

Conclusions

Ecostratigraphy and Paleobathymetry of the Study Area

The five sections previously discussed represent a transitional sequence from a shallow, carbonate platform to a deep, basin which

existed during the Middle Ordovician. Four of the five studied sections Evan's Ferry, Cedar Springs, St. Clair and Silver City constitute a transect located in the northern part of the study area. (See Figure 5 on page 16.) This transect trends roughly perpendicular to the northeast-southwest trending strike belts and ranges from shallow carbonate platform sediments in the northwest to deep basinal terrigenous sediments in the southeast. The fifth studied section, in Raccoon Valley, is located in the same strike belt as the Evan's Ferry section (the St. Paul belt) both being bounded on the southeast by the Copper Creek fault. The Raccoon Valley section is not part of the northern transect but is included in this study for better temporal and spatial control of the trilobite data from the sequence.

A preliminary bathystratigraphic interpretation (Figure 14) of the northern transect has been constructed which shows the inferred depths recorded by the lithologies present. The northwesternmost section in the transect is Evan's Ferry (EF). This section represents a near shore environmental complex with typical shallow carbonate platform lithologies and formations. The Cedar Springs (CS) section, to the southeast of Evan's Ferry, consists of these same lithologies and formations; however, the paleobathymetry is inferred to have been shallower in general than at Evan's Ferry. The Cedar Springs section represents an area closer to the shelf edge and may record a possible topographic high during the Middle Ordovician.

The next section southeastward, Red Hill Branch (RHB), is not treated in this study. This section represents a complex pattern of

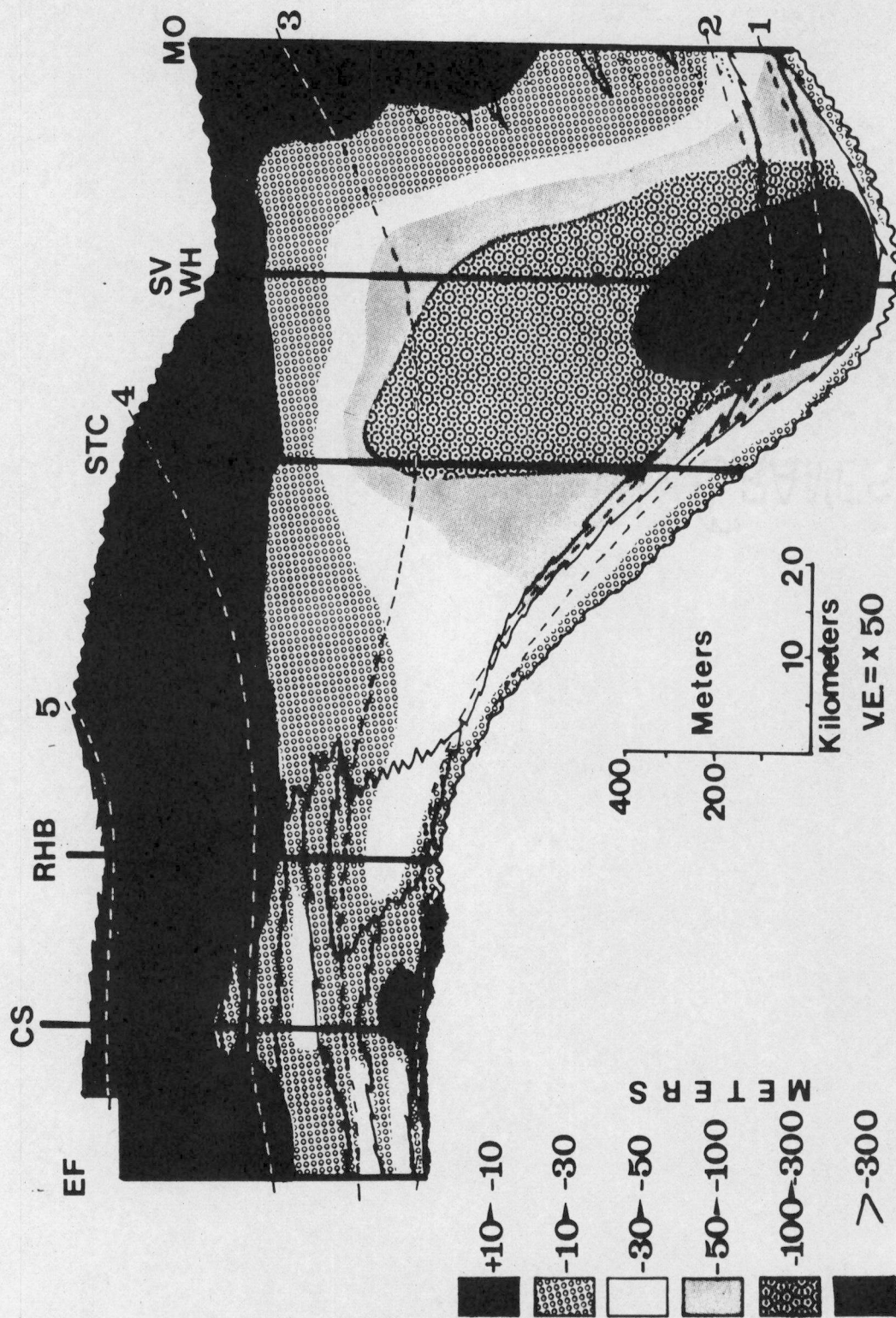


Figure 14. Bathymetric cross section of the northern transect.

shelf edge facies which marks the transition from shallow platform lithologies to deeper water slope and basin lithologies (Ruppel, 1979). The fourth section, St. Clair (St. C), is different in many respects from the sections northwest of it. Here are only rare shelf lithologies at the base of the section (the Mosheim and Asbury members of the Lenoir Formation); most of the section consists of the slope and basinal Blockhouse and lower Sevier formations. The uppermost part of the Sevier is considered to be shallow terrigenous platform material representing the culmination of the filling of the Sevier Basin with clastics from the south and southeast. Silver City (SV) the southeasternmost section studied is much like St. Clair except that it contains much less Lenoir and a much greater thickness of the slope material of the Whitesburg Formation.

The final and southeasternmost section of the transect is the stratigraphic section at Mosheim (MO). It is not dealt with in depth in the present study (see Benedict, in prep.) and represents an area of deposition more proximal to the terrigenous clastics source than any of the other sections within the northern transect. A bathystratigraphic cross section of the transect in which the Raccoon Valley section is located is given in Benedict and Walker (1978, Figure 6, page 17). The Raccoon Valley (RV) section is much like the Evan's Ferry section except that paleoenvironments represented by the Benbolt Formation attained deep subtidal water depths during deposition.

All of the sections discussed above are characterized by (1) an unconformity underlain by the Knox Group at the base of the section,

(2) a transgressive-regressive event and (3) an influx of terrigenous clastics at the top of the section. The unconformity is the post-Knox unconformity which represents an emergence and erosion of the Knox Formation during the Early Ordovician in the study area and elsewhere. The transgression within the study area marks the initiation of the subsidence of the Sevier Basin and peribasinal carbonate platform environments further discussed by Benedict and Walker (1978). The next event was a major regression recorded in the lithologies of all five studied sections. This transgression-regression was brought about by a time lag, which probably existed between the subsidence of the Sevier Basin and the late arrival of sediments into the starved basin, discussed by Benedict and Walker (1978). The sediments that filled the Sevier Basin are thought to have had their source in highlands that existed to the south and southeast (Benedict and Walker, 1978; Berry, 1974a, 1974b; and Walker and Laporte, 1970).

Generic Composition of the Trilobite Assemblages

Five trilobite assemblages have been recognized within the study area. These are the Illaenid, Asaphid, Pliomerid, Raphiophorid-Remopleurid and Harpid assemblages. The Illaenid Assemblage is represented by the genera Illaenus, Nanillaenus and Bumastus. The Asaphid Assemblage is almost entirely represented by the genus Isotelus and rarely by Homotelus and Isoteloides (?). The Pliomerid Assemblage is characterized by the genus Pliomerops and the genus Pilekia only rarely. The Raphiophorid-Remopleurid Assemblage consists of the genera

Lonchodomas, Ampyx, Ampyxina and Robergia. The fifth and final assemblage is the Harpid Assemblage which is represented by the genera Dolichoharpes and Paraharpes. Other genera are found within the study area, including Cybeloides, Encrinurus, Ceraurinella, Ceraurus, Sphaerexochus, Calyptaulax and Eomomorachus. These genera have not been assigned to any one assemblage because, in general, they occur with all of the shelf assemblages to various degrees or are extremely rare. Encrinurus, however, appear to be more closely related in occurrence stratigraphically with the Asaphid Assemblage in most cases. The genus Calyptaulax appears to be analogous in part to the pelagic early Ordovician assemblage discussed by Fortey (1975) which consists largely of the trilobite genus Carolinites. This is, in part, supported by the ubiquitous nature of Calyptaulax in the shelf environments.

Paleogeographic and Paleobathymetric Distribution of the Trilobite Assemblages

After the generic composition of the assemblages was determined, the stratigraphic distribution of these assemblages was plotted on the cross section of the northern transect. The plotted occurrences of these assemblages mark the stratigraphic intervals in which the given assemblage constitutes a major percent of the trilobites present in that interval. By plotting the occurrences of the trilobite assemblages on the stratigraphic cross section of the northern transect, certain relationships may be seen among the paleogeographic and paleobathymetric positions of the assemblages through time. In the following discussion

of the positions of the assemblages through time Figures 15, 16, and 17 are used for reference. The time lines employed in this treatment are discussed in Walker (1977, Appendix 1) and Benedict and Walker (1978), and are based on biostratigraphic and physical or lithologic criteria.

Prior to the time represented by time line one (T_1) the illaenids (Figure 15) were located in the shallow subtidal portion of the Lenoir Formation of the St. Clair section. With the subsidence of this area and the formation of the Sevier Basin, at T_2 , the illaenids were no longer indigenous to this section. They are, however, found rarely in the Lincolnshire Formation of the Cedar Springs section at time T_2 . No specimens (identifiable at the generic level) were collected from the Lincolnshire at Cedar Springs; however, illaenid fragments are present in the formation at that locality. By the time represented by line T_3 , the Illaenid Assemblage was dominant in the Lincolnshire and Rockdell formations at Cedar Springs and in the Rockdell of the Evan's Ferry section. With the continued transgression of the platform environments between the times of lines T_3 and T_4 , the dominance of the Illaenid Assemblage became restricted mainly to the Benbolt of Evan's Ferry. The regression of the shelf environments began just prior to the time represented by line T_4 in this transect. This regression is accompanied by an expansion of the paleogeographic extent of the Illaenid Assemblage. By T_4 the illaenids occupy the Wardell, Bowen and Witten of the Cedar Springs and the Wardell and Witten of the Evan's Ferry section.

The Asaphid Assemblage (Figure 15) is found in the Lenoir Formation at Silver City and St. Clair immediately prior to the time represented

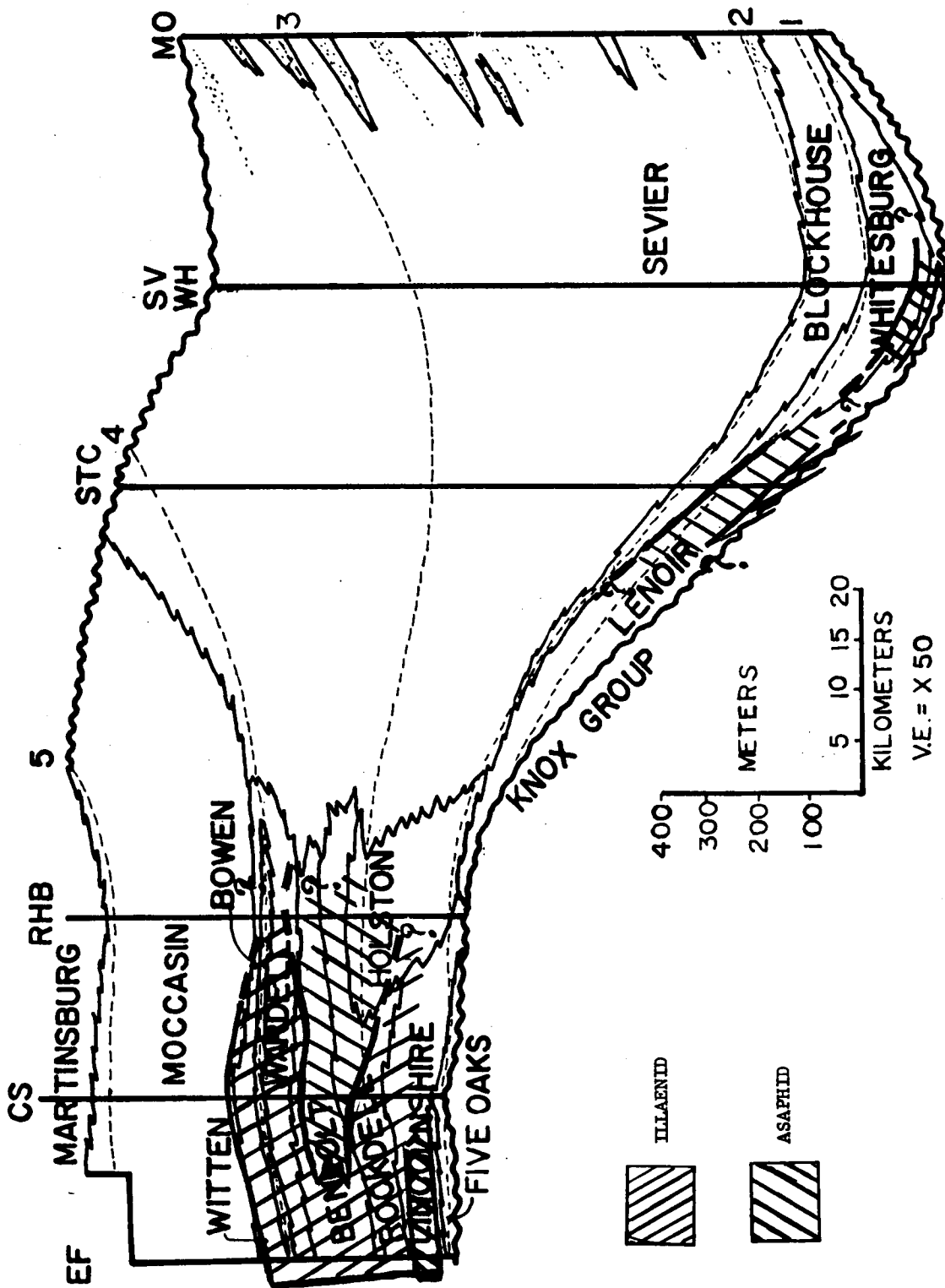


Figure 15. Stratigraphic positions of the Illaenid and Asaphid assemblages.

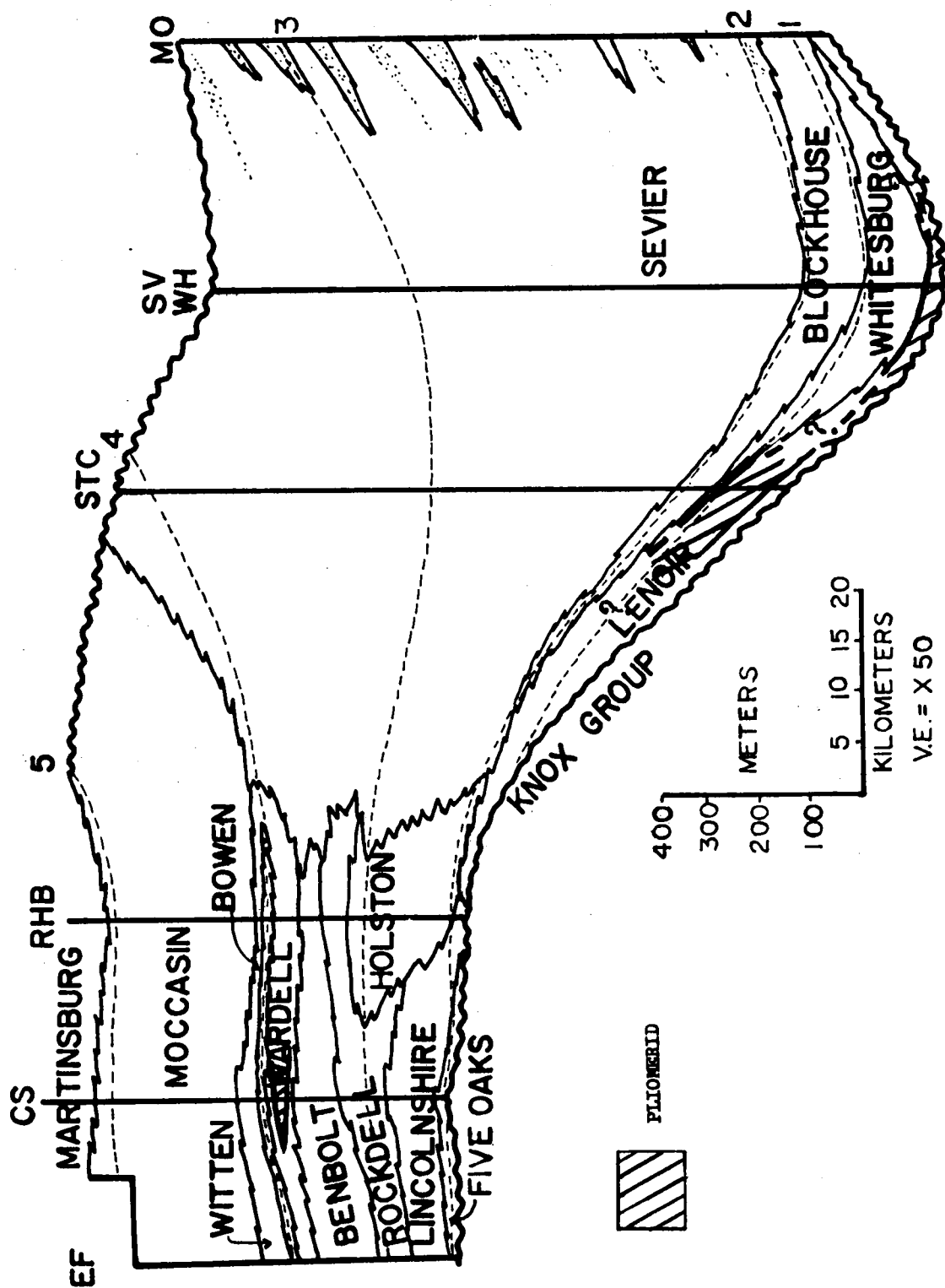


Figure 16. Stratigraphic positions of the Pliomerid Assemblage.

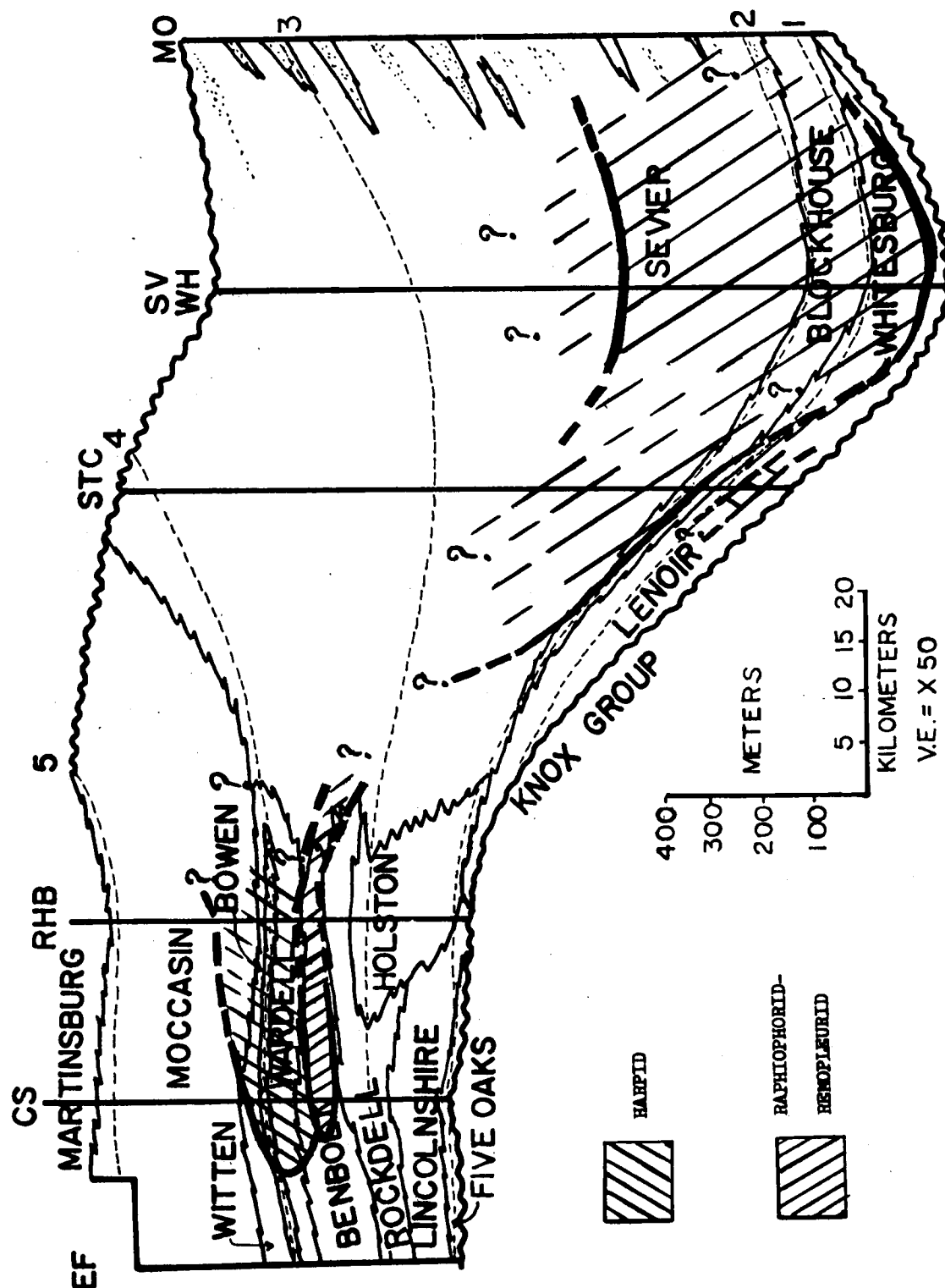


Figure 17. Stratigraphic positions of the Harpid and Raphiophorid-Remopleurid assemblages.

by line T_1 . By the time represented by line T_1 , this assemblage is found only in the upper Lenoir of the St. Clair section. The subsidence of the Sevier Basin is very marked by the time represented by time line T_2 . Between T_2 and T_3 , the Asaphid Assemblage is found only in the Lincolnshire of the Evan's Ferry section. This change in the position of the Asaphid Assemblage records a shift towards the northwest away from the area of major subsidence. Between the times represented by lines T_3 and T_4 , when maximum transgression had been attained in the Cedar Springs section, the Asaphid Assemblage is found here in the middle Benbolt Formation. By the time of line T_4 when regression or shallowing and consequential reduction and exclusion of the deeper water environments was the rule in the Sevier Basin and peribasinal environments, the Asaphid Assemblage was no longer a dominant element in any stratigraphic interval of any of the studied sections. This geographic shifting and final reduction of the Asaphid Assemblage is interpreted to represent an attempted survival response to the initial westward shift and final exclusion of the suitable niches for habitation by the asaphids. The availability of these niches was apparently changing in this area during the Middle Ordovician caused mainly by the eustatic change in sea level and/or the influx of the terrigenous clastics from the south and southeast across the Sevier Basin.

The Pliomerid Assemblage (Figure 16) is found in the upper Lenoir of the Silver City and St. Clair sections before the time represented by time line T_1 . By the time represented by T_2 , the Pliomerid Assemblage is found only in the upper Lenoir of St. Clair. This assemblage is not

present after T_2 in the studied sections except for its rare occurrence in the Wardell Formation of the Cedar Springs section between T_3 and T_4 . Perhaps this reduction and final exclusion from the study area during the downwarping of the Sevier Basin suggests an inability of the pliomorids to adapt to the changing niches of the evolving basin.

With the continued subsidence of the Sevier Basin, the three previously established assemblages (Illaenid, Asaphid and Pliomerid) were gradually displaced northwestward and finally almost completely replaced by two new assemblages which were probably introduced from the south and southeast. These newly introduced assemblages are the Raphiophorid-Remopleurid Assemblage and the Harpid Assemblage. The Raphiophorid-Remopleurid Assemblage (Figure 17) is found in the study area just before the time represented by time line T_1 mainly in the Whitesburg Formation of the Silver City section. This section appears to have been an area of major subsidence in the Sevier Basin. By the time of T_2 , this assemblage had expanded into the uppermost Lenoir and Blockhouse formations of the St. Clair section as well as the Blockhouse Formation of the Silver City section. By the time represented by time line T_3 , the Sevier Basin was beginning to ahallow as a result of the influx of terrigenous clastics from the south and southeast, and the Raphiophorid-Remopleurid Assemblage began to be replaced by the Harpid Assemblage in the Ottosee Formation of the area south of the Raccoon Valley section. The upper Sevier of the northern transect in the Silver City and St. Clair sections represents a shallow terrigenous platform much like the upper Sevier south of the Raccoon Valley section.

The major transgression of the seas and the accompanying deeper water environments moving over the previous shelf environments during the Middle Ordovician in the study area culminates in the middle Benbolt in the Cedar Springs section. The Raphiophorid-Remopleurid Assemblage is found in the middle Benbolt in the Cedar Springs section which was deposited between the times represented by time lines T_3 and T_4 . This occurrence probably represents the greatest northwestward advance of the Raphiophorid-Remopleurid Assemblage upon the carbonate shelf into an environment which has been inferred to have been deepest subtidal. The genus Lonchodomas found in the middle Benbolt is interpreted as having been the uppermost slope representative of this assemblage.

The occurrence of the Harpid Assemblage (Figure 17) in the northern transect appears to be mainly in a narrow stratigraphic interval which includes the Bowen Formation. The Bowen Formation represents the first major influx of terrigenous clastics from the south and southeast onto the carbonate platform. Time line T_4 has been placed within the Bowen in the northern transect. The same Harpid Assemblage occurs in the southern portion of the study area at Raccoon Valley within the Benbolt between time lines T_2 and T_3 . The Harpid Assemblage is present in the upper Benbolt, Wardell, Bowen and Witten of the Cedar Springs section just before, during and after the time represented by time line T_4 . This observation indicates that the Harpid Assemblage occurred first in the southern portion of the study area and then invaded northwestward into the northern portion. Areas southeast of the Raccoon Valley section record an influx of the harpids in great numbers in the terrigenous

environments of the upper Sevier and Ottossee formations deposited during the time between the times represented by lines T_2 and T_3 . The harpids were probably adapted to the shallow terrigenous clastic environment which existed around the newly emergent area on the south and southeast margins of the Sevier Basin. As the shallow clastic environment spread across the Sevier Basin to the northwest, trilobites endemic to the near shore terrigenous clastic environment of the southeast migrated with the environments. Changes in food webs, and changes in substrate and other parameters which accompanied the clastic influx will be examined in the section on the paleoecology of specific trilobite genera.

Paleoecology of the Trilobite Genera

The illaenids are inferred to have been vagrant-benthos deposit feeding forms because of the large, relatively heavy exoskeleton that would tend to hinder any great mobility of the organisms such as that required in a nekto-benthic or pelagic mode of existence. Ludvigsen (1978) has inferred that some closely related genera such as Bumastoides and Nanillaenus were burrowing types adapted to carbonate mud substrates.

The isotelids appear to have been vagrant-benthos deposit feeders which were shallow burrowers as well. A closely allied genus Anataphrus which has the same general exoskeleton dimensions and ratios of the genera present here (Isotelus, Homotelus and Isoteloides) has been found in what has been inferred to be a burrowing position with its cephalon horizontal and its thorax directed vertically down into the substrate (Finch, 1904).

Genera such as Ceraurus, Ceraurinella, Sphaerexochus, Cybeloides, Encrinurus, Calyptaulax and Eomonorachus have much greater skeletal surface to substrate contact area than the illaenids and isotelids. This increase in surface contact area is interpreted as being an adaptation for staying afloat on the highly fluid substrates in the deeper subtidal environments (Ludvigsen, 1978). This interpretation of epifaunal habit is also suggested by (1) presence of pygidial spines, (2) presence of large genal spines, (3) a decrease in overall size and (4) increased numbers of thoraxial segments. Dolichoharpes and Paraharpes bear long, broad and flat lower lamellae which would probably allow members of these genera to survive and move about on rather fluid substrates.

Most of the trilobite genera discussed above appear to have been restricted to specific types of substrate. The genus Calyptaulax (and the cheirurids to a lesser extent) appear not to have been restricted from any of the environments except the supratidal, intertidal and deeper basinal environments. The same characteristic of Calyptaulax was noted by Ludvigsen (1978). As has been mentioned previously in this report, Calyptaulax is thought by the author to have been nekto-benthic or nekctic in habit; it is present in most of the carbonate platform environments within the study area. Ludvigsen (1975) has proposed a nocturnally active, predatory life for this genus, partly because the schizochroal eyes are better adapted to dim light and better optical resolution for movement perception.

The genus Robergia is interpreted as having been a nekto-benthic form (personal communication, Benedict, 1979). This genus is found in the lithologies of the Sevier Formation which represent basinal environments and yet it bears large, well-developed eyes. The numerous thoracic segments of Robergia indicate the presence also of numerous feather-like appendages known as exites. As is noted by Levi-Setti (1975) and Harrington, in Moore (1959), these exites probably served as swimming structures. At the same time, these exites are thought to have functioned as gills in the trilobites. Numerous gills would have no doubt aided in the ability for Robergia to inhabit the basin environments where oxygen tension may have been low at times.

Lonchodomas, Ampyx and Ampyxina are interpreted as having been pelagic trilobites (personal communication, Benedict, 1979). The characteristically small and delicate exoskeleton of these genera would lend support to this hypothesis. These trilobites were eyeless and, therefore, would have had difficulty in competing for food acquisition with the shallow platform trilobites such as Calyptaulax. As is suggested by Cook and Taylor (1975) in studies elsewhere the endemic shelf faunas were also probably separated from the slope and basin genera by the position of a permanent thermocline. Shelf faunas were better adapted to the environments in which the water temperature varied with the seasonal atmospheric temperatures, whereas water temperatures below the permanent thermocline were more or less low and stable. The genera Lonchodomas, Ampyx and Ampyxina which are found in slope and basinal lithologies probably were better adapted, therefore, to the

cold water basin environments from which the platform genera appear to have been excluded entirely. The raphiophorids may have been suspension feeders suggested by the lack of organic detritus and algae on the basin substrate and the marked increase in the abundance of plankton mentioned by Berry (1974a). Most of the available nutrients were probably in the water mass at or near the surface as phytoplankton and zooplankton. The availability of plankton greatly increased in the Middle Ordovician as a response to the greater availability of nutrients which probably accompanied the clastics which were derived from the south and southeast of the study area (Berry, 1974a).

In summary, it appears as though three recognizable assemblages were initially present in the study area. These are the Illaenid, Asaphid and Pliomerid assemblages. The area was a shallow carbonate platform on the eastern margin of the North American craton. The assemblages were largely present in the shallow subtidal and deep subtidal carbonate environments of the platform. Many of the genera were vagrant-benthic, infaunal and epifaunal deposit feeders. Some of the genera present were probably nekto-benthic scavengers or predators such as the genus Calyptaulax. The illaenids mainly inhabited the shallow subtidal platform environments, while the asaphids, pliomerids and their associated genera were mostly indigenous to the deep subtidal environments.

With the formation of the Sevier Basin and the terrigenous uplands to the south and southeast of the basin, two new assemblages migrated into the region. The Raphiophorid-Remopleurid Assemblage was adapted

to a cold water, open marine pelagic existence and soon became widespread within the Sevier Basin deep water environments. The filling of the Sevier Basin by an influx of terrigenous sediments which spread onto the carbonate platform and, possibly was accompanied by a change in the food source available in this area, occurred next. A planktonic food source as well as a clastic substrate were probably characteristic of the shallow terrigenous platform environments which bordered the uplands to the south and southeast of the developing Sevier Basin. The shifting of a shallow water terrigenous environment northwest across the basin as the latter slowly filled was accompanied by the migration of the Harpid Assemblage which was endemic to the near shore, shallow water terrigenous environment around the uplands. The combination of terrigenous clastic influx and trilobite migration from the south and southeast resulted in the reduction and finally exclusion of many of the niches previously inhabited by the other four assemblages in almost all parts of the study area.

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APPENDICES

APPENDIX A

PREPARATION OF SAMPLE MATERIAL

Cleaning

Many of the collected specimens were partly encased in matrix. These specimens were freed from the matrix by using various methods. The first step, if necessary, was trimming unneeded matrix away with either a hammer and chisel or a trim saw. An electric vibro-engraver was commonly used to trim away matrix after soaking the specimen in a water bath for a period of 10 to 24 hours. This soaking procedure tended to loosen some of the calcareous and clayey matrix from around the specimen. For still more delicate work, an S.S. White air abrasive unit was used to abrade the final matrix away from the surface of the specimens.

Photography and Plate Preparation

The specimens were then prepared for photographing by coating them with sublimate of ammonium chloride using the method of Teichert (1948). Each specimen was oriented in the same position as it would appear in the plate and coated from the upper left-hand side of the specimen. Specimens were photographed using a 35 mm S.L.R. camera equipped with a bellows and using Kodak Panatomic-X film and printed on Kodabromide Polycontrast F paper.

APPENDIX B

SECTION LOCALITIES

Table B-1. Thesis Area Section Localities.

Section	Descriptive Location	Latitude/Longitude
Evan's Ferry	In Dry Valley on U.S. Hwy. 25E, 9.2 miles north of the U.S. Hwy. 25E/U.S. 11W junction	36° 23' 30" Lat. 83° 27' 00" Long.
Cedar Springs	Turn north onto Cedar Springs Church Rd. Off U.S. Hwy. 131, 2.9 miles east of the U.S. Hwy. 131/U.S. Hwy. 25E junction. Cedar Springs section in field on west side of the C.S. Church Rd. Base of section at C.S. Church.	36° 22' 30" Lat. 83° 22' 30" Long.
St. Clair	On Hwy. 113, 1/4 mile east of town of St. Clair, in fields and quarry on south side of road	36° 19' 30" Lat. 83° 04' 30" Long.
Silver City	1/2 mile south of town of Silver City on road to state fish hatchery in field on hill on northeast side of road	36° 12' 45" Lat. 83° 10' 00" Long.
Raccoon Valley	In Raccoon Valley on no. & so. sides of R.V. Rd., east of I-75. Base of section at Stanely Cem.	36° 00' 00" to 36° 15' 00" Lat. 83° 52' 30" to 84° 52' 30" Long.

APPENDIX C

SYSTEMATIC PALEONTOLOGY

The following is a taxonomic discussion of all of the trilobite genera which are represented in this report and of the material collected from within the study area. A total of 538 specimens, not including the specimens from the Silver City section, were used in this study. (For diagnostic features of higher taxa, see Moore, 1959.)

CLASS TRILOBITA Walch

ORDER PTYCHOPARIIDA Swinnerton

SUBORDER PTYCHOPARIINA Richter

SUPERFAMILY REMOPLEURIDACEA Hawle and Corda

FAMILY REMOPLEURIDIDAE Hawle and Corda

SUBFAMILY REMOPLEURIDINAE Hawle and Corda

GENUS ROBERGIA Wilman

*(Plate 2, Figures 31, 32; Figure 7, page 20, Item 1)

Description. Length of eye lobes (exsagital) less than 1/2 of cephalon (sagital); glabella narrow posteriorly, expanding between eye

*Refers to plates at end of Appendix and to Figures previously mentioned (e.g., Figure 7, page 20, Item 1).

lobes, glabellar tongue long (sagital) and broad (transverse); three pairs of deep lateral furrows present; with narrow cephalic border and doublure anteriorly and laterally; genal spines originating opposite midpoint of eye lobes; posterior sections of facial sutures running out to posterolateral corners of fixigenae. Thorax of 11 segments; pleurae transversely directed, terminating in small posteriorly directed spines, with deep diagonal pleural furrows. Pygidium with length about equal to width axis extending close to posterior margin; pleural fields flat, with three pairs of pleural furrows and posterior spines. (Whittington, in Moore, 1959, p. 0 327-238)

Material. Numerous specimens of Robergia were used in this study; exact abundance numbers are not available, however. All of the Robergia specimens were collected from the Silver City section. [Refer to Benedict dissertation (in prep.) for more quantitative data concerning this genus.] Material comes from the Blockhouse Formation of the Silver City section and consists mostly of glabellae and pygidia; whole specimens were rare. All specimen were preserved as either molds or casts.

R. sp.

(Plate 2, Figures 31, 32)

Description. Length of eyes one-third length of cephalon; three pairs of deep lateral furrows present. Thorax with 11 segments, terminating in small, posteriorly directed spines. Pygidium with flat pleural fields and short posterior spines.

Material. Same as under the Robergia generic Material discussion.

SUBORDER ASAPHINA Salter

SUPERFAMILY ASAPHACEA Burmeister

FAMILY ASAPHIDAE Burmeister

SUBFAMILY ISOTELINAE Angelin

GENUS ISOTELUS DeKay

(Plate 2, Figures 12, 17, 18, 19; Figure 7, page 20, Item 2)

Description. Cephalon and pygidium mostly with poorly defined flattened border. Frontal area moderately long, cephalic axis ill defined, almost obsolete in several species, slightly expanding in front of medium-sized eyes situated somewhat behind transverse midline of cranidium; no posterior border furrow; genal angles rounded, pointed, or with short genal spines. Hypostoma almost parallel-sided, posterior margin with broad (transverse), deep notch; anterior lobe short. Thoracic axis considerably broader than pleurae. Pygidial axis broad, poorly defined, almost obsolete in several species; pleural fields smooth or very faintly ribbed. (Jaannusson, in Moore, 1959, p. 0 339)

Material. A total of 131 specimens (32 cephala, 63 pygidia, 6 hypostomae, 22 cranidia and 8 librigenae) of the genus Isotelus was collected and used in this study. Isotelus was collected from the Evan's Ferry section in the Eidson, Hogskin, Rockdell and Benbolt formations.

In the Cedar Springs section Isotelus was collected from the Benbolt, Wardell, and Bowen formations. Isotelus was collected from the Lenoir at the St. Clair section and the Lenoir and Whitesburg formations at the Silver City section. The Raccoon Valley section yielded Isotelus from the Benbolt formation. Most of the specimens were silicified; the remaining specimens were preserved as original unaltered hard parts.

I. sp.

(Plate 2, Figures 17, 18)

Description. Cephalic axis indistinct or not present; eyes large and situated posteriorly of cephalic (transverse) midline; genal spines short or absent altogether. Cranidium with greatly constricted borders at eye notches; margins expanding forward. Hypostoma with nearly parallel sides, almost flat; with deep notch in posterior border. Pygidium smooth with pleural furrows obsolete or nearly so.

Material. A total of 126 specimens (27 cephalae, 63 pygidia, 22 cranidia and 8 librigenae) was collected. For localities of collected specimens refer to the Isotelus generic Material discussion.

I. copenhagenensis Ross and Shaw

(Plate 2, Figure 12)

Description. Eyes of cephalon erect and nearly one half of total height of each librigena in lateral view. Surface ornamentation consists of fine pits. Anterior branch of facial suture diverging only slightly anterolaterally so that sides of cranidium are nearly parallel.

Material. Three recognizable cephalons were collected from the Upper Eidson Formation at Evan's Ferry.

I. iowensis (Billings)

(Plate 2, Figure 19)

Description. The cephalon is characterized by short genal spines which become nearly parallel posteriorly. The cephalon is very complex, lacks surface ornamentation. Facial sutures are indistinct and eyes are moderately large.

Material. Two recognizable cephalons were collected from Evan's Ferry: one from the lower Rockdell, and the other from the lower Benbolt.

GENUS HOMOTELUS Raymond

(Plate 2, Figure 9; Figure 7, page 20, Item 3)

Description. Cephalon without trace of border; cephalic axis poorly defined, expanding in front of eyes; no frontal area, glabella reaching cephalic margin; eyes of moderate size, slightly in front of transverse midline of cranidium; no posterior border furrow; genal angles pointed in type species. Hypostoma as in Isotelus. Thoracic axis about twice width of pleurae in dorsal view. Pygidium with narrow, poorly defined, flattened border; axis wide (transverse) anteriorly, comparatively well defined, pleural fields smooth. (Jaanusson, in Moore, p. 0 341)

Material. One Homotelus specimen was collected from the Benbolt Formation of the Evan's Ferry section.

H. sp.

(Plate 2, Figure 9)

Description. Pygidium slightly convex, indistinct pleurae; poorly defined axial region, broad and flattened.

Material. Refer to Homotelus discussion of Material.

GENUS ISOTELOIDES Raymond

(Plate 2, Figure 15; Figure 7, page 20, Item 4)

Description. Cephalon and pygidium with well-defined, flattened border; frontal area moderately long, in type species slightly shorter than 0.25 of total length of cephalon; glabella rather well defined, slightly expanding in front of moderately large eyes situated at about transverse midline of cephalon; faint posterior border furrow may be present; genal angles produced into spines. Hypostoma in type species with broadly rounded lateral margin and broad (transverse) notch in posterior margin. Thoracic axis about as broad as pleurae. Pygidial axis rather well defined, moderately broad; pleural fields in type species with faint ribs. (Jaanusson, in Moore, p. 0 341)

Material. Two silicified Isoteloides pygidia were collected for this study. They were taken from the Evan's Ferry section in the Eidson Formation.

I. sp.

(Plate 2, Figure 15)

Description. Pygidium convex with well-defined, flattened border; pleural regions distinct; axis broad and flattened.

Material. Refer to Isoteloides discussion of Material.

SUBORDER ILLAENINA Jaanusson

SUPERFAMILY ILLAENACEA Hawle & Corda

FAMILY ILLAENIDAE Hawle & Corda

SUBFAMILY ILLAENINAE Hawle & Corda

GENUS ILLAENUS Dalman

(Plate 1, Figures 3, 6, 8; Figure 7, page 20, Item 5)

Description. Thorax with 10 segments. Eyes of moderate size. Rostral flange long, hourglass shaped. Anterior wings of hypostoma broad (transverse), quadrangular. Pygidium about as large as cephalon or slightly smaller, axis short, narrowing toward rear. (Jaanusson, in Moore, 1959, p. 0 372)

Material. Illaenus is represented in this study by 50 specimens (24 cephalo, 24 pygidia, 1 hypostoma and 1 librigena). Specimens were collected from the Hogskin, Rockdell, Benbolt and Wardell formations at the Evan's Ferry section. At the Cedar Springs section Illaenus was

collected from the Lincolnshire, Rockdell, Benbolt, Wardell, Bowen and Witten formations. Only the Lenoir Formation yielded Illaenus at the St. Clair section.

I. sp.

Description. Cephalon convex with glabellar furrows very indistinct, eyes moderately large; glabella expanding anteriorly of eyes. Pygidium convex, smooth or with very faint terraced lines.

Material. Illaenus sp. is represented in this study by 21 cephalae, 24 pygidia, 1 hypostoma and 1 librigena. For collection localities of the specimens refer to Illaenus discussion of Material.

I. angusticallis Billings

(Plate 1, Figure 8)

Description. Dorsal furrows over one-half total length of cephalon. Cephalon slightly convex, eyes large and prominent. Surface of cephalon finely punctate.

Material. Two identifiable cephalae were collected from the lower Benbolt at Evan's Ferry.

I. crassicauda Wahlenberg

(Plate 1, Figures 3, 6)

Description. Cephalon with short dorsal furrows, eyes small and reach posterior margin. Cephalon very convex and smooth surfaced.

Facial sutures are parallel in dorsal view with librigenae inflated and genal angles rounded.

Material. One identifiable cephalon was collected from the upper Benbolt at Evan's Ferry.

GENUS NANILLAENUS Jaanusson

(Plate 1, Figures 4, 7, 9, 11, 13; Figure 7, page 20, Item 6)

Description. Thorax with eight segments. Pygidium considerably smaller than cephalon, axis well defined, longer than postaxial field. Eyes of moderate size; posterior parts of cephalic axial furrows converging forward. Rostral shield and hypostoma unknown. (Jannusson, in Moore, 1959, p. 0 373)

Material. Sixty-two specimens (6 cephalae and 56 pygidia of Nanillaenus were collected. Specimens were collected from the Rockdell, Benbolt and Wardell formations at Evan's Ferry. The Cedar Springs Lincolnshire, Benbolt, Wardell and Witten formations also yielded specimens of Nanillaenus. The Rockdell and Benbolt formations at Racoon Valley also yielded several specimens. Almost all of the specimens were preserved as original, unaltered hard parts; very few specimens were preserved as molds.

N. sp.

Description. Cephalon length is less than one-half width, eyes moderately large, glabellar furrows indistinct. Pygidium flattened, as well as axial region; lateral borders converging slightly anteriorly.

Material. Five cephalae and 45 pygidia (some with thoracic segments attached) were collected from the study area. For localities of collected specimens, refer to Nanillaenus discussion of Material.

Nanillaenus conradi (Billings)

(Plate 1, Figures 4, 11, 13)

Description. Genal angles not extended as in other species of this genus (e.g., N. punctatus). Dorsal furrows converge anteriorly and become obsolescent anteriorly. Cephalon length is one-half of cephalon width, glabella is indistinctly punctate. Pygidial posterior margin is semicircular in outline.

Material. Five recognizable pygidia and one cephalon were collected from the Cedar Springs and Evan's Ferry sections. At Cedar Springs two pygidia were collected from the lower Benbolt. At Evan's Ferry one cephalon and two pygidia were collected from the lower Benbolt and one pygidium from the upper Benbolt.

Nanillaenus latiaxiatus Raymond and Narraway

(Plate 1, Figures 7, 9)

Description. Cephalon length less than one-half width, strongly arched, dorsal furrows deep and become indistinct less than one-half distance to anterior margin of cephalon; they converge slightly for most of their length. Pygidial length to width ratio is 0.6 and the pygidium is rectangular in outline. Axial lobes on pygidium are strongly convexed.

The pygidium is marked by abrupt truncation of lateral extremities which are at nearly ninety degree angles with the anterior margins.

Material. Six recognizable pygidia were collected from Cedar Springs and Evan's Ferry. At Cedar Springs, one pygidium was collected from the lower Benbolt. At Evan's Ferry, three pygidia were collected from the lower Rockdell and two from the lower Benbolt.

SUBFAMILY BUMASTINAE Raymond

GENUS BUMASTUS Murchison

(Plate 1, Figures 5, 10, 12, 14, 15; Figure 7, page 20, Item 7)

Description. Thorax with 8 to 10 segments; axis very broad, axial furrows poorly defined. Pygidal axis furrows generally not developed. (Jannusson, in Moore, p. 0 374)

Material. Bumastus is represented by 113 specimens, including 92 cephalae, 20 pygidia and 1 complete specimen. Specimens assigned to the genus were collected from the Hogskin, Rockdell, Benbolt, Wardell and Witten formations at Evan's Ferry. The Lincolnshire, Rockdell, Benbolt, Wardell, Bowen and Witten formations at Cedar Springs yielded specimens of Bumastus. Raccoon Valley yielded Bumastus from the Lincolnshire and Benbolt formations. The Bumastus specimens were preserved as original unaltered hard parts mostly; a few silicified specimens were collected.

B. sp.

(Plate 1, Figures 10, 12)

Description. Cephalon very convex, eyes moderately small; glabellar furrows extending over one-half length of cephalon. Pygidium very convex, nearly as long as wide.

Material. Bumastus is represented by 107 specimens including 87 cephalata and 20 pygidia. For localities of collected specimens, refer to Bumastus discussion of Material.

B. bellevillensis Raymond and Narraway

(Plate 1, Figure 5)

Description. Cephalon very arched, incurved, very wide with small, distinct, dorsal furrows ending one-half distance from posterior to anterior margins of cephalon in relatively deep outcurved lunettes.

Material. Four identifiable cephalata were collected at Cedar Springs and Evan's Ferry. One cephalon was taken from the lower Benbolt and one from the upper Witten at Cedar Springs. At Evan's Ferry one cephalon was taken from the lower Rockdell and one from the lower Benbolt formation.

B. indeterminatus (Walcott)

(Plate 1, Figures 14, 15)

Description. Genal angle rounded, cephalon circular in outline anteriorly. The dorsal glabellar furrows are arcuate; converging and

then diverging anteriorly, not ending in lunate depressions. Furrows extending three-fourths of distance to anterior margin of cephalon.

Material. One cephalon and one nearly complete specimen were collected from Cedar Springs. The cephalon was collected from the lower Witten and the whole specimen from the upper Witten.

SUBORDER HARPINA Whittington

FAMILY HARPIDAE Hawle & Corda

GENUS DOLICHOHARPES Whittington

(Plate 2, Figures 11, 16; Figure 7, page 20, Item 8)

Description. Cephalon ovate in outline, strongly convex; glabella strongly convex, with short median and anterior lateral glabellar furrows; alae depressed below rest of genae; fringe with deep girder extending to tips of prolongations, genal roll and prolongation broad and vertical, brim narrow, with flat lower and concave upper lamellae; pits large, irregularly and closely spaced, with tendency to radial arrangement in brim; coarse reticulate ornament on external surface of glabella and genae (except posterior lobes and alae), merging into fringe; curved ridge on posterior glabellar lobes, smooth paired oval area between posterior and median lateral glabellar furrows. Hypostoma possesses deep and very oblique middle furrow and pointed posterior ring. Pygidium short, wide (transverse), with three or four distinct segments. (Whittington, in Moore, 1959, pp. 0 417-418)

Material. Eight specimens of this genus were collected from the study area for this report. Six lower lamellae and two almost complete specimens were collected. The Cedar Springs section yielded specimens of this genus from the Benbolt and Witten formations. This genus was also collected from the Lenoir Formation of the St. Clair section and Benbolt Formation of the Raccoon Valley section. The specimens collected were preserved by silicification and as molds.

D. sp.

(Plate 2, Figure 16)

Description. Cephalon very convex, as is glabella. Fringe with deep furrow, genal roll and prolongations broad and vertical, narrow brim, large pits on exterior, anterior border of fringe. Pygidium length one-half width.

Material. Seven specimens of Dolichoharpes sp. were collected for this study. For localities of collected specimens, refer to Dolichoharpes discussion of Material.

D. uniserialis (Raymond)

(Plate 2, Figure 11)

Description. Dorsal portion of fringe is inflated anteriorly, coarsely pitted with pits larger at external and internal margins.

Material. One specimen in which the glabella and lower lamellae were preserved, was collected from the lower Benbolt at Cedar Springs.

GENUS PARAHARPES Whittington

(Plate 2, Figure 21; Figure 7, page 20, Item 9)

Description. Outline of cephalon oval; glabella convex, carinate; alae large, not depressed; fringe with girder extending to tips of prolongation, brim flat, large pits in rows flanking the girder, along external margin, and on prolongations. Thorax with 23 to 25 segments. External surface of genae (not alae) with raised, radiating ridge.

Material. Six silicified specimens of Paraharpes including partial cephalon and lower lamellae. Specimens were collected from the Benbolt, Wardell and Witten formations at Cedar Springs.

P. sp.

(Plate 2, Figure 21)

Description. Cephalon oval, brim flat; large pits concentrated at anterior margin of alae near glabella.

Material. See Material discussion under Paraharpes.

SUBORDER TRINUCLEINA Swinnerton

FAMILY RAPHIOPHORIDAE Angelin

GENUS AMPYX

(Plate 2, Figure 26; Figure 7, page 20, Item 10)

Description. Glabellar spine long, upwardly curved, circular in cross section; with three pairs of ovate muscle scars on glabella,

fourth pair at extremities of occipital furrow; alae absent; genal spines circular in cross section. Thorax with six segments; pleural furrows deepening outward, last three pairs curving forward, concave toward front. Pygidium with two paired rows of muscle scars on axis; pleural fields with single pair of pleural furrows. External surface with fine pits, terraced lines on vertical borders and doublure.

(Whittington, in Moore, 1959, p. 0 426)

Material. Numerous specimens were collected for this study, but exact numbers are not available. All Silver City specimens are in the possession of G. L. Benedict. Refer to Benedict (unpublished dissertation, in prep.) for a more quantitative approach to this genus at the Silver City section. Many specimens were collected from the Blockhouse Formation at Silver City. Specimens were also collected from the Lenoir and Blockhouse formations at St. Clair. The material includes cephalae and pygidia preserved either as molds or casts.

A. sp.

(Plate 2, Figure 26)

Description. Glabellar spine long, round, curved upwards. Thorax with six segments. Pygidium with indistinct pleural furrows.

Material. Refer to Ampyx generic Material discussion.

GENUS AMPYXINA, Ulrich

(Plate 2, Figure 25; Figure 7, page 20, Item 11)

Description. No glabellar spine; alae large; rolled cephalic border narrow. Thorax with five segments. First longer (sagital, exsagital) than others; pleural furrows curving outward-backward. (Whittington, in Moore, 1959, p. 0 426)

Material. Many specimens of Ampyxina were collected for this research, however, exact numbers are not available. See Benedict (unpublished dissertation, in prep.) for a more quantitative approach and other related data for this genus. All specimens were collected from the Silver City section in the Blockhouse Formation and include cephalata and pygidia, preserved as molds.

A. sp.

(Plate 2, Figure 25)

Description. No glabellar spine. Pygidium with well-defined pleural furrows.

Material. Refer to Ampyxina generic Material discussion.

GENUS LONCHODOMAS Angelin

(Plate 2, Figures 19, 23; Figure 7, page 20, Item 12)

Description. Like Ampyx but glabella diamond shaped in outline, carinate, with long median glabellar spine which is subquadrate in

section directed horizontally; glabella with two pairs of muscle scars; genal spines subquadrate in section. Thorax with five segments. Pleural regions of pygidium with two pairs of narrow pleural furrows.

(Whittington, in Moore, 1959, p. 0 427)

Material. Numerous specimens were collected for this study. See Benedict for a quantitative approach to this genus (unpublished dissertation, in prep.). Numerous pygidia and cephalae collected from the Lenoir at St. Clair and the Lenoir, Whitesburg and Blockhouse formations at Silver City are preserved as either unaltered hard parts or as casts.

L. sp.

(Plate 2, Figures 19, 23)

Description. Glabellar spine hollow, diamond shaped in outline, slightly tortioned in many specimens. Two pleural fields indistinctly defined on pygidium.

Material. Refer to Lonchodomas generic Material discussion.

ORDER PHACOPIDA Salter

SUBORDER CHEIRURINA Harrington and Leanza

FAMILY CHEIRURIDAE Salter

SUBFAMILY CHEIRURINAE Salter

GENUS CERAURINELLA Cooper

(Plate 2, Figures 2, 7; Figure 8, page 21, Item 1)

Description. Cheirurid trilobite with subquadrate glabella expanding forward anteriorly; anterior portion of fixigenae narrow, short genal spines, and deeply depressed diagonal pleural furrows. Eyes opposite 2p (i.e., second lobe of glabella from posterior) lobes. Pygidium with pair of long outer axially recurved granulose spines which originate from first pygidial pleura. Second pygidial pleura bears short, granulose spines. Glabella and fixigenae covered with fine to coarse tubercles. Surface granulation relatively fine in comparison with other ceraurids. (Modified from Henningsmoen, in Moore, 1959, p. 0 432; Cooper, 1953)

Material. Eleven specimens (9 cephalae and 2 hypostomae) were collected from the study area for this research. This genus was collected from the Eidson and Hogskin formations at Evan's Ferry. The Wardell of Cedar Springs also yielded specimens of this genus, as did the Benbolt Formation at Raccoon Valley. The specimens were preserved either as molds or silicified.

C. sp.

(Plate 2, Figure 7)

Description. Subquadrate glabella expanding forward, with short genal spines; surface of cephalon finely granulose. Hypostoma finely pitted, ovoid in outline.

Material. Seven cephalae and two hypostomae were collected. For collection localities of specimens, refer to Ceraurinella generic discussion.

C. typa Cooper

(Plate 2, Figure 7)

Description. Anteriorly, fixigenae narrow, palpebral lobes opposite 2p lobes (lobes positioned second from posterior). The 1p lobes (positioned first from the posterior) are of even width. The 2p lobes are narrower distally and wider proximally to glabella. Fixigenae are tuberculate. Occipital ring evenly granulose but tubercles are concentrated toward lateral extremities. The occipital ring is highly arched dorsally. Posterior branch of facial suture is almost subparallel with the posterior marginal furrows of the cephalon.

Material. Two identifiable silicified cephalae were taken from the upper Eidson Formation at the Evan's Ferry section.

GENUS CERAURUS Green

(Plate 2, Figures 6, 8; Figure 8, page 21, Item 2)

Description. Glabella expanding forward, with three pairs of short lateral furrows; eyes set well away from glabella, opposite 3p; fixigenae with long genal spines. Thoracic segments generally 11. Pygidium with long pair of axially recurved pleural spines from anterior segment. Surface tuberculation coarse. (Henningsmoen, in Moore, 1959, p. 0 433)

Material. A total of 17 specimens (13 cephalae, 2 librigenae and 2 pygidia) of Ceraurus was collected for this study. Ceraurus was collected from the Eidson, Rockdell and Benbolt formations at the Evan's Ferry section, and from the Witten Formation at Cedar Springs. The specimens were preserved mainly by silicification.

C. sp.

(Plate 2, Figure 8)

Description. Glabella expanding forward, coarsely granulose or pitted. Pygidium with long, recurved, posteriorly directed spines.

Material. Fifteen specimens (14 cephalae and 1 pygidium) were collected for this study. Refer to Ceraurus generic Material discussion for collection localities of these specimens.

Ceraurus dentatus Raymond and Barton

(Plate 2, Figure 6)

Description. Cephalon possesses small eyes which are positioned toward the posterior margins and less than one-half of total length of cephalon and without eyelines. Two very long genal spines borne by cephalon which are generally less divergent than in other species of the same genus.

Material. Two identifiable silicified cephalae were collected at the Cedar Springs and Evan's Ferry sections. One was collected from the upper Wardell Formation at Cedar Springs and the other from the lower Benbolt at Evan's Ferry.

SUBFAMILY SPHAEREXOCHINAE Opik

GENUS SPHAEREXOCHUS Beyrich

(Plate 2, Figure 1; Figure 8, page 21, Item 3)

Description. Preoccipital pair of lateral glabellar furrows are distinct, curved, usually reaching occipital furrow, with two additional pairs of short lateral glabellar furrows in some species. Thorax with 10 segments, pleurae with poorly defined flanges, bluntly rounded spines. Surface smooth. (Henningsmoen, in Moore, 1959, p. 0 436)

Material. Fourteen silicified specimens of this genus were collected for this study. Thirteen cephalae and one almost complete specimen were collected (only the pygidium was missing). Sphaerexochus was collected from the Wardell at Cedar Springs and from the Benbolt of the Raccoon Valley section. The specimens collected were preserved by silicification.

S. sp.

Description. Glabella circular and very convex in outline, posterior glabellar lobes set off from glabella by deeply impressed glabellar furrows.

Material. Eight specimens were collected from the study area. For collection localities of these specimens, refer to Sphaerexochus generic Material discussion.

S. parvus Billings

(Plate 2, Figure 1)

Description. Posterior furrows on cephalon entirely encircle the basal glabellar lobes. Two anterior glabellar lobes are faintly impressed. The basal glabellar lobes are nearly circular in outline. The glabella is circular in outline.

Material. Five cephalata and one cephalon with eight thoracic segments attached were collected at Raccoon Valley and Cedar Springs. One cephalon was collected from the upper Wardell at Cedar Springs. Three specimens, including the one with eight thoracic segments attached to the cephalon, were collected from the middle Benbolt while the other two cephalata were collected from the lower Benbolt at Raccoon Valley.

FAMILY PLIOMERIDAE Raymond

SUBFAMILY PLIOMERINAE Raymond

GENUS PLIOMEROPS Raymond

(Plate 2, Figure 14; Figure 8, page 21, Item 4)

Description. No indentation on frontal glabellar lobe as in Pliomera, and lacks denticulations on anterior cephalic border, bears proparian facial sutures, and small submedian eyes. Thorax with 14 to 19 segments, inflated pleurae. Pygidium semicircular with five axial rings, five pairs of flat pleurae and long terminal axial piece.

(Modified from Harrington, in Moore, 1959, p. 440; Cooper, 1953)

Material. For the exact number of specimens from Silver City, refer to Benedict (unpublished dissertation, in prep.). The St. Clair section yielded six pygidia some of which have portions of the thorax attached. Pliomerops was collected from the Lenoir of the Silver City and St. Clair sections. Most of the specimens were silicified.

P. sp.

(Plate 2, Figure 14)

Description. Thorax with inflated pleurae. Pygidium semicircular in outline with five axial rings and five pairs of flat pleurae.

Material. Refer to Material discussion of Pliomerops.

SUBFAMILY PILEKIINAE Sdzuy

GENUS PILEKIA Barton

(Plate 2, Figure 13; Figure 8, page 20, Item 5)

Description. Glabella prominent, wider than long, strongly tapering forward, strawberry-shaped; lateral glabellar furrows directed inward and slightly backward; length (exsagital) of successive lateral glabellar lobes increasing from front to back; frontal glabellar lobe short and small; surface of glabella granulose; fixigenae narrow (transverse) without anterior areas, pitted; eyes small, well forward, close to glabella; palpebro-ocular ridges short; posterior sections of facial sutures cutting lateral margins immediately in front of genal angles which are ?rounded or produced into spines. Thorax of ?12 segments;

pleurae with oblique furrows, pleural extremities produced into long curved spines. Pygidium with four axial rings and triangular terminal axial piece reaching posterior margin; pleural regions with four pairs of furrowed pleurae ending in long free spines arranged in groups of two. (Harrington, in Moore, 1959, p. 0 441)

Material. One specimen of this genus, a cephalic mold, was collected from the Wardell of Cedar Springs.

P. sp.

(Plate 2, Figure 3)

Description. Glabella prominent, tapering forward noticeably, lateral glabellar furrows directed posteriorly.

Material. See discussion of Pilekia Material.

FAMILY ENCRINURIDAE Angelin

SUBFAMILY ENCRINURINAE Angelin

GENUS ENCRINURUS Emmrich

(Plate 1, Figure 1; Figure 8, page 21, Item 6)

Description. Glabella widening markedly forward, with three pairs of lateral or transglabellar furrows; eyes more or less stalked. Thorax with 11 or 12 segments. Pygidium subtriangular, longer than broad with 5 to 10 pairs of ribs. (Henningsmoen, in Moore, 1959, p. 0 446)

Material. This genus is represented by four specimens; all of which are silicified pygidia from the Benbolt Formation of the Raccoon Valley section.

E. sp.

(Plate 1, Figure 1)

Description. Pygidium triangular in outline; longer than wide with six pairs of ribs.

Material. Same as for Encrinurus generic Material description.

SUBFAMILY CYBELINAE Holliday

GENUS CYBELOIDES Slocum

(Plate 1, Figure 2; Figure, 8, page 21, Item 7)

Description. Three lateral glabellar lobes more or less distinctly separated from the remainder of the glabella by longitudinal furrows, eyes far back, eye ridges distinct; cranidium strongly pustulose and spiny. Pygidium highly arched along anterior margin, with vertical margins, converges to acutely rounded posterior tip; four segments strongly anklyosed with anterior pleura bent strongly posteriorly so as to enclose the narrower segments of the middle and posterior portions. (Modified from Henningsmoen, in Moore, 1959, p. 0 448; Cooper, 1953)

Cybeloides virginiensis Cooper

(Plate 1, Figure 2)

Description. Pygidium long, narrow, prow shaped, very convex with vertical sides. Five sets of tubercles located along axis. Axis is annulate, dorsal furrows well defined, four pairs of nodal pleurae posteriorly deflected, outer pair long and recurved so as to frame the pygidium.

Material. Three recognizable silicified pygidia were collected from the upper Eidson at Evan's Ferry.

SUBORDER PHACOPINA Struve

SUPERFAMILY DALMANITACEA Vogdes

FAMILY PTERYGOMETOPIDAE Reed

SUBFAMILY PTERYGOMETOPINAE Reed

GENUS CALYPTAULAX Cooper

(Plate 2, Figures 3-5; Figure 8, page 21, Item 8)

Description. Cephalon highly vaulted; frontal lobe of glabella may be prolonged sideward in sickle-shaped elevations of genae that embrace eyes anteriorly and laterally and are cut off from frontal lobe by facial sutures; 3p lateral glabellar lobes distinctly triangular, large, protruding a little less than frontal lobe, 2p lobes smaller than in Eononorachus; central area more or less arched, never depressed;

longitudinal furrows may be present; 2p lateral glabellar furrows distinctly oblique in anteromesial direction, 1p furrows subparallel to 2p furrows; genal spines present or absent. Pygidium highly vaulted, generally subtriangular; posterior margins of rings undulating (narrow curve laterally, flat broad curve mesially). (Struve, in Moore, 1959, p. 0 492)

Material. A total of 94 specimens (56 glabellae, 35 pygidia and 3 pygidia with several thoracic segments attached. From the Raccoon Valley section, three pygidia were collected in the lower Benbolt. Several specimens were collected from the Silver City section in the Lenoir Formation. These trilobites have not been added to the total number of Calyptaulax specimens counted in the present study. For a quantitative approach to this section see Benedict (unpublished dissertation, in prep.). Nine specimens were taken from the Cedar Springs section. Four pygidia and one cephalon were collected from the upper Wardell Formation, two cephalata from the Bowen, and one cephalon and one pygidium from the lower Witten. Seventy-two specimens were collected from the Evan's Ferry section. Forty-six cephalata and 24 pygidia were collected from the upper Eidson. One cephalon was collected from the lower Hogskin and one from the lower Rockdell formations. Three cephalata and three pygidia were collected from the lower Benbolt. Three cephalata were taken from the Wardell Formation. The specimens were preserved by silicification.

C. sp.

(Plate 2, Figure 3)

Description. Cephalon coarsely tuberculate, highly vaulted; lateral glabellar lobes triangular; eyes large, extending above glabella. Pygidium highly vaulted.

Material. Eighty specimens were collected (42 cephalata, 35 pygidia and 3 pygidia with several thoracic segments attached). For localities of collection, refer to Calyptaulax generic Material discussion.

C. callirachis Cooper

(Plate 2, Figure 4)

Description. Anterior border of cephalon smooth, sharply defined and produced anteriorly into acutely rounded lip-like frontal protrusion. Axial dorsal furrows are shallow and broad. The palpebral lobes are narrow and nontuberculate. The forward position of the occipital ring is tuberculate, posterior portion granulose. The occipital ring is highly arched.

Material. Thirteen identifiable cephalata were taken from the upper Eidson at Evan's Ferry.

C. mesleri Cooper

(Plate 2, Figure 5)

Description. Axial portion of the glabella essentially flat with very numerous, coarse tubercles on glabella and anterior preglabellar

field. Anterior margin produced into a lip-like border. Lateral glabellar lobes wholly discrete. Axial furrows deep and narrow.

Material. One identifiable cephalon was collected at Evan's Ferry from the upper Benbolt.

GENUS EOMONORACHUS Delo

(Plate 2, Figure 10; Figure 8, page 21, Item 9)

Description. Cephalon vaulted; glabella with large subrhombic frontal lobe, 3p (third from posterior) lateral lobes subtriangular, protruding laterally less than frontal lobe, 2p lobes smaller than 3p lobes, 1p lobes well detached, small, rounded tubercles; narrow 2p lateral glabellar furrows slightly oblique in anteromesial direction, shallow, deep, adaxially but complete, central area depressed; eyes moderately large, close to glabella, somewhat distant from posterior border furrows, genal spines slender, rather long. Pygidium distinctly triangular, strongly vaulted; axis slender, almost reaching posterior margin; with eight clearly defined rings distinct and some indistinct, pleural regions with seven or eight pairs of broadly rounded, unfurrowed ribs. (Struve, in Moore, 1959, p. 0 492)

Material. One cephalon (a badly weathered cast) was collected from the Wardell at Cedar Springs.

E. sp.

(Plate 2, Figure 10)

Description. Cephalon vaulted, glabella with large, subrhombic lobe, lateral glabellar lobes triangular; eyes large.

Material. Refer to discussion of Material under Eomonorachis for localities of collected specimens.

APPENDIX D

PLATES

Plate 1. Illaenidae and Encrinuridae.

1. Encrinurus sp., dorsal view of pygidium, 2X (RV 4 BE 90.03, UTGSM 10055).
2. Cybeloides virginiensis, oblique posterodorsal view of pygidium, (EF EI 1, UTGSM 10025).
- 3., 6. Illaenus crassicauda; 3. dorsal view of cephalon, 1.5X (EF BE 23.14, UTGSM 10017); 6. left lateral view of cephalon, 1.5X (EF BE 23.14, UTGSM 10017).
8. Illaenus angusticollis, dorsal view of cephalon, 1.5X (EF' 18-I, UTGSM 10015).
- 4., 11., 13. Nanillaenus conradi; 4. dorsal view of cephalon, 2X (EF' 19 M4, UTGSM 10016); 11. dorsal view of pygidium, thorax attached, 3X (EF 25-I); 13. dorsal view of pygidium, 2.5X (EF' 26-3).
7. Nanillaenus sp., oblique posterodorsal view of thoraxial segments, 2.5X (EF' 18 A-3).
9. Nanillaenus latiaxiatus, dorsal view of pygidium, 2X (EF' 18 H-3).
5. Bumastus bellevillensis, ventral view of cephalon, 2X (EF RO 14.00, UTGSM 10013).
- 10., 12. Bumastus sp.; 10. dorsal view of pygidium, 2.5X (EF' 18-13); 12. dorsal view of cephalon, 2X (EF 23-6c).
- 14., 15. Bumastus indeterminatus; 14. right laterview of complete specimen, 2X (EF WI 6201, UTGSM 10051); 15. dorsal view of same.

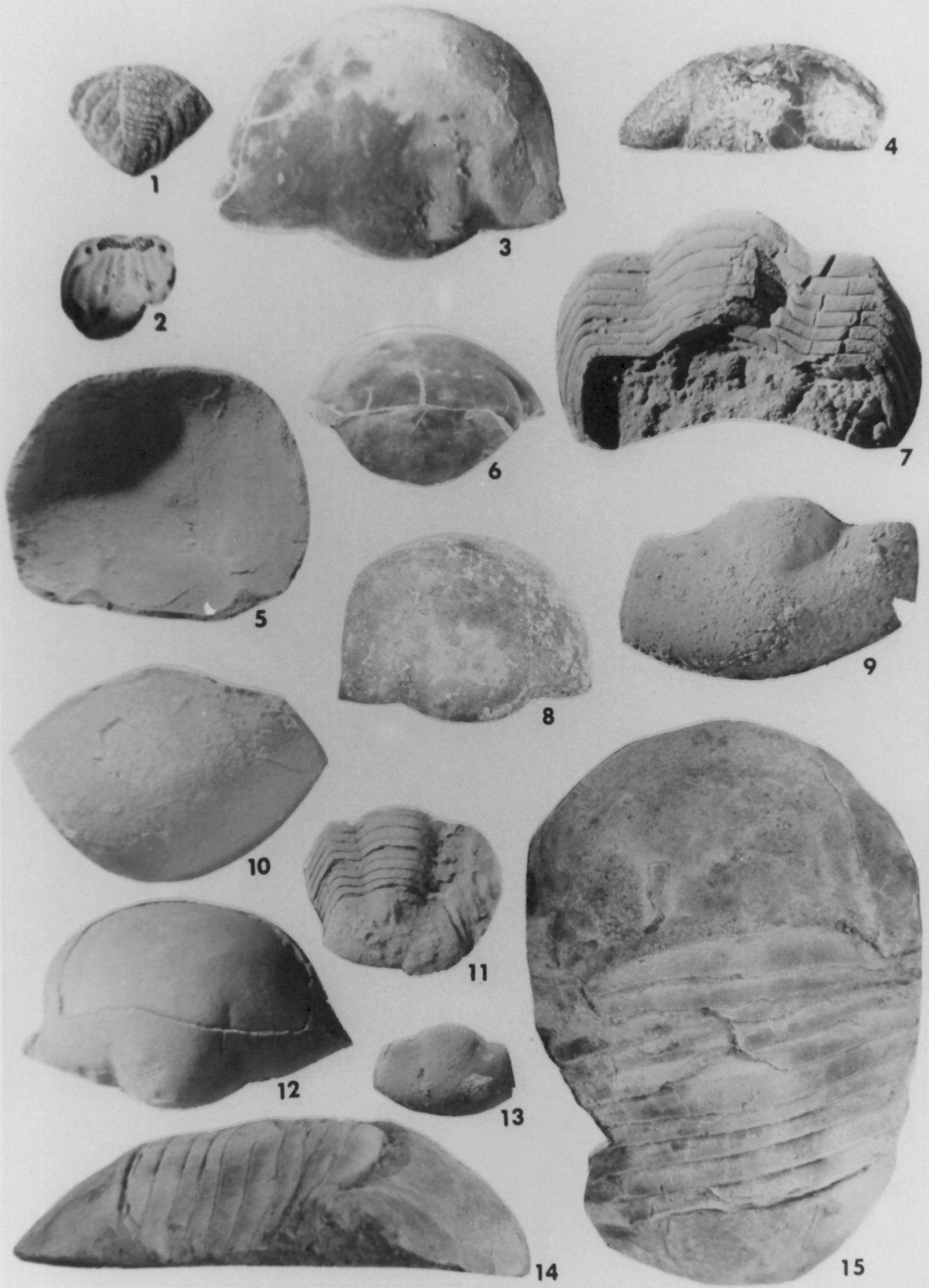


Plate 1.

Plate 2. Cheiruridae, Pterygometopidae,
Asaphidae, Harpidae, Pliomeridae,
Raphiophoridae and
Remopleurididae.

1. Sphaerexachus parvus, dorsal view of cephalon, 2X (CS BE 56.02a, UTGSM 10040).
2. Ceraurinella sp., dorsal view of hypostoma, 7X (RV 4 BE 90.07, UTGSM 10056).
7. Ceraurinella typa, dorsal view of cephalon, 2X (EF EI 2, UTGSM 10022).
6. Ceraurus dentatus, dorsal view of cephalon, 2X (CS BE 5505, UTGSM 10039).
8. Ceraurus sp., dorsal view of cephalon, 5X (EF EI 3).
3. Calyptaulax sp., dorsal view of pygidium, 3X (EF' 25-7).
4. Calyptaulax mesleri(?), dorsal view of cephalon, 2X (EF' 23-21, UTGSM 10026).
5. Calyptaulax callirachis, dorsal view of cephalon, 3X (EF EI 9, UTGSM 10032).
9. Homotelus sp., dorsal view of pygidium, 3X (EF' 18I).
10. Eomonorachis sp., dorsal view of cephalon, 2X (CS WA 58.02c, UTGSM 10046).
11. Dolichoharpes aniserialis, oblique dorsal view of cephalon and fringe, 2X (CS WI 62.09, UTGSM 10041).
16. Dolichoharpes, ventral view of fringe thorax and pygidium, 2X (CS BE 50.04, UTGSM 10048).
12. Isotelus sp., cf. copenhagenensis, left lateral view of cephalon, 2X (EF EI 86, UTGSM 10005).
- 17., 18. Isotelus sp.; 17. dorsal view of hypostoma, 5X (EF EI 20, UTGSM 10008); 18. dorsal view of pygidium, 2X (EF EI 102).
19. Isotelus sp. cf. iowensis, left lateral view of cephalon, 2X (EF RO 14.07, UTGSM 10001).

13. Pilekia sp., dorsal view of cephalon, 3X (CS WA 58.10, UTGSM 10044).
14. Pliomerops sp., dorsal view of thoraxial segments, 2X (LE 100).
15. Isoteloides(?), dorsal view of pygidium 5X (EF EI 53, UTGSM 10006).
- 20., 24. Robergia sp.; 20. dorsal view of cephalon, 6X (SV 1.01);
24. dorsal view of pygidium, 6X (sample SV 1.02).
21. Paraharpes sp., dorsal view of portion of fringe, 2X (CS WI 62.11b, UTGSM 10043).
- 22., 23. Lonchodomas sp.; 22. dorsal view of cephalon, 4X (St. C. 135-155.06); 23. dorsal view of pygidium, 5X (St. C. 135-155.07).
25. Ampyxina sp., dorsal view of pygidium, thorax attached, 6X (SV 1.03).
26. Ampyx sp., dorsal view of cephalon, 6X (SV 1.04).

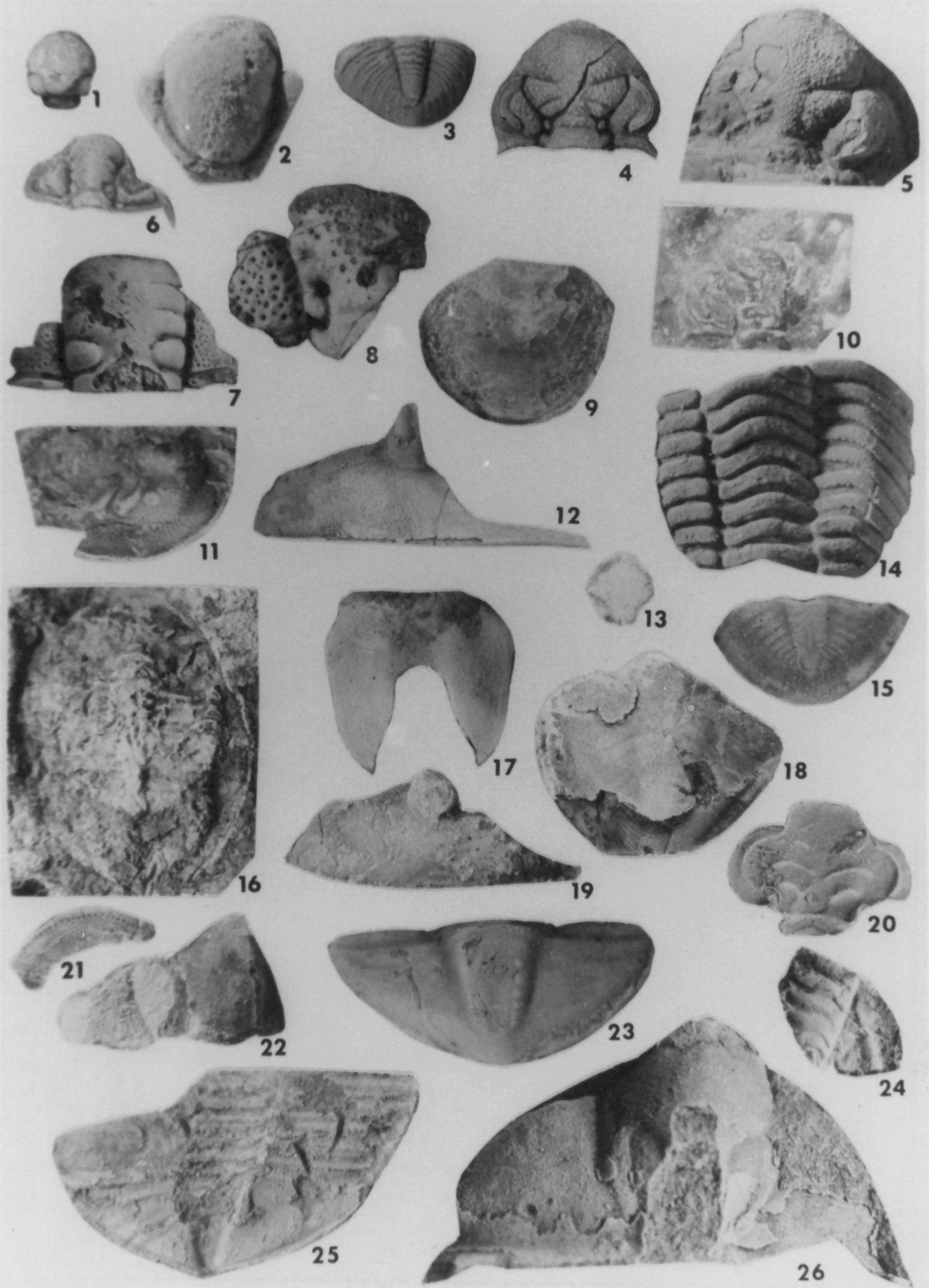


Plate 2.

VITA

Micheal Ray Maitland was born in Deadwood, South Dakota, on June 27, 1950. He graduated from Pemberton Township High School, New Jersey, in June of 1968.

In June of 1973, he entered The University of Tennessee at Martin. He married Joann W. Quinlan on December 24, 1976. In May of 1977, he received a Bachelor of Science in Geology.

He then entered the graduate degree program at The University of Tennessee, Knoxville, in September of 1977, and received a Master's of Science degree in Geology in December of 1979.

Upon graduation from The University of Tennessee, he will report for work to Exxon Corporation, South Texas Division, at Corpus Christi, Texas, where he has accepted a position as a production geologist.