JT32
16

To the Graduate Council:

I am submitting herewith a thesis written by Deborah Ann Capaccioli entitled "Biostratigraphy, Petrology, and Paleodepositional Environments of the Upper Silurian-Lower Devonian Ross Formation, west-central Tennessee." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Geology.

Thomas W. Broadhead

Thomas W. Broadhead, Major Professor

We have read this thesis and recommend its acceptance:

Robert E. McLaughlin

Kenneth R. Walker

Accepted for the Council:

Cwminkel

Vice Provost
and Dean of The Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirments for a Master's degree at the University of Tennessee, Knoxville, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made.

Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in his absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature Deborah Ann Capaccioli

Date 12/10/86

BIOSTRATIGRAPHY, PETROLOGY, AND PALEODEPOSITIONAL ENVIRONMENTS OF THE ROSS FORMATION, UPPER SILURIAN-LOWER DEVONIAN, WEST-CENTRAL TENNESSEE

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Deborah Ann Capaccioli

March 1987

ACKNOWLEDGMENTS

I would like to thank the members of my committee, Dr. Kenneth Walker, Dr. Robert McLaughlin and especially my committee chairman, Dr. Thomas Broadhead, for their support, guidance, and suggestions.

Special thanks go to my friends throughout the department who helped me in all stages of my work. Their comments, suggestions and discussions were all greatly appreciated.

I would like to thank my family, for without them none of this would have been possible. I would also like to give a special thanks to Joseph Paul, who always supported and encouraged me.

Financial support was provided by the University of Tennessee Department of Geological Sciences Discretionary Fund and by the Appalachian Basin Industrial Associates. Fieldwork in Parsons Quarry was allowed by Vulcan Materials, Inc., Don Smith, geologist.

ABSTRACT

The Ross Formation (Upper Silurian-Lower Devonian) is exposed in the western valley of the Tennessee River in west-central Tennessee and consists of five members that grade laterally into each other from north to south. To the north, the Rockhouse Limestone Member, a fossiliferous grainstone to packstone with minor shale partings underlies the Birdsong Shale Member, a fossiliferous packstone to wackestone interbedded with fossiliferous shale. To the south, in northern Hardin County, the Rockhouse Limestone Member underlies the sparsely fossiliferous, dense, recrystallized lime mudstone of the Ross Limestone Member, whereas in southern Hardin County, the Rockhouse Shale Member is below the Ross Limestone. The Bear Branch facies, found within the Ross Limestone in northern Hardin County, is a cross-bedded, hematitic grainstone with hematitic superficial ooids (less than 5 laminations).

The Ross Formation was deposited in a shallow epeiric sea, and represents environments similar to those of the Helderbergian sequences of New York and Oklahoma. In Late Silurian time, the Rockhouse Shale was deposited to the south, while farther north, in shallower, subtidal waters, the Rockhouse Limestone was deposited with only a minor amount of shale present.

The water shallowed even more northward, where a high-energy, crinoidal sandbank environment (Decatur Limestone) had persisted during much of the Late Silurian. During the Early Devonian, the area to the north deepened, and the sandbanks of the Decatur were overlain by interbedded skeletal limestone and fossiliferous shale of the Rockhouse Limestone, which in turn was overlain by the quiet, offshore, muddy shelf deposits represented by fossiliferous shale and skeletal packstone of the Birdsong Shale. Simultaneously, to the south, shallowing occurred reflected by the quiet, restricted shallow subtidal to lagoonal deposits of the Ross Limestone. In a localized area of the Ross Limestone, shoaling occured along with an increase in water energy and an influx of clays causing a concentration of iron oxides. Hematitic ooids and bioclastic debris were deposited in cross-stratified beds of this shallow, subtidal environment of the Bear Branch facies.

The Silurian-Devonian boundary in the study area was determined by the first appearance of the conodont Icriodus woschmidti (hesperius-woschmidti Zone), which occurs approximately 2.0m below the Ross-Decatur contact at Parsons Quarry (northern facies) and 2.2m above the contact at Olive Hill (southern facies). Although most Icriodus platform elements are fragmental, a few were identified as _I. postwoschmidti_, which correlate with the _eurekaensis_ Zone or the d1c gamma Zone of Nevada and Spain respectively.

Although relatively abundant in the shallower environments of the Rockhouse and Decatur Limestones, conodonts, especially _Icriodus_, were scarce in the deeper sublittoral environments of the Birdsong Shale. Conodont elements were not observed in the lagoonal environments of the Ross Limestone, and in the hematitic Bear Branch facies.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

PLATE PAGE

CHAPTER 1

INTRODUCTION

General Introduction

The Ross Formation (Upper Silurian-Lower Devonian) is chiefly a skeletal limestone and fossiliferous shale exposed in the western valley of the Tennessee River in west-central Tennessee. In this area, the Ross Formation and the underlying Decatur Formation represent virtually continuous sedimentation from the Pridoli (Late Silurian) to the Lochkov (Early Devonian) (Broadhead, Neff and Reid, 1983). Previous work in this area has dealt with megafaunal listings and generalized lithostratigraphic descriptions and correlations. (Dunbar, 1919; Wilson, 1949; Walker and Pruitt, 1975; Reid, 1983). Only recently have studies focused on paleoecological interpretations and microbiota biostratigraphy.

Historical Background

The Ross Formation was first described in 1876 by Safford, although the first detailed study was by Dunbar

(1919). According to Dunbar, the Ross and overlying Devonian units (figure 1) consists of, in ascending order, the Rockhouse Shale, the Olive Hill Formation, the Birdsong Shale, and the Decaturville Chert overlain by the Quall Limestone and the Harriman Chert. The Olive Hill Formation contained three members, in ascending order, the Ross Limestone, the Bear Branch-Pyburn Limestone and the Flat Gap Limestone.

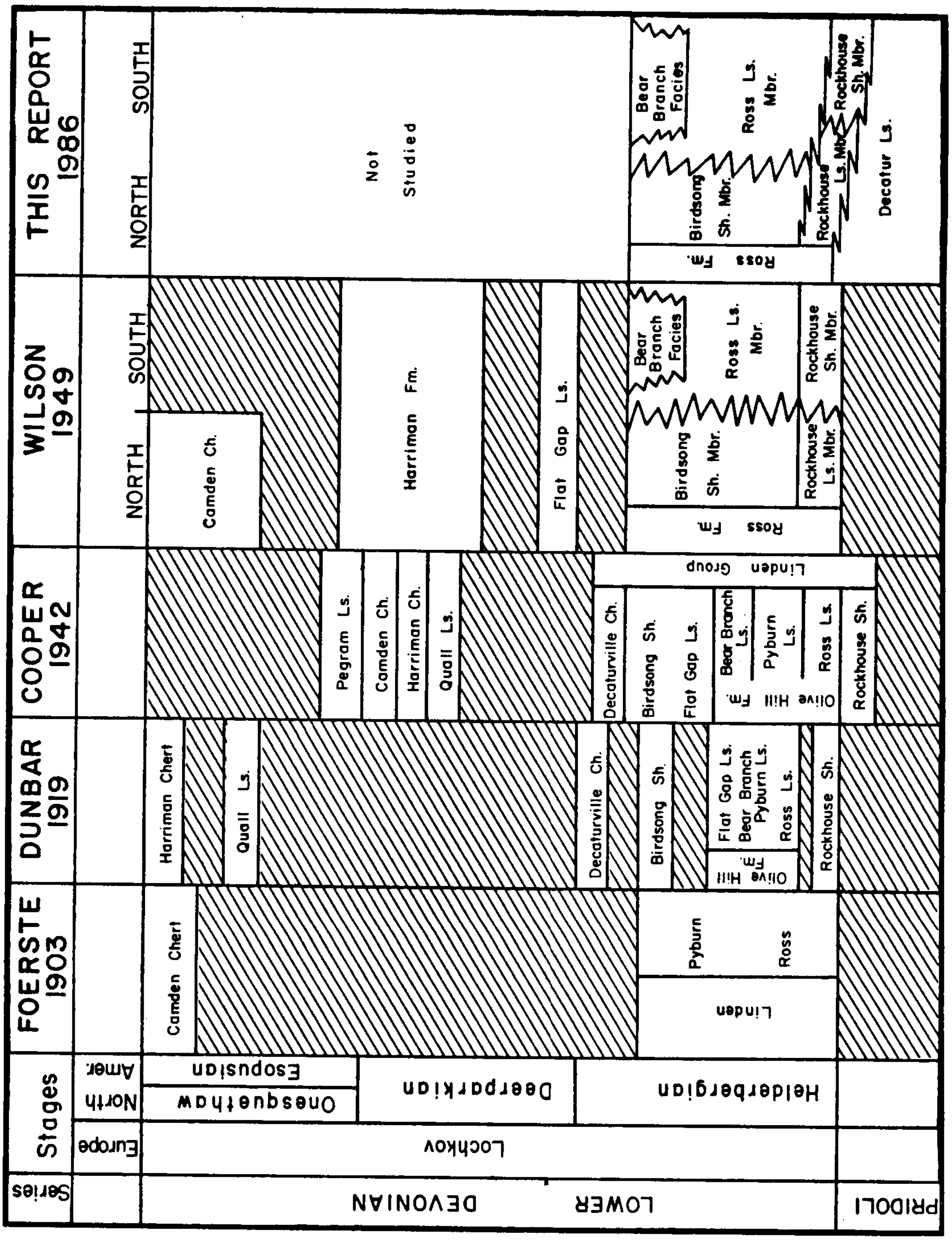
The Rockhouse Shale was thought by Dunbar to be separated from the Olive Hill Formation (Ross Limestone Member) by a disconformity. Dunbar (1919, p.40) states

> The Rockhouse Formation lies between Middle Silurian and Lower Devonian Limestones, being separated from either by a disconformity, so that its known stratigraphic relations are noncommittal as to its Silurian or Devonian age.

By using faunal affinities and paleobiogeographic evidence he concludes that the Rockhouse Shale is most likely Devonian in age, stating "the formation is near the Siluro-Devonian boundary line . . . shown by the presence of Silurian holdovers. . . ."

One point strongly held by Dunbar was that the Birdsong Shale was not equivalent to the Ross Limestone,

Figure 1. Historical development of uppermost Silurian and Lower Devonian stratigraphic nomenclature in the Western Valley of the Tennessee River. Correlation is not to scale chronostratigraphically nor in terms of stratigraphic thickness of units.


THIS REPORT 1986
NORTH
SOUTH
Not Studied
Bear Branch Facies
Ross Ls. Mbr.
Birdsong Sh. Mbr.
Rockhouse Ls. Mbr.
Rockhouse Sh. Mbr.
Decatur Ls.
Ross Fm.
WILSON 1949
NORTH
SOUTH
Camden Ch.
Harriman Fm.
Flat Gap Ls.
Bear Branch Facies
Ross Ls. Mbr.
Birdsong Sh. Mbr.
Rockhouse Ls. Mbr.
Rockhouse Sh. Mbr.
Ross Fm.
COOPER 1942
Pegram Ls.
Camden Ch.
Harriman Ch.
Quall Ls.
Decaturville Ch.
Birdsong Sh.
Flat Gap Ls.
Bear Branch Ls.
Pyburn Ls.
Ross Ls.
Olive Hill Fm.
Rockhouse Sh.
Linden Group
DUNBAR 1919
Harriman Chert
Quall Ls.
Decaturville Ch.
Birdsong Sh.
Flat Gap Ls.
Bear Branch
Pyburn Ls.
Ross Ls.
Olive Hill Fm.
Rockhouse Sh.
FOERSTE 1903
Camden Chert
Pyburn
Ross
Linden
Stages
North Amer.
Europe
Esopusian
Onesquethaw
Deerparkian
Helderbergian
Lochkov
Series
LOWER DEVONIAN
PRIDOLI

as previously stated by Foerste (1903). Dunbar argues (p.64)

> To make the Birdsong equivalent to the Ross Limestone would require an abrupt change in the lithology within the distance of ten or twelve miles... although each formation is known to maintain its distinctive lithology for many miles and to show no evidence of transition on approaching these localities.

According to Dunbar, faunal evidence against the Birdsong being a facies equivalent of the Ross Limestone includes the brachiopod Eospipifer macropleura, which is the most diagnostic "guide" fossil in the New Scotland Formation (Lower Devonian) of New York. This brachiopod is abundant within the shaley and the coarser limestone layers in the Birdsong but was said, by Dunbar, to be absent in the Ross Limestone at the Olive Hill section. The New Scotland and Birdsong faunas are very similar and are considered to be Helderbergian (earliest Devonian) in age (Amsden, 1962).

Cooper et al. (1942) made considerable changes in the classification of the formational units of this area (figure 1). The Rockhouse Shale was assigned to the Silurian, conformably overlain by the Olive Hill Formation, Flat Gap Limestone, Birdsong Shale and Decaturville Chert. All of these, including the

Rockhouse, were placed in what Cooper et al. called the Linden Group. No explanations were given for any of these changes.

Wilson (1949) revised Dunbar's (1919) classification, placing all the beds overlying the Decatur Limestone (Silurian) and underlying the Flat Gap or Harriman formations into one unit called the Ross Formation (figure 1). This formation includes the Rockhouse Shale, the Rockhouse Limestone, the Birdsong Shale, and the Ross Limestone members and the Bear Branch facies. Wilson's classification is now the most widely accepted for this interval.

The basal part of the Ross Formation is composed of the Rockhouse Limestone and the Rockhouse Shale, which grade laterally into one another in central Hardin County (figure 2). These units were thought by Wilson to rest unconformaby upon the Decatur Limestone (Silurian), but a more recent study by McComb and Broadhead (1980) suggests a lithically distinct but conformable relationship between the Rockhouse Limestone and the Decatur Limestone farther north in Decatur County.

Wilson's major modification involved Dunbar's units: Ross Limestone, Pyburn Limestone, Birdsong Shale, and Flat Gap Limestone. The Ross Limestone and the Pyburn Limestone were combined because the only

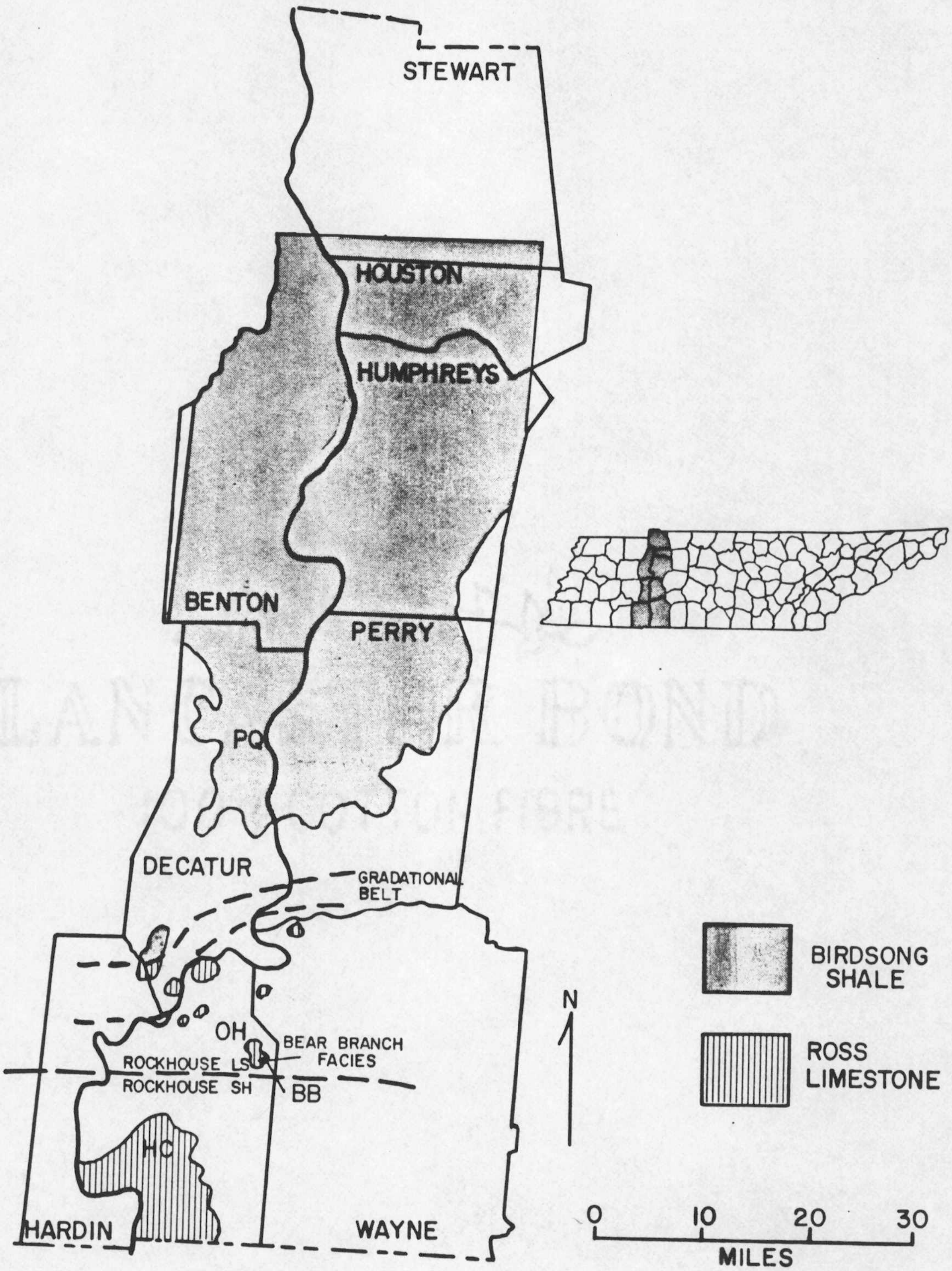


Figure 2. Geographic distribution map of the units of the Ross Formation (From Wilson, 1949, p.285).

criterion for separation of these units by Foerste (1903) and Dunbar (1919) was the presence or absence of "Camarocrinous" bulbs (the "root" of the large camerate crinoid Scyphocrinites). Wilson also showed that the Ross then grades northward into the Birdsong Shale near the Decatur County line (figure 2). Dunbar's argument for the noncontemproaneity of the Birdsong Shale and Ross Limestone was based mainly on the presence of the "guide fossil" Eospirifer macropleura, which was found only in the Birdsong Shale. Wilson states (p. 293) "Since then this brachiopod, reported by Dunbar (idem, p.60) to be '. . . confined to the Birdsong Formation . . . ,' has been found to be common in the Ross Limestone member and in the Rockhouse Limestone member...." Wilson also mentions that there is one critical exposure along the Tennessee River (now Kentucky Lake) that shows a gradation within the outcrop from typical Birdsong lithology to a Ross Limestone lithology. The Flat Gap Limestone was upgraded to a formation by Wilson and regarded to be unconformable above the Ross Formation. The facies relationships of the Ross Formation as interpreted by Wilson, are shown in figure 3. Wilson's interpretation of the structures present in relationship to the facies is shown in the small inset map of figure 3. Although the facies relationship was not disputed,

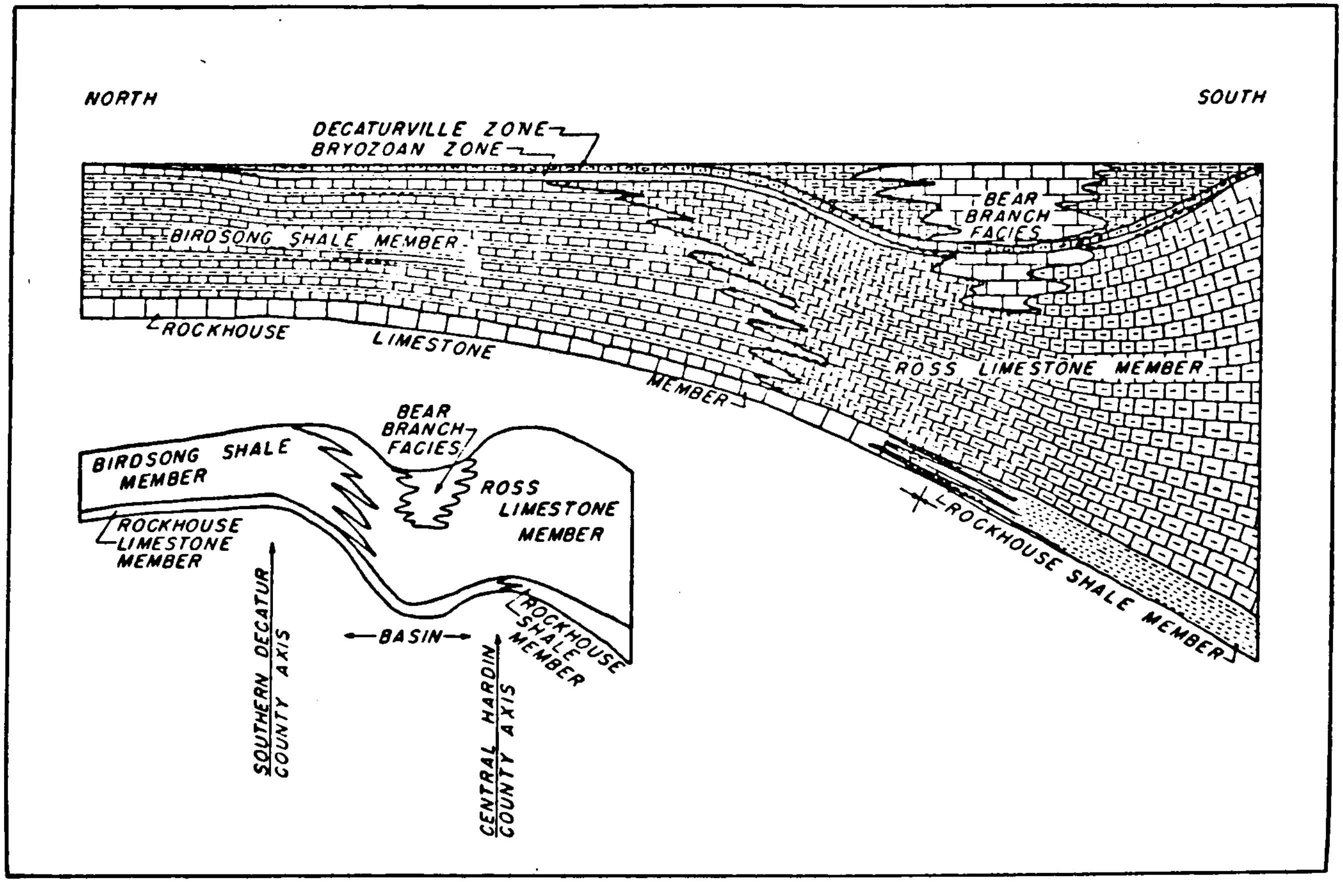


Figure 3. Diagramatic section along the western valley of the Tennessee River showing the vertical and lateral distribution and relationships of the units of the Ross Formation. The small inset map shows the relations between major facies change and structures (from Wilson, 1949, p.282).

the structures shown are most probably incorrect and will be discussed in chapter II.

Reid (1983) performed the first petrologic evaluation of the Rockhouse Limestone and Birdsong Shale members of the Ross Formation. She sampled and described three localities, including the type section of the Birdsong. These sections represented a continuous sequence of skeletal limestone and shale beds with little change in lithology. All three sections were located in the "northern facies" (figure 2) of Decatur and Benton counties. Her analysis of the northern facies of the Ross Formation revealed "a transgressive (i.e., 'deepening') sequence from subtidal crinoidal sandbanks (Decatur Limestone) to the quiet, offshore shelf environment subject to terrigeneous influx (Birdsong Shale member of the Ross Formation)" (Reid, 1983, p.72).

In a study by McComb and Broadhead (1980) the Rockhouse Limestone member was determined, on the basis of conodonts, to be entirely of Lochkovian age (Early Devonian). They also determined that the upper 1-2 meters of the Decatur Formation (previously considered by Wilson, 1949, to be Silurian) contains the conodont, Icriodus woschmidti, which closely approximates the Silurian-Devonian boundary by its first appearance. This suggests that the upper 2 meters of the Decatur is

Lochkovian (Lower Devonian) in age, it is conformable with the Rockhouse.

The shelly megafauna of the Ross Formation is Helderbergian (lowermost Devonian) in age and is closely related to other Helderbergian faunas, such as those from the Haragan Formation of Oklahoma, and the New Scotland Formation of New York (Amsden, 1960).

Purpose of Investigation

The present study had two pruposes. The first was to determine the environment of deposition of the southern exposures of the Ross Formation and their facies relationships with the northern exposures previously described by Reid (1983). The approach to this part primarily included field descriptions and petrographic analysis of the Rockhouse Shale, the Rockhouse Limestone, the Bear Branch facies and the Ross Limestone, units that do not occur to the north. Secondly, a biostratigraphical analysis of the conodont fauna for both the northern and southern exposures (facies) of the Ross Formation was conducted to establish a biozonation, determine an upper age limit, and examine facies control on conodont distribution.

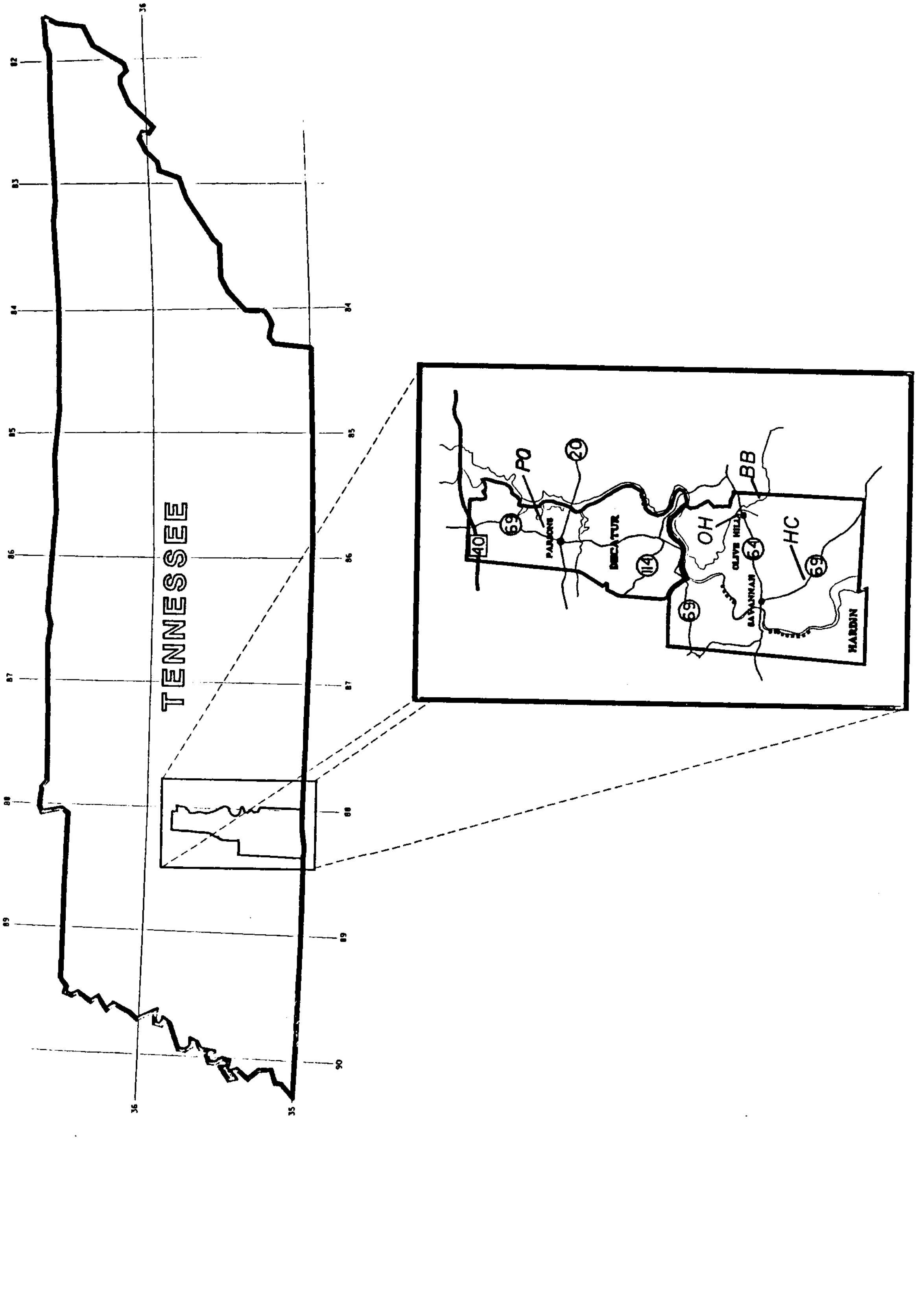
Location of Study

The studied areas of the Ross Formation lie within Decatur and Hardin counties in west-central Tennessee (figure 4). Three major sections were measured: (1) Parsons Quarry (Vulcan Materials, Inc., operators), located along Highway 69, 3 miles N-NE of Parsons, Decatur County; (2) Olive Hill, a roadcut and outcrop along state highway 64 at Olive Hill, Hardin County; and (3) an outcrop along Bear Branch, a small tributary of Indian Creek, 2 miles south-southeast of Olive Hill, Hardin County, off of State Highway 64, which represents the type section of the Bear Branch facies (Wilson, 1949). A fourth incomplete section along Horse Creek, 2 miles southeast of Maddox, Hardin County, off of State Highway 69, also was sampled for the Rockhouse Shale and Ross Limestone.

Methods

The localities were chosen for this study primarily because collectively they represent a nearly complete section, and individually they represent the major members studied, except for the Horse Creek location, which was the only outcrop of the Rockhouse Shale found.

Figure 4. Location of study in Decatur and Hardin Counties. Parsons Quarry (PQ), Olive Hill (OH), Bear Branch (BB), and Horse Creek (HC).


TENNESSEE
PO
20
69
40
DECATUR
114
OH
BB
HC
64
69
69
HARDIN

Each section was measured bed-by-bed with samples collected at any lithic change but at an interval of not more than 1 meter (because of the location and nature of the outcrop at Bear Branch, this sampling procedure was not always possible). Samples collected were sufficiently large in size (approximately 3 kg) so that both conodont and petrographic analysis could be performed on each sample. A detailed description of the measured sections based on field and petrographic analyses of acetate peels and thin sections is given in appendix A.

A total of 65 stratigraphyically oriented samples was taken from the four sections. Each sample was slabbed at least once, and the slab was polished, etched and a replica acetate peel was made. The samples taken from Olive Hill and Bear Branch were slabbed twice, the second slab used for preparation of a 5x8 cm thin section. 28 thin sections were made, and 8 of these were analysed by the point count technique following the method of Chayes (1954), with the analyses listed in appendix B. The remaining rock of all the samples was crushed and dissolved in diluted formic acid for approximately 12-16 hours. The insoluble residues were wet-sieved, dried, and picked for conodonts and other microfossils.

CHAPTER II

PETROLOGY AND PALEODEPOSITIONAL ENVIRONMENTS

Petrology--Introduction

Previous studies of the petrology of the Ross Formation have dealt primarily with the Rockhouse Limestone and Birdsong Shale members (Walker and Pruitt, 1975; Reid, 1983; Broadhead, Neff and Reid, 1983). This report deals primarily with the petrology of the Rockhouse Limestone Member, the Ross Limestone Member, and the Bear Branch facies of the Ross Limestone. Samples of the Rockhouse Shale also were collected; no detailed petrologic study was made on these because the outcrop was very small and weathered. Samples of the carbonate beds in the Birdsong Shale were also collected, primarily for biostratigraphic study, but also for comparison with Reid's (1983) study.

Assigning a specific lithic type to the Ross Formation is difficult because the members differ greatly from one another. Walker and Pruitt (1975) characterized the formation as alternating mudstone (shale) and limestone beds. This is largely true only for the Birdsong Shale and to some extent the Rockhouse Limestone. Wilson (1949) mentioned that at some localities the Rockhouse contains very little terrigenous silt, whereas at other localities only thin partings of shale are present. He gave a 1:3 shale-limestone ratio for the Rockhouse exposure at Olive Hill. Walker and Pruitt (1975) gave a 1:2 shale-limestone value for the member at Parsons Quarry. The Ross Limestone was last described by Wilson (1949) as being a dark-blue, dense, argillaceous limestone, containing a geographically and stratigraphically restricted lithotype, the Bear Branch facies, which is an oolitic ironstone (hematitic limestone).

Samples were collected from each locality beginning 3 meters below the Ross-Decatur contact, except at Bear Branch, where samples were collected as far down into the Ross as possible (1.4m), and at Horse Creek where the outcrop was limited (1.0m thick). Carbonate samples were classified according to Dunham (1962) with most carbonate lithologies falling into the grainstone and packstone category. Representative samples from each facies were point counted except for the Ross Limestone, all samples of which were recrystallized mudstone. The combined field, acetate peel, and thin section descriptions are given in appendix A and point count data are given in appendix B. The samples will be described by locality in the following pages.

Olive Hill

The Olive Hill section is located in central Hardin County and contains the Rockhouse Limestone and the Ross Limestone members of the Ross Formation, and the underlying Decatur Limestone. The total section was measured from three different outcrops (A,B,C) (figure 5) along the same roadcut, with a total of 22 samples obtained for analysis (figure 6). Figure 7 shows the stratigraphic distribution of allochems and matrix for the Olive Hill section.

Four samples of the Decatur Limestone were collected at Olive Hill (unit O1A). These can be described collectively as being coarse- to medium-grained, medium- to thick-bedded echinodermal packstone/grainstone. The echinoderm grains, consisting mostly of crinoid columnals and plates, are the dominant fossil constituents (30-40%). These commonly are corroded and abraded, but well preserved, fragmented, and partly silicified grains and articulated columnals also are present. Almost all echinoderm grains have syntaxial overgrowths.

The abundance of other fossil allochems tends to increase upward in the section. Bryozoans are common (7-15%) only in the top two samples (OHD-1, OHD-2), with ramose, fenestrate, and rare encrusting types. Brachiopods generally are impunctate and commonly partly

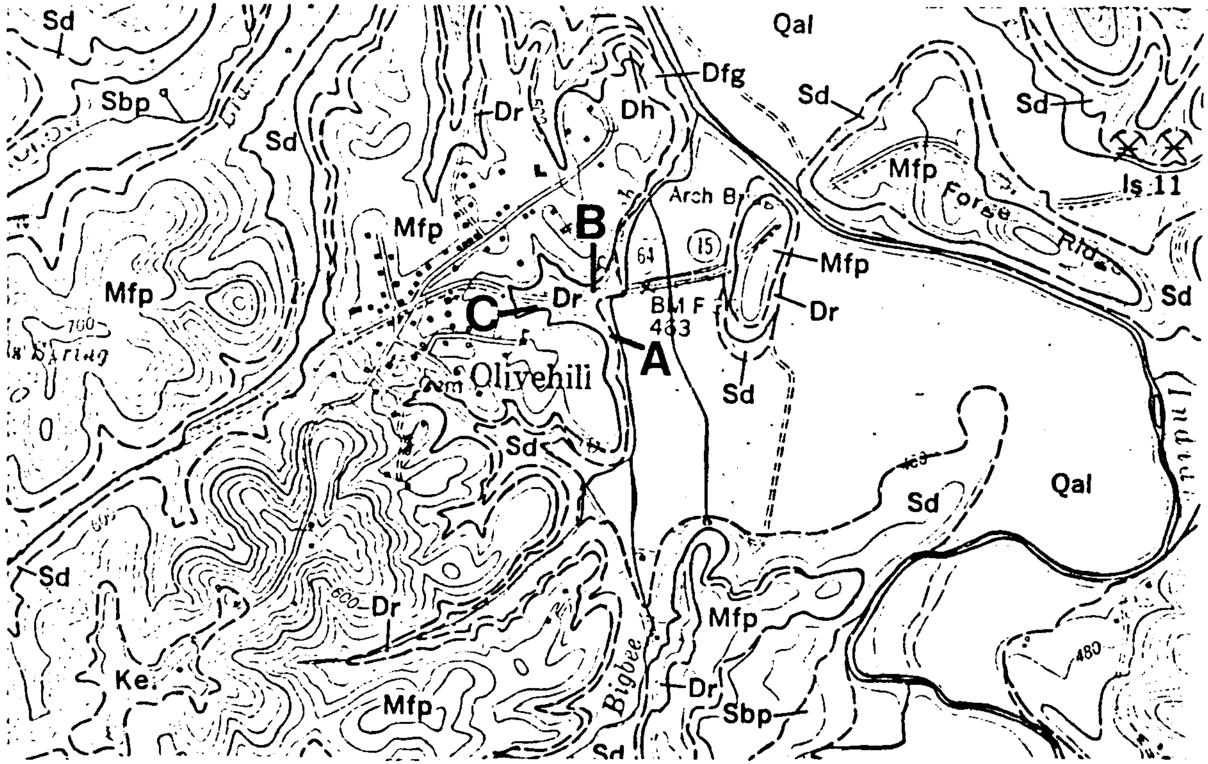


Figure 5. Topographic map of Olive Hill. Section shows outcrops A, B, C. From Olive Hill quadrangle map, scale 1:25,000.

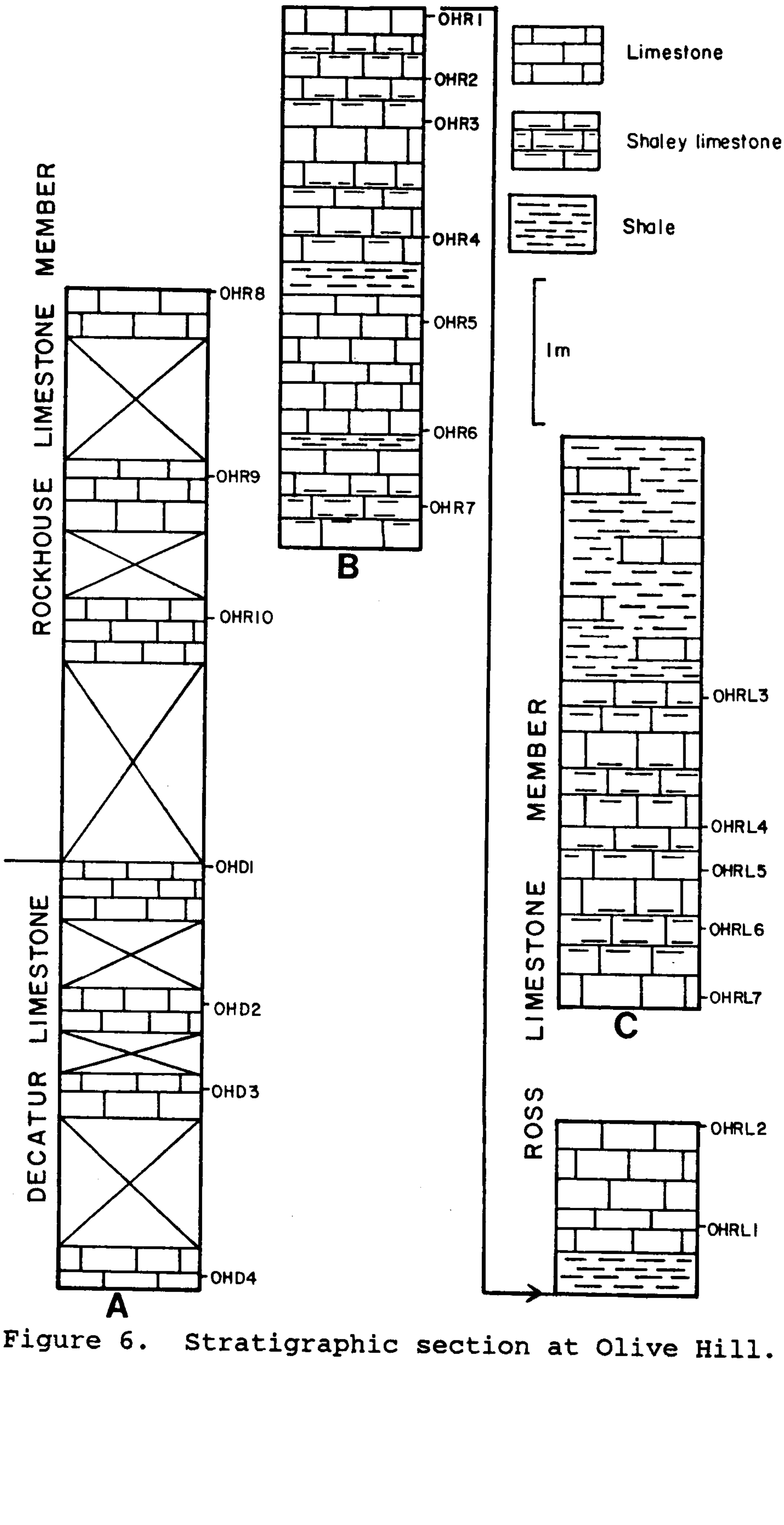
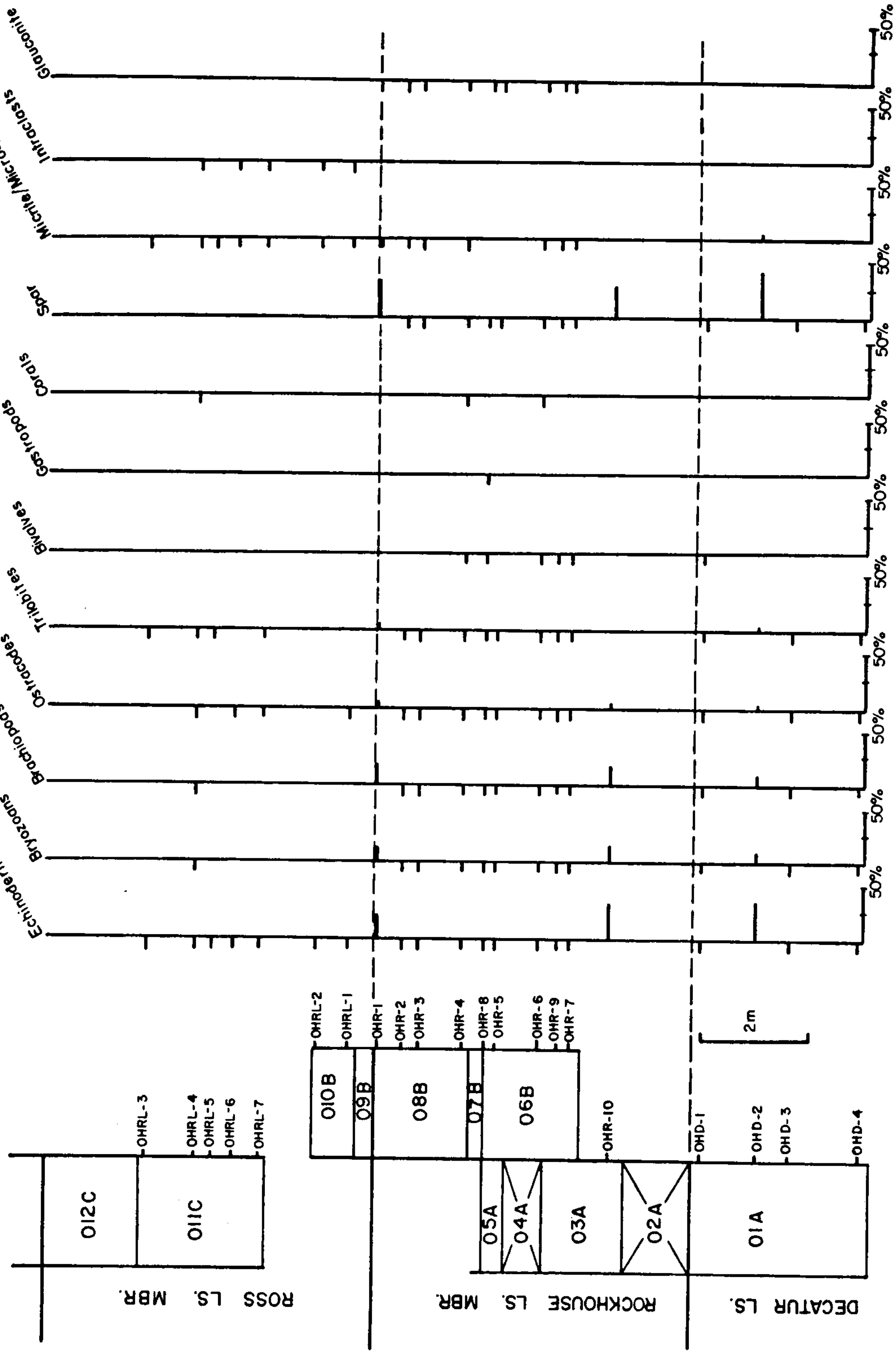


Figure 6. Stratigraphic section at Olive Hill.

Figure 7. Stratigraphic distribution of allochems and matrix for Olive Hill section. Lines to right of section denote sample locations; short lines to left of columns indicate presence in each sample; bars to right of columns indicate abundance in point counted slides.



Glauconite
Intraclasts
Micrite/Microspar
Spar
Corals
Gastropods
Bivalves
Trilobites
Ostracodes
Brachiopods
Bryozoans
Echinoderms
50%
OHRL-2
OHRL-1
OHR-1
OHR-2
OHR-3
OHR-4
OHR-8
OHR-5
OHR-6
OHR-9
OHR-7
2m
OHRL-3
OHRL-4
OHRL-5
OHRL-6
OHRL-7
OHR-10
OHD-1
OHD-2
OHD-3
OHD-4
O10B
O9B
O8B
O7B
O6B
O12C
O11C
O5A
O4A
O3A
O2A
O1A
ROSS LS. MBR.
ROCKHOUSE LS. MBR.
DECATUR LS.

silicified. At the top of the Decatur, sample OHD-1 contains large abraded brachiopods in association with large echinoderm columnals. Other allochems present throughout the Upper Decatur are small numbers of ostracodes (some articulated) and rare trilobite fragments.

The Decatur samples show a distinct trend in the amount of micrite present as matrix. OHD-4 was classified as a packstone while at the top of the section OHD-1 is a grainstone. Shale partings were not observed and much of the outcrop was covered. Styolites are well developed and common in all samples.

The Ross Formation at Olive Hill spans outcrops A, B, and C, and is divided into eleven informal units, the lowest seven of which comprise the Rockhouse Limestone member. There is an overlap between outcrops A and B (see Figure 5), and there is section missing between outcrops B and C. Each unit will be described separately.

The actual contact between the Decatur Limestone and the Ross Formation lies within a 1.4m covered interval (unit O2A). Differentiation of the Rockhouse from the Decatur was made primarily on the basis of color and texture, with the Rockhouse being coarser grained and dark to medium gray in color, whereas the Decatur was tannish pink in color. An increase in fossil diversity, especially brachiopods, also characterizes the Rockhouse (Reid, 1983).

The presence of glauconite was another criterion used in recognition of the Rockhouse. Wilson (1949) stated "The top few feet of the member are very glauconitic" whereas Reid (1983) noted that the first occurrence of glauconite in northern outcrops "is not within the lowest beds of the Rockhouse--but appears from 0.8m to 2.1m above the contact." The lowest sample (OHR-10) taken from the Rockhouse does not contain any glauconite and is not more than 1.7m from the basal contact. Stratigraphically higher (0.8m) from OHR-10, but across the road (outcrop B), sample OHR-7 also contained no glauconite. The first appearance of glauconite occurs in sample OHR-9 at outcrop A, 1.0m above from OHR-10 (0.2m up from OHR-7). By using the average known distance of the first occurence of glauconite (5.36m) from Reid (1983) as a boundary indicator, the boundary would be placed approximately in the middle of the covered unit or close to 2.0m below the first observed appearance of glauconite.

Unit O3A, consisting of coarse-grained grainstone (OHR-10, OHR-9) is composed predominately of echinoderm grains, brachiopods and bryozoans with minor ostracodes and trilobites. The major difference between the faunas of the Decatur and Rockhouse is the dramatic increase in the abundance (and diversity) of brachiopods. Point count data of sample OHR-10 shows 18% brachiopods in contrast to 6% in the topmost Decatur sample (OHD-2). The valves are randomly oriented and many are partly silicified.

Bryozoan abundance and diversity also increases up section across the Decatur-Ross boundary. Ramose and encrusting bryozoans are very abundant in samples OHR-9 and OHR-10; OHR-9 contains far more encrusting bryozoans than any other sample in the Ross Formation at this locality. These bryozoans may have encrusted an organism that is no longer preserved. They commonly appear to be encrusting around sparry patches and in some cases geopetal sediment (figure 8). Fenestrate fragments also are common in this unit, and in one sample (OHR-9) a large part of a frond is preserved.

Syntaxial overgrowths are present on almost all echinoderm grains. There are a few occurrences of bladed cement on fossil allochems, but for the most part, there is no evidence for the overgrowths to be marine in origin. Columnals are both articulated and disarticulated; abraded and fragmented grains and silicified grains are common. Echinoderm grains in the Decatur tend to be better preserved than those in the Ross (Rockhouse), an observation which also was made by Reid (1983). She suggested that the abrasion might be

Figure 8. Photomicrographs of algae and bryozoans of the Rockhouse Limestone.

1. Dasyclad algae. Sample OHR-3.

2. Dasyclad algae. Sample OHR-3.

3. Large unidentified bryozoan, tangential view. Sample OHR-3.

4. Bryozoan encrusting large, spar-filled void. Sample OHR-9.

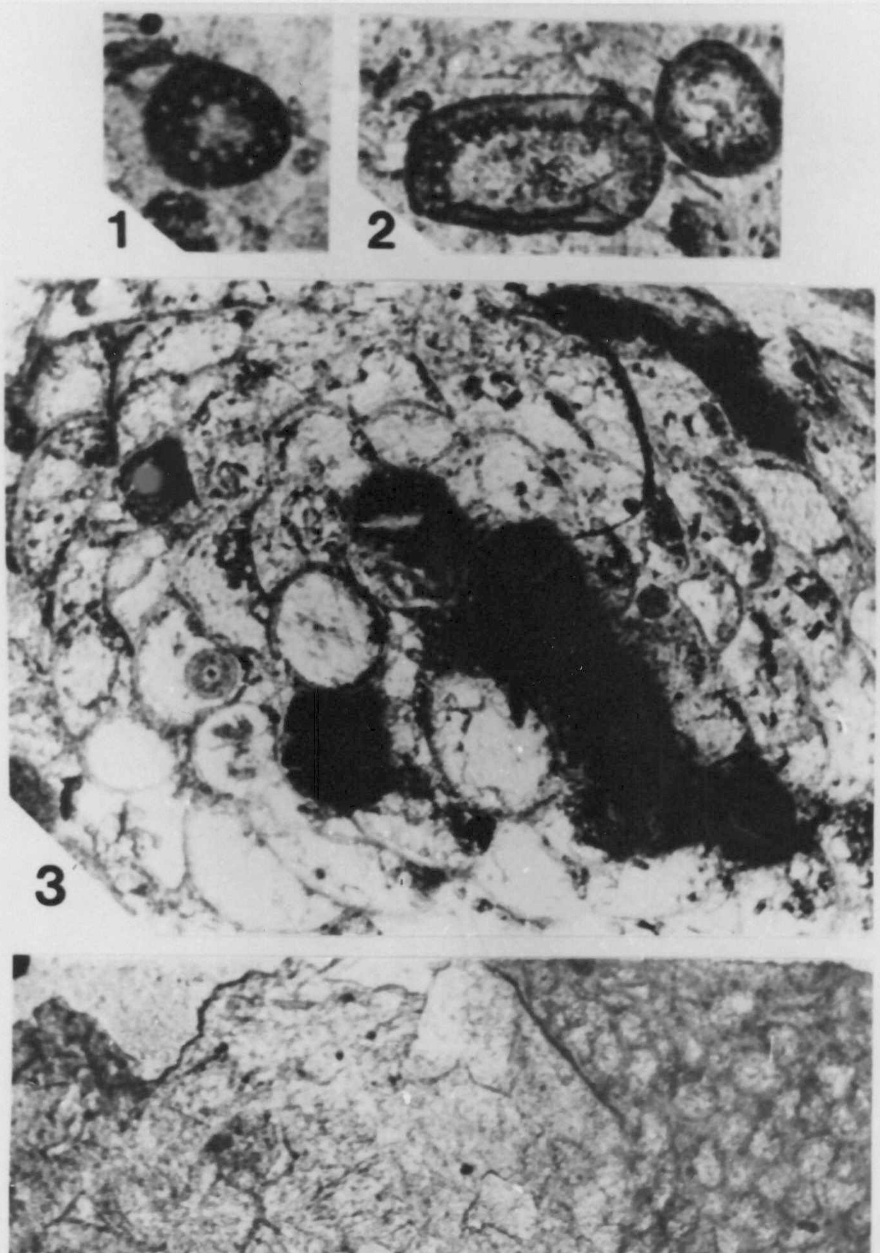


Figure 8.

biological in origin rather than physical, because articulated stems are common, suggesting little if any transportation. This may also be the case for the Rockhouse at this locality, although fragmented and abraded allochems may indicate some transportation (higher energy level).

Unit O5A, separated from O3A by a covered section (O4A), contains the same association of fossil allochems as the previous section (O3A), although the relative abundances differ. The most significant change is the increase in trilobite debris. Fragments of exoskeletons are common as well as a few large complete (or nearly complete) segments, and both genal and pygidial spines.

Bryozoans are still abundant, with ramose and fenestrate types being the most common. Fenestrates generally tend to be fragmented whereas the ramose forms tend to be larger in size than in stratigraphically lower units. Encrusters are also found in this unit, but are not as large or widespread as in unit O3A. Brachiopod and ostracode valves and echinoderm grains tend to be the surfaces upon which these bryozoans encrusted. Rugose corals are also evident, both in outcrop and in thin sections. Echinoderm grains and brachiopods are commonly silicified. Glauconite is present in small amounts, generally as pore fillings in bryozoans. The matrix is spar, which mainly consists of syntaxial overgrowths on echinoderm grains.

Across the road from unit O5A is a better exposed outcrop of the top half of the Rockhouse Limestone (unit O6B). Unit O6B contains both packstone and grainstone beds with numerous shale partings and shale beds. Micrite content decreases up section.

Echinoderm grains continue to be the dominant fossil allochem in O6B; columnals are commonly articulated and in varying states of preservation. Silica replacement and glauconite pore filling of grains occurs in the upper half of the unit. Brachiopods are very common, and valves generally are found convex up. Geopetal fillings are associated with many of the larger valves. Silicified and articulated valves were observed in all samples.

Bryozoans are still very abundant with all types observed. As in unit O3A, there is one sample (OHR-6) that contains abundant encrusting as well as ramose and fenestrate growth forms. Articulated ostracodes are common throughout the unit, as well as abundant disarticulated valves. Trilobite material includes whole segments and many fragmented pieces.

The uppermost unit of the Rockhouse Limestone at Olive Hill, O8B, is separated from the previously described unit by a gray shale with nodular limestone

(O7B). Unit O8B is a medium-bedded, coarse-grained, glauconitic grainstone with minor shale parting. Echinoderm grains are the dominant fossil allochem and, as in the previous units, are variously preserved, commonly found articulated and silicified or glauconite-filled. The typical Rockhouse lithology exhibited by sample OHR-2 is shown in figure 9.

Brachiopod diversity and abundance increases up section and silicification of the valves is common. Many valves are articulated, but they are randomly oriented, suggesting that none is preserved in life position. Bryozoans remain very common and well preserved, but encrusting types have decreased in abundance; brachiopods and echinoderm grains tend to be the encrusted surfaces. Ostracodes are common to abundant, and are frequently articulated. Trilobite material is also common. Rare calcareous algae (dasycladacean) are present in sample OHR-3 (figure 8).

Spar is the dominant matrix, commonly occuring as syntaxial overgrowths on echinoderm grains. Patches of secondary dolomite are common, especially in OHR-3, where they originally were areas of micrite, most probably burrows.

The Ross Limestone Member overlies the Rockhouse Limestone Member, separated by a 0.3m shale and nodular limestone unit. The Ross Limestone (units O10B and

Figure 9. Representative samples of the Rockhouse Limestone and Ross Limestone Members.

1. Photo-negative of thin section OHR-2, a fossiliferous grainstone. Bar is 1cm.

2. Photo-negative of thin section OHRL-7, a recrystallized lime mudstone showing burrows, intraclasts, and laminations. Bar is 1cm.

3. Photo-micrograph of HCRS-1, showing neomorphic microspar and a trilobite fragment.

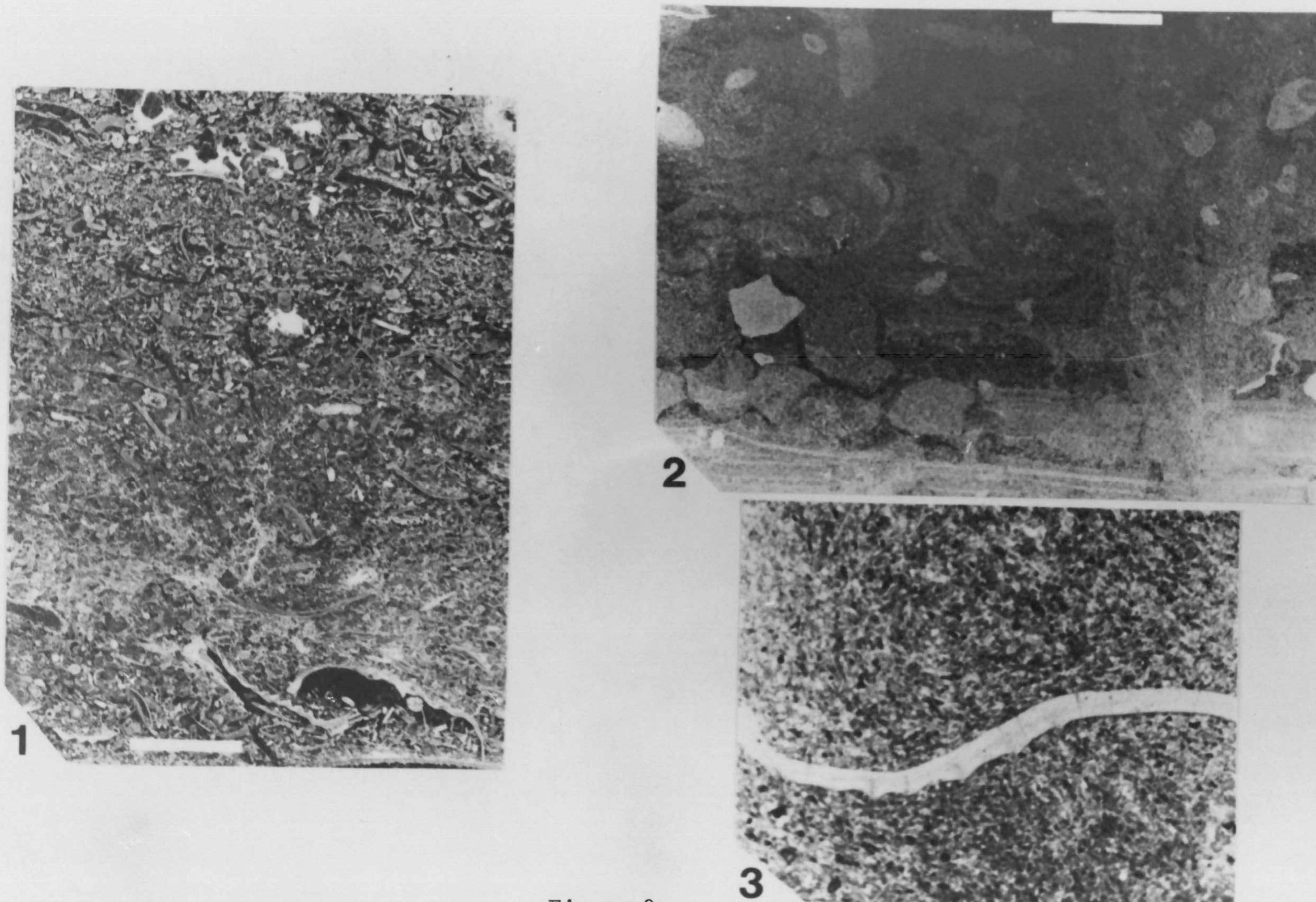


Figure 9.

O11C) is a dense, dark-blue argillaceous limestone with thin shale partings that are obvious on weathered outcrop. Wilson (1949 p.288) described weathered slabs as showing a "buff-colored periphery around an unbleached blue core", which is very characteristic of the samples obtained. Thin section analysis of the samples shows secondary (neomorphic) microspar, quartz (sand), with few fossil allochems. The spar is mottled with a few patches appearing to cross-cut other patches, or layers (laminations), suggesting that the first are burrows. Intraclasts are present in one sample (OHRL-7), and in some cases distinguishing clasts from burrows is difficult. Figure 9 shows a photo-negative of the burrows, clasts, and laminations of sample OHRL-7 as well as a photomicrograph of the typical Ross lithology at Horse Creek (HCRL-1).

Very small echinoderm grains and ostracode valves are present in all samples. OHRL-4 also contains large and well preserved encrusting and ramose bryozoans, trilobite fragments, brachiopod fragments, tabulate corals, and worm tubes(?), along with echinoderm grains. On the outcrop, bedding planes of the Ross Limestone Member are the only noticeable areas of fossil concentration, with a fauna similar to, but not as diverse or abundant, as that of the Rockhouse or the Birdsong members, its northern facies equivalents

(Wilson, 1949). The top unit of the Ross Limestone member, O12C, is a gray, moderately fossiliferous shale unit with discontinous beds of nodular limestone.

<u>Bear Branch</u>

The type section of the Bear Branch facies of the Ross Formation was described by Wilson (1949) as a "massive, cross bedded, medium to coarse-grained, red hematitic limestone, the upper part of which is less ferruginous". Other localities are described as being less ferruginous, thick bedded and cross-bedding less common. The type section, located 2 miles south-southeast of Olive Hill along Bear Branch (a tributary of Indian Creek) is approximately 12m in thickness (figure 10). Figure 11 shows the stratigraphic distribution of allochems and matrix for the Bear Branch section. Contact is gradational between Ross Limestone and Bear Branch facies, and the Bear Branch was interpreted by Wilson as being "a restricted facies equivalent to the upper part of the Ross Limestone member."

The iron is considered a primary deposit having accumulated in the form of oolitic coatings of hematite on various grains (echinoderms and other fossil allochems) and has been thought to resemble the Silurian Clinton iron ores (Dunbar, 1919). On the average, the

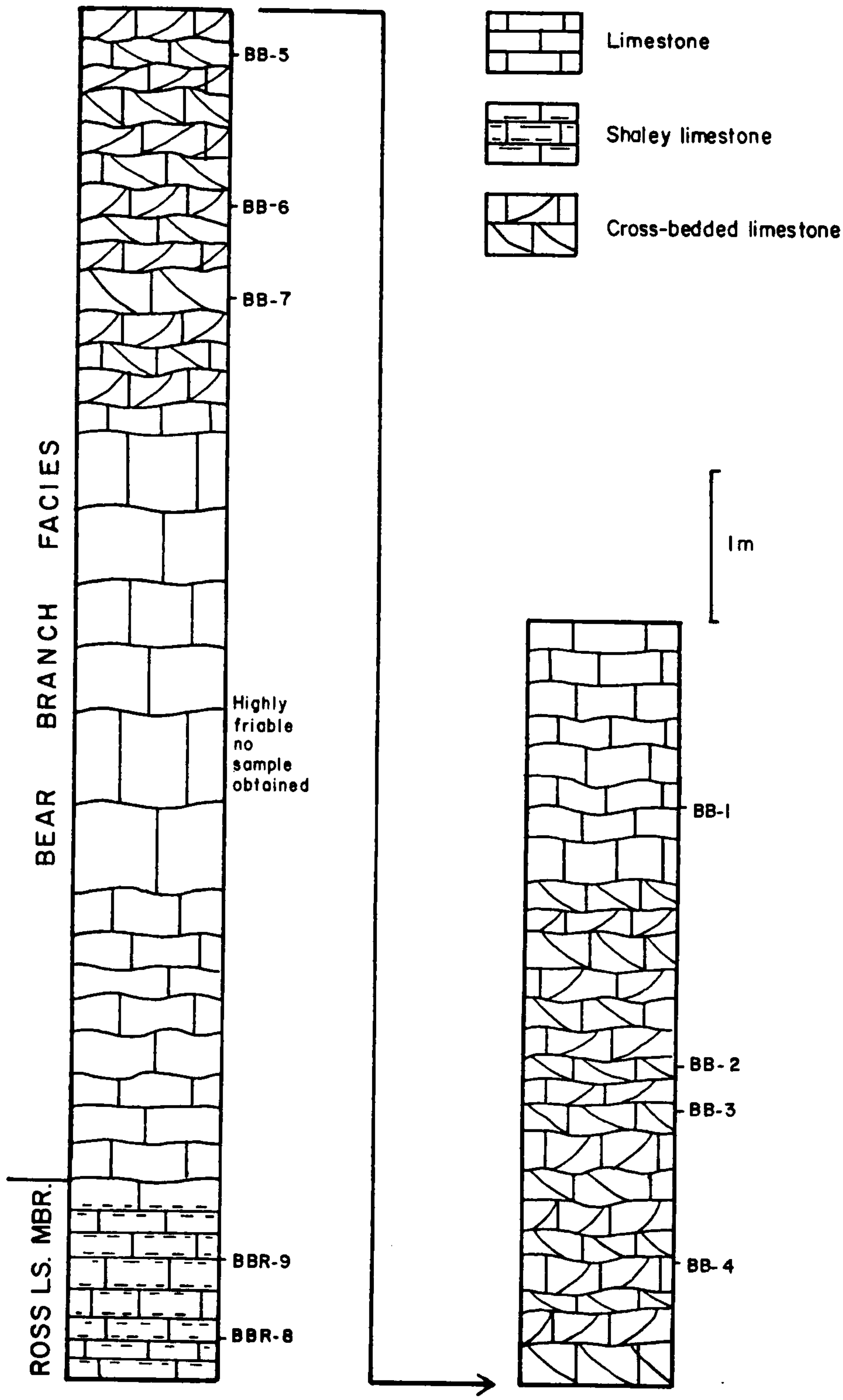
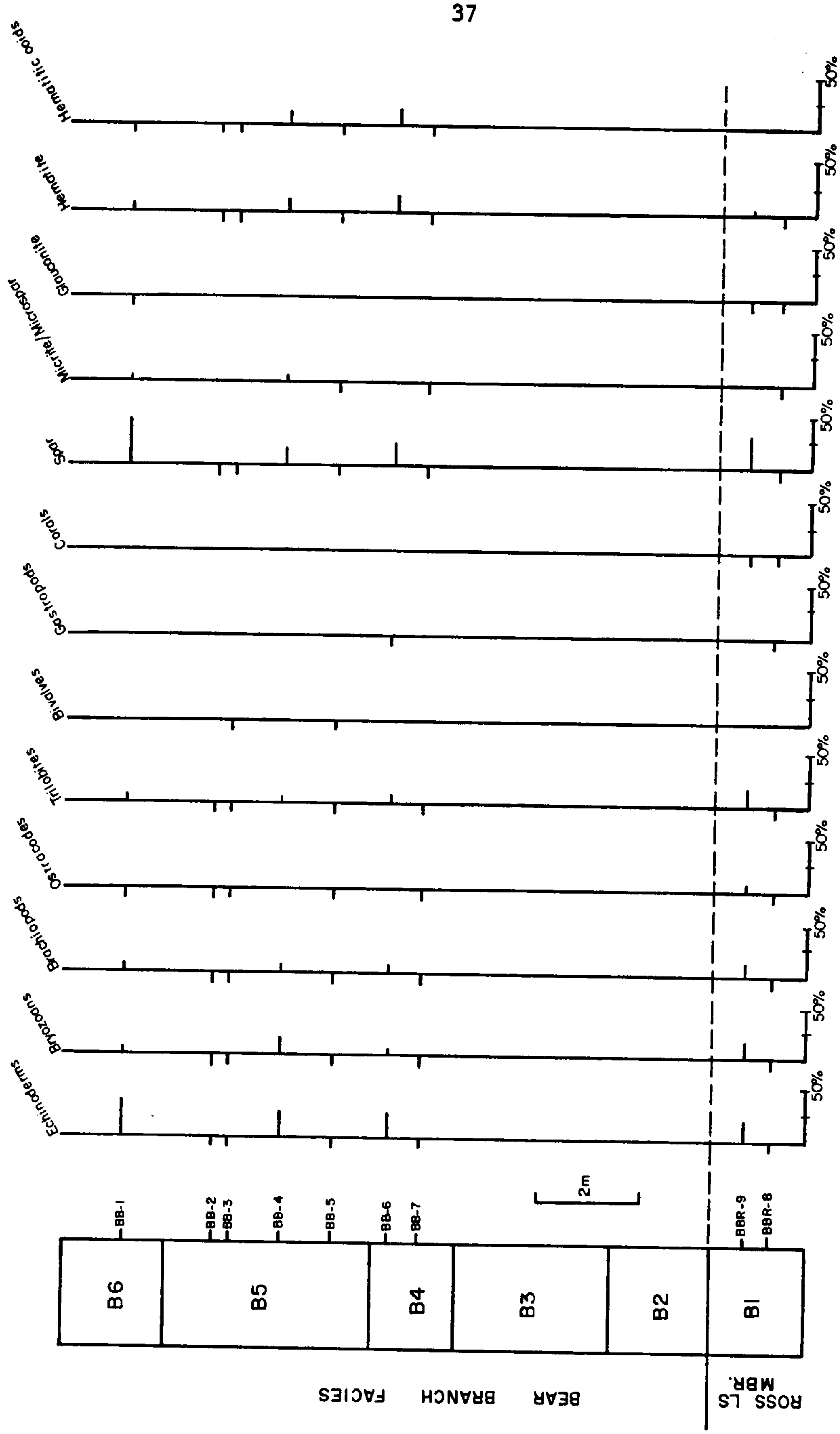


Figure 10. Stratigraphic section at Bear Branch.

Figure 11. Stratigraphic distribution of allochems and matrix for Bear Branch section. Lines to right of section denote sample locations; short lines to left of columns indicate presence in each sample; bars to right of columns indicate abundance in point counted slides.


Hematitic ooids
Hematite
Glauconite
Micrite/Microspar
Spar
Corals
Gastropods
Bivalves
Trilobites
Ostracodes
Brachiopods
Bryozoans
Echinoderms
50%
BB-1
BB-2
BB-3
BB-4
BB-5
BB-6
BB-7
BBR-9
BBR-8
2m
B6
B5
B4
B3
B2
B1
BEAR BRANCH FACIES
ROSS LS MBR.

iron content is 20-26% (low grade ore) and the same beds were once mined before the Civil War at an outcrop near Clifton (Wilson, 1949), approximately 4 miles east of Olive Hill, 2 miles northeast of Bear Branch. The distribution of the Bear Branch facies is very limited with all exposures found within a 4.5 mile radius. Wilson (1949, p.298) stated:

> The initial extent was undoubtedly much greater, but it is believed that this facies was originally confined to the partially enclosed basin of the Ross Sea, surrounded by belts of shoal water representing the Ozark dome to the west, the southern Decatur County axis to the north, the Nashville dome to the east, and the central Hardin County axis to the south. If this interpretation is correct, [it] suggests that the center of deposition of the Bear Branch facies probably lay west of the preserved remnants, probably in what is now north-central Hardin County.

At Bear Branch the first unit, B1, represents the Ross Limestone. Outcrop along the creek was limited, especially higher in the section where much of the exposure is seen only in the creek bottom. The Ross Limestone of B1 is a bluish gray, medium-to fine-grained, medium-bedded grainstone with hematitic stringers and shale partings. The hematite is generally found as oolitic coatings and/or pore fillings of fossil allochems. Glauconite is also present as small pellets and pore fillings in fossils. Terrigenous clastic debris (quartz sand and silt) is present in minor amounts (1-5%).

Echinoderm grains are the dominant fossil allochem (16%) along with abundant brachiopods (11%), trilobite debris (15%), and ostracodes (4%). The echinoderm grains are generally plates and disarticulated columnals and are typically small (1mm-4mm). The brachiopods tend to be smaller in size than in the other sections. Articulation of the valves is common, and the brachiopods, in general, are most abundant on bedding planes.

Trilobite debris is common, with some segments being large (10mm-20mm) and well preserved, not fragmented. Ostracodes are common, some being articulated. Bryozoans are present in minor amounts, and most are found in the slightly coarser grained and stratigraphically lower sample of the Ross (BBR-8).

Patches of secondary dolomite in this unit suggest micrite-filled horizontal burrows. Spar is the dominant matrix type, mainly consisting of syntaxial overgrowths on echinoderm grains. As with the Rockhouse Limestone, there are some fibrous cements present, but for the most part, there is no evidence for marine cementation.

The contact between the Ross Limestone and the Bear Branch facies is gradational, consisting of alternating thin-bedded to very thin-bedded bluish grainstone and hematitic grainstone (unit B2). The bluish limestone is fossiliferous, predominately consisting of brachiopods with echinoderms and corals on bedding surfaces. The hematitic layers increase rapidly in thickness upward, to a massive-bedded, friable, fossiliferous, profusely hematitic grainstone (unit B3).

Unit B4 consists of cross-bedded, very fossiliferous, coarse grained interbedded grainstone and hematitic grainstone (oolitic ironstone). Figure 12 is a photo-negative of sample BB-7 showing the hematitic and carbonate layers as well as small scale cross-bedding. On weathered outcrop the cross-beds are easily seen, with some cross-bed sets more resistant than others because of a greater amount of calcium carbonate.

Fossil allochems, dominantly echinoderms and brachiopods make up the interbeds in this unit, along with minor bryozoans, trilobites, ostracodes and bivalves and small hematitic ooids. Echinoderm grains are large (10mm-20mm) and commonly found as articulated columnals. Brachiopods are also large (20mm-30mm) and commonly found on bedding planes, although they are also present within the limestone beds. Orientation of the valves tends to be random, and articulated valves are common, especially on bedding surfaces. Silicification of the valves is common. Trilobite material is common to abundant in B4, with large and small fragments present throughout the unit. Bryozoans occur in minor

Figure 12. Representative samples of the Bear Branch facies.

1. Photo-negative of thin section BB-7, a cross-bedded, hematitic grainstone. Dark colored layers are limestone, light colored layers are hematite. Bar is 1cm.

2. Photo-micrograph of oolitic hematite of Bear Branch, sample BB-6. Hematite (dark colored) occurs as oolitic laminations on fossil allochems, and as fillings in pore spaces.

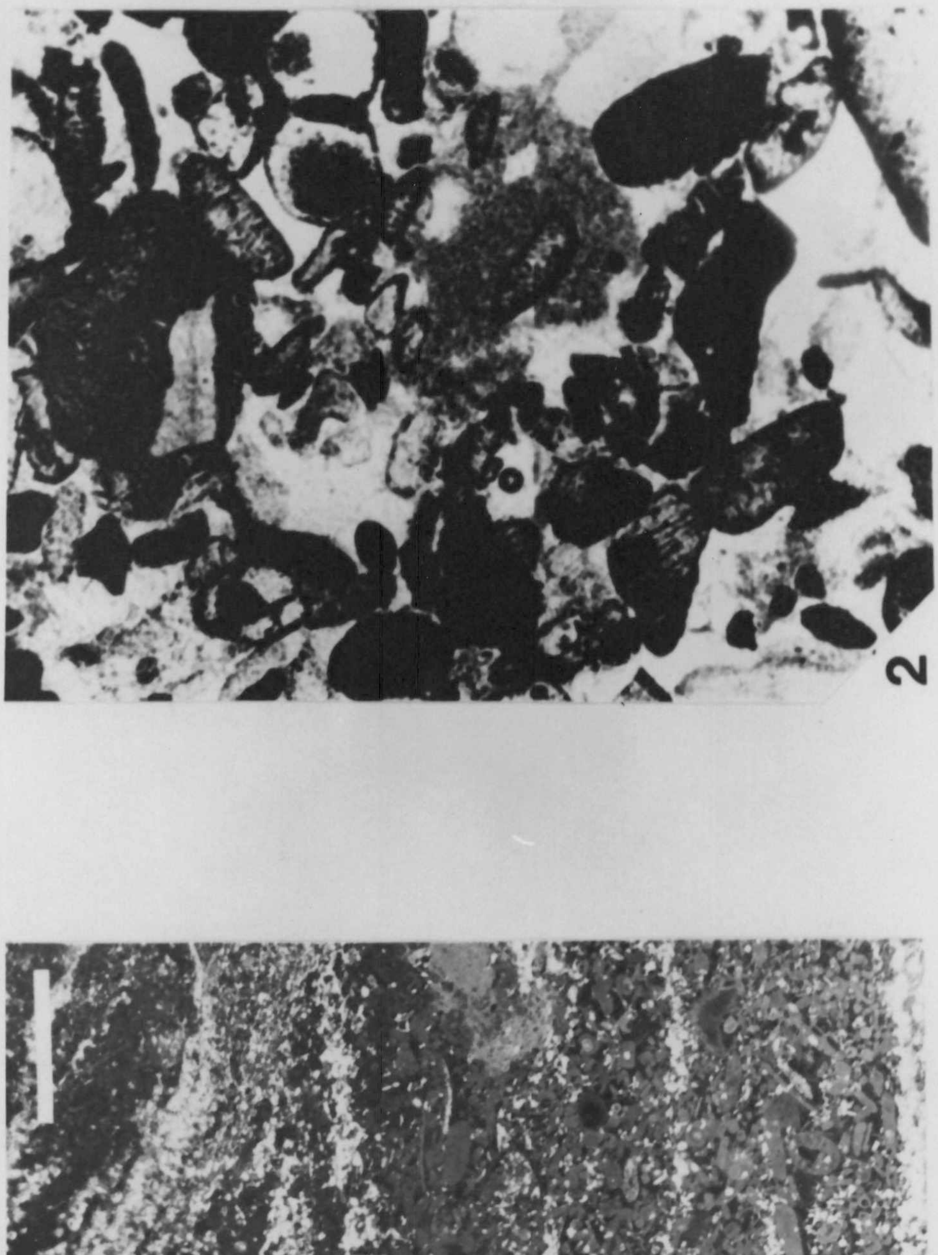


Figure 12.

amounts, usually as ramose and encrusting types. Ostracodes and bivalves are minor to rare in abundance.

Spar is the dominant matrix type. Small areas of micrite mixed with small fossil allochems (predominantly echinoderm grains) are present, which possibly represent burrows.

Unit B5 is a hematite-rich, cross-bedded, coarse-grained grainstone. The hematite occurs mostly as oolitic coatings on fossil grains, as well as replacement of fossils, as fillings of pore spaces, and as individual pellets (figure 12). In all cases, the grains are moderately rounded. Cross-bedding is planar-tabular with irregular (wavy) bedding surfaces.

Echinoderm grains are the dominant fossil allochem in this unit; they are predominately small in size (1mm-4mm) although larger grains are present in all samples, especially as seen on weathered outcrop. Most echinoderms show some degree of abrasion and/or fragmentation. Articulation of columnals and silicification of the grains are common thoughout the unit.

Brachiopods are common throughout B5 and are usually oriented convex side up. Trilobite material is also common, but there is a decrease in abundance from lower units. Bryozoans also show a decrease in abundance, with some encrusting and ramose types observed. Ostracodes and bivalves are rare.

Spar is the dominant matrix, although there are layers and patches of micrite, especially in sample BB-5. The spar is predominantly syntaxial overgrowths on echinoderm grains.

The top unit at Bear Branch, B6, is characterized by a dramatic decrease in the hematite content with an increase in fossil abundance. Particularly noticeable is the increase in large articulated crinoid columnals and brachiopod valves. There also is an increase in ostracodes, although these are present only in minor amounts. Other fossil allochems include trilobite fragments and bryozoans.

The unit is a medium to thickly bedded, coarse-grained grainstone with hematite stringers. Bedding planes are irregular and generally contain the greatest proportion of hematite; cross-beds are absent. Hematite grains (generally not oolitic) are also found in micritic layers or patches within the beds.

The contact between the Bear Branch and the overlying Flat Gap Limestone is gradational. Wilson (1949) reports that at all localitites, the contact between the Ross Formation and the Flat Gap Limestone is sharp and unconformable except at Olive Hill, where it is not sharp and may be conformable or separated by only a minor break in deposition. Although this is not the same outcrop that Wilson described, it is in close proximity (less than a mile) to it.

Horse Creek

The Horse Creek section is a small, partly covered outcrop along Horse Creek in southern Hardin County (figure 13). Other localities used by Wilson (1949) to make his composite Horse Creek section were sought, but were either completely covered or not accessible. Two samples of the Rockhouse Shale Member were taken, one of which was from a limestone bed within the shale. Four samples were taken from the overlying Ross Limestone member.

The Rockhouse Shale Member is restricted to south-central Hardin County (see figure 2, p. 7). Wilson gives an average thickness of 25 feet (7.6 m); only 1.08m was observed at this locality.

The Rockhouse Shale is described as being a gray, fossiliferous, calcareous shale with occasional beds of limestone (Wilson, 1949). The outcrop sampled contained virtually no fossils, except for some large *Scyphocrinites* bulbs within one sparsely fossiliferous limestone bed. This bed has the typical Ross Limestone lithology, bluish-gray, dense argillaceous limestone. Small echinoderm grains, trilobites, ostracodes and brachiopods are present along with minor quartz silt. The bed is laminated and contains many possible burrow traces, most of which are horizontal in orientation.

The contact between the Rockhouse Shale and the Ross Limestone is sharp, with a layer of large *Scyphocrinites*

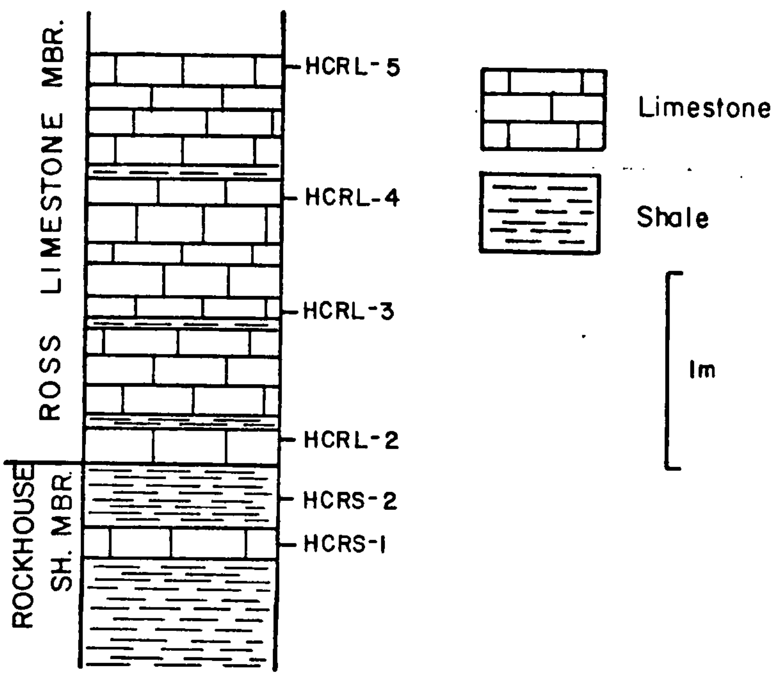


Figure 13. Stratigraphic section at Horse Creek.

bulbs marking the base of the limestone. The lithology of the Ross Limestone is basically the same as at Olive Hill (a siliceous, fine-grained, dense grainstone). Burrows, laminations, erosional surfaces and minor intraclasts are present along with few fossil allochems, which include echinoderm grains, trilobites, ostracodes, brachiopods and bryozoans. The outcrop contains many shale partings and fissile shaley limestone layers, in which the majority of the fossil allochems, most commonly Scyphocrinites bulbs and articulated echinoderm stems, are found.

Parsons Quarry

The northernmost locality studied is Parsons Quarry, located 3 miles north of Parsons in Decatur County. The Decatur Limestone (Silurian) is overlain by the Ross Formation, consisting of the Rockhouse Limestone and Birdsong Shale members. These formations and members were sampled; acetate peels were made of each sample (Figure 14). An overall summary of this section will be made based upon data from Reid's unpublished Master's thesis (1983) combined with data from the peels made for this study.

Five samples of the Decatur Limestone were collected, beginning 3m below the Decatur-Ross contact. Generally the Decatur is a coarse-grained, echinodermal packstone, with minor grainstone beds present. Shale partings are common, increasing towards the top of the section. Diversity of the

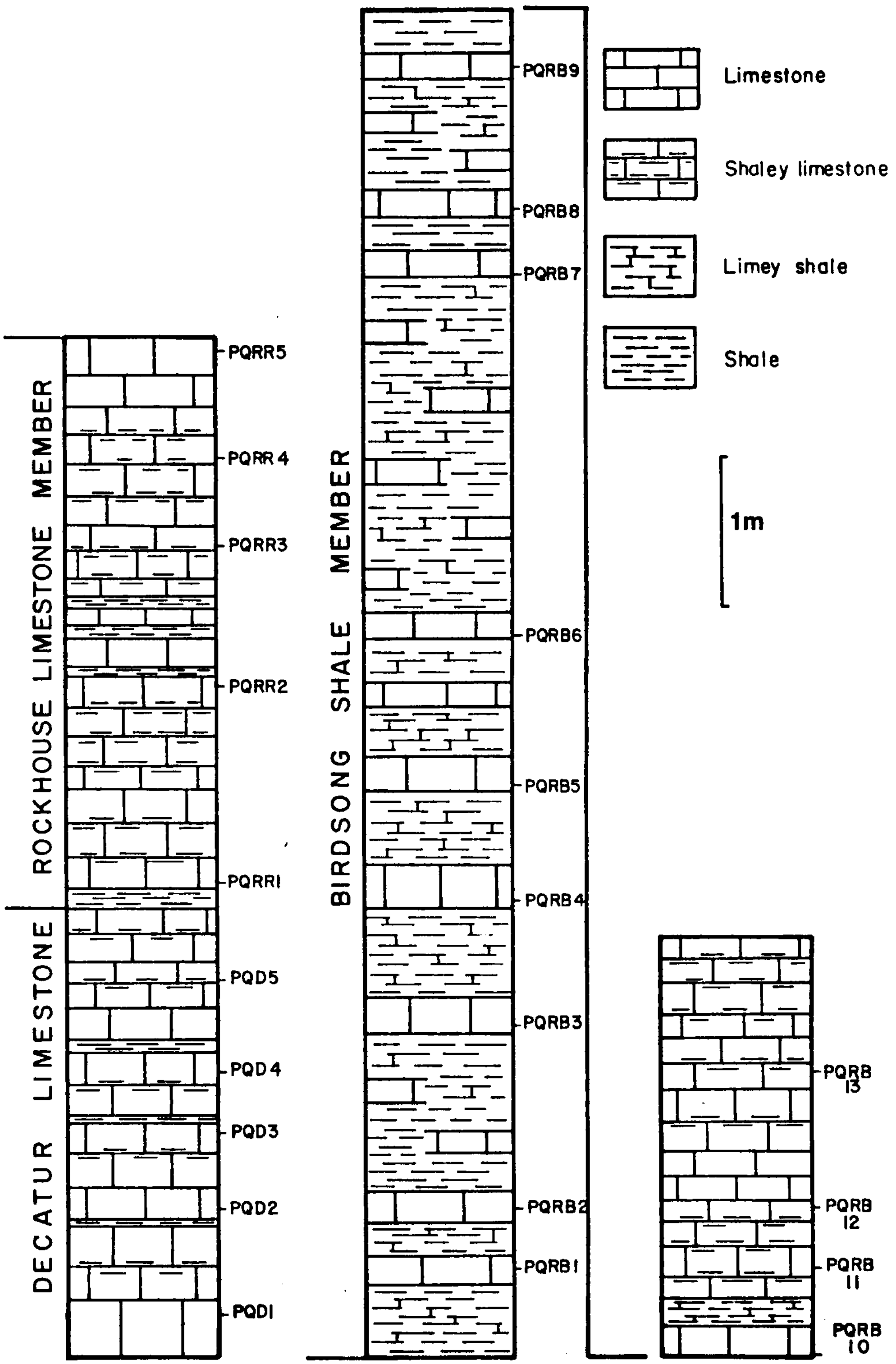


Figure 14. Stratigraphic section at Parsons Quarry.

fossil allochems also increases up section, with brachiopods and bryozoans especially becoming abundant. Other fossils present are trilobites, ostracodes, and corals (rare), with preservation ranging from good to abraded and fractured.

The contact between the Decatur Limestone and the Rockhouse Limestone member is marked by a 10cm shale bed. Above this shale, the Rockhouse is a thinly-bedded, coarse-grained packstone/grainstone with numerous shale partings and beds and shaley limestone. Samples of the Rockhouse are predominantly packstone. Glauconite is present in minor amounts at the base of the unit and increases in abundance upward. The fauna is very diverse with echinoderm grains, brachiopods, bryozoans, trilobites, and ostracodes present in all samples; corals and bivalves are less common. Preservation of allochems ranges from good to poor. Both abraded and fragmented grains, and articulated crinoid stems and brachiopod valves are present in some samples.

The Birdsong Shale is marked by a dramatic increase in the amount of shale, with the lithology characterized as a shaley limestone and fossiliferous terrigenous mudstone. Reid described two units of the Birdsong, lower and upper. The upper is distinguished from the lower by the presence of large crinoid stems and ramose bryozoans in the very-thin-to thin-bedded packstone beds. The same subdivision can be seen based on samples collected for the present study.

The lower Birdsong consists of thin-bedded, medium- to fine-grained skeletal packstone/wackestone interbedded with shale and thick shaley limestone units. Glauconite is abundant throughout the unit. A high diversity and abundance of fossil allochems (brachiopods and bryozoans) is observed, although there are beds (layers) that are less fossiliferous. The fauna is similar to that of the Rockhouse, consisting of echinoderm grains, brachiopods, bryozoans, trilobites, ostracodes, and rugose corals. Preservation ranges from good to very poor, with most grains showing some degree of abrasion and fracturing; unidentifiable fossil debris is present in many samples.

Limestone beds in the upper Birdsong show a decrease in the amount of micrite matrix present; most beds are a thin-bedded grainstone/packstone. Some samples contain alternating layers of grainstone and packstone. An increase in the diversity of fossil allochems was noted by Reid, especially in the bryozoans, with some samples near the top of the unit being almost entirely composed of encrusting bryozoans. Large, robust crinoid stems, most of which are extensively silicified, are very abundant throughout the lower half of this unit. Other fossils present are brachiopods, trilobites, ostracodes, and rugose corals, most ranging from well preserved and articulated to fragmented and abraded. Shale beds also contain many fossil allochems, especially crinoid stems and brachiopods.

Paleodepositional Environments of the Ross Formation

Previous work on the depositional environments of the Ross Formation is very limited (Reid, 1983; Walker and Pruitt, 1975). Environmental investigations and faunal correlations primarily have concerned the Birdsong Shale Member (Amsden, 1962; Laporte, 1969; Reid, 1983).

Wilson (1949) first introduced the currently accepted generalized facies interpretation of the Ross Formation (see figure 3,p.9). He suggested that the Birdsong Shale and Ross Limestone members are lateral facies of each other; both contain similar faunas, although the Birdsong fauna is more diverse and abundant. The occurrence of the "bryozoan zone" (Wilson, 1949; Petersen, 1972) throughout both the Birdsong and Ross Limestone also supports the conclusion that they were deposited at or near the same time. The different facies of the Ross Formation tend to be very distinct, with sharp boundaries separating the units at most outcrops. A gradational contact between the Ross and Birdsong members was found by Wilson in northern Hardin County; this exposure has been covered since then by water due to damming of the Tennessee River. It was reported to have contained 20 feet of typical Birdsong lithology overlain by 15 feet of Ross lithology.

The Birdsong biofacies, especially the brachiopod component is very similar to the fauna of the Helderberg Group in New York, and of the Haragan Formation in Oklahoma (Amsden, 1962; Laporte, 1969; Petersen, 1972; Reid, 1983). Both the brachiopod fauna (Dunbar, 1919; Amsden, 1958; Boucot and Johnson, 1967) and the ostracode fauna (Wilson, 1935; Lundin, 1968; Petersen, 1972) of the Birdsong, Haragan and New Scotland/Kalkberg (Helderberg Group) have been described in detail and are similar. Dunbar (1919) suggested that the "Haragan shale of Oklahoma represents a western arm of this same epeiric sea" extending from Alabama up through Kentucky to New York (figure 15).

The Helderbergian sequence of New York and Oklahoma is thought to represent deposition in a broad, epicontinental (epeiric) sea (Amsden, 1962; Laporte, 1979). Shaw's (1964) and Irwin's (1965) models of epeiric clear water sedimentation (figure 16) indicate the generalized energy zones in epeiric seas which influenced the type of sediment deposited but do not consider specific depositional regimes.

Laporte (1969) demonstrated how the Helderberg sequence of New York was associated with an epeiric sea. The oldest formation of the Helderberg Group, the Manlius, was deposited in a low energy, broad, intertidal lagoon with localized tidal flats, prograding over protected subtidal deposits influenced by periodic storms. Seaward, the Coeymans Formation was deposited as a series of crinoid mounds and

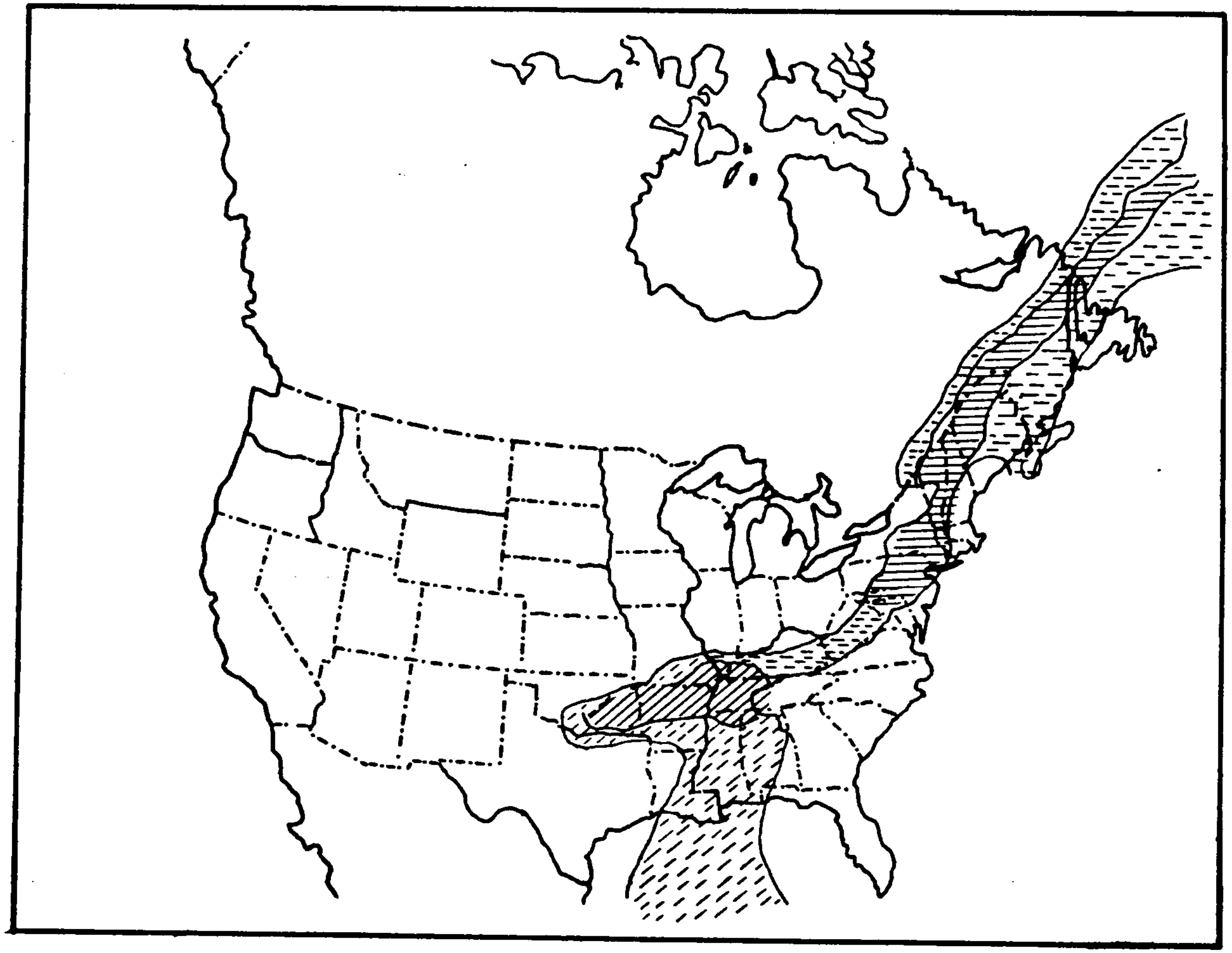


Figure 15. Paleogeographic map of New Scotland time in eastern North America. The known extent of the seas is shown by solid lines, and the conjectural expanse by broken lines (modified from Dunbar, 1919, p.23).

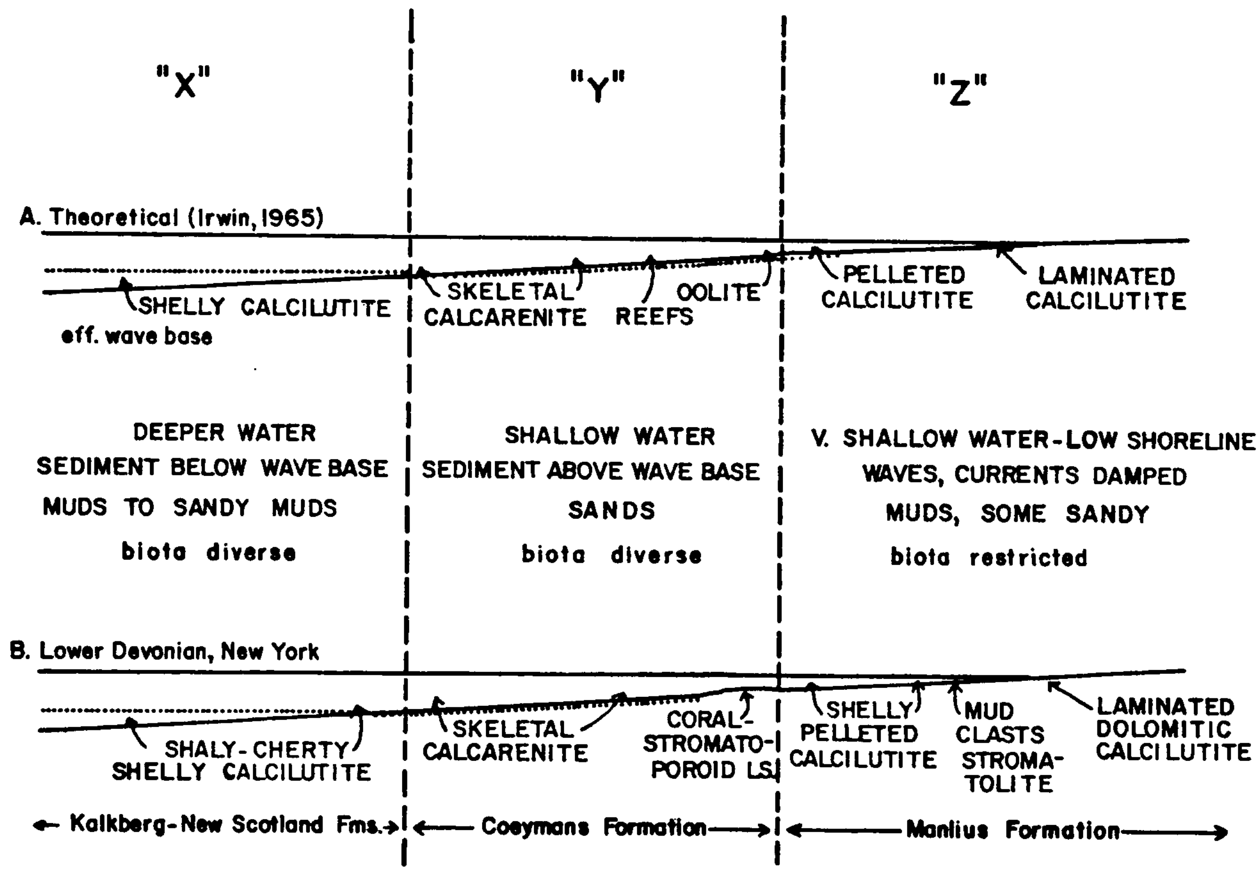


Figure 16. Model of shallow marine sedimentation showing theoretical and actual distribution of major sediment types. A) Theoretical epicontinental clear-water sedimentaiton after Irwin (1965). B) Lower Devonian Helderberg Group in central and eastern New York, after Rickard (1962), and Laporte, (1967, 1969). (after Heckel, 1972).

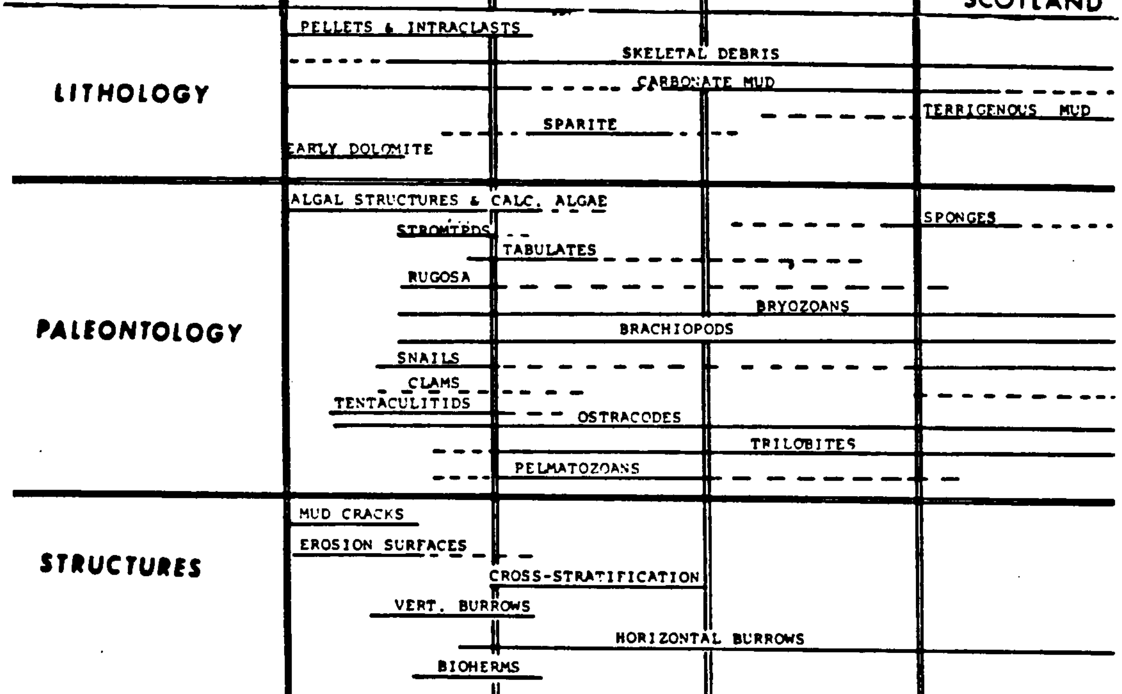
banks in a high energy, shallow environment. These mounds served as barriers between the lagoonal waters and the more open marine environment farther offshore, which is represented by the Kalkberg-New Scotland formations. Criteria used for recognition of these facies are variations in constituent carbonate grain types, mud-spar ratios, fossil abundance and diversity and presence of primary sedimentary structures. A summary of the lithology, paleontology, sedimentary structures, and depositional environments is shown in table 1.

Amsden (1962) believed that the Silurian-Early Devonian strata of Oklahoma (Henryhouse, Haragan-Bois d'Arc formations) were deposited "in relatively widespread, generally shallow seas . . . ." The Haragan-Bois d'Arc formations grade laterally into one another and have faunas and lithologies similar to those of the Kalkberg-New Scotland formations of New York, although Reid (1983) pointed out that the Oklahoma sequence represents an overall shallowing (regressive) environment instead of a deepening (transgressive) sequence shown in New York.

The Decatur-Rockhouse Limestone-Birdsong Shale sequence was suggested by Reid (1983) to be a deepening (transgressive) sequence. The echinoderm-rich Decatur Limestone (Silurian) is thought to represent subtidal crinoidal sandbanks, a similar environment to that of the Coeymans Formation of New York and the Fittstown member of

Table 1. Summary of lithology, paleontology, sedimentary structures, and environments of lower-middle Helderberg units in New York with inferred environmental equivalents from the Upper Silurian and Lower Devonian of west-central Tennessee (after Laporte, 1969).

STRAT. UNITS	MANLIUS	COEYMANS	KALKBERG	NEW SCOTLAND
LITHOLOGY PALEONTOLOGY STRUCTURES	(see chart below)			
ENVIRONMENT	TIDAL FLAT-LAGOON: POOR CIRCULATION. HIGHLY VARIABLE ENVIRONMENT.	HIGH AND LOW ENERGY SUBTIDAL: GOOD CIRCULATION. STABLE ENVIRONMENT EXCEPT FOR VARYING WATER AGITATION.	OPEN, SHALLOW SHELF LOW ENERGY; HIGHLY STABLE ENVIRONMENT WITH GOOD CIRCULATION. LOW TERRIGENOUS INFLUX.	OPEN, SHALLOW SHELF; LOW ENERGY. VARIATIONS CAUSED BY PERIODIC TERRIGENOUS INFLUX.
TENNESSEE EQUIVALENTS	ROSS	BEAR BRANCH ROSS DECATUR	ROCKHOUSE	BIRDSONG



the Bois d'Arc Formation in Oklahoma. In slightly deeper, subtidal waters, the Rockhouse Limestone member was deposited, with a more diverse fauna than the Decatur, plus minor carbonate mud matrix and shale partings, indicating an environment that was below normal wave base but was periodically subjected to waves and currents. Reid (1983) indicated that the Rockhouse was said to resemble the Kalkberg Formation of New York and the Cravatt member of the Bois d'Arc Formation of Oklahoma. The Birdsong Shale is an argillaceous limestone, interbedded with terrigenous mudstone, a lithology similar to the Haragan and the New Scotland formations, which are considered to be low energy shelf deposits with fine-grained terrigenous influx. The Rockhouse Limestone at Olive Hill contains rare calcareous algae in the upper unit, which suggests that the Rockhouse environment at this locality was shallowing into that of the Ross Limestone.

In a report on early to middle Paleozoic carbonate facies of the central Appalachian shelf, Laporte (1971) described the shallow subtidal facies (Manlius Formation) as having two idealized end members, calcarenites (biosparites or grainstones) and calcilutites (biopelmicrites or wackestones). The calcilutites are described as lacking evidence of frequent wave or current agitation and winnowing, therefore the matrix is primarily micrite. Burrow-mottling is common and usually well preserved. Primary current stratification may have been present, but was probably disturbed by burrowing organisms. Brachiopods and ramose bryozoans are the common fossil allochems, with fossils in general showing a moderate diversity but low abundance. Laporte stated that the skeletal grains are usually whole and articulated or poorly sorted fragments without any preferred orientation.

The Manlius Formation also contains tidal flat deposits containing abundant intraclasts, vertical burrows, mudcracks, and erosional surfaces. Laporte (1969, p.110) stated that the "shallow subtidal conditions existed marginally to the tidal flats, and that the supratidal and subtidal environments shifted periodically."

The Ross Limestone member of the Ross Formation has many of the characteristics of this shallow subtidal/lagoonal to tidal flat facies. It is a dense, thin-bedded, argillaceous limestone with intraclasts and a moderately diverse fauna of low abundance. Many beds within the unit apppear to be unfossiliferous. There is little indication of an indigenous shelly fauna with the majority of the fossils concentrated on bedding surfaces indicating that the shells probably were washed in by storms. The fossils present within the beds are generally well preserved. Both horizontal and vertical burrows are abundant, some cross-cut others, and some cut across laminated sediment. Intraclasts are also present and were probably derived from higher reaches of the tidal flat.

This shallow subtidal environment represented by the Ross and Manlius developed below mean low water and above mean wave base. Laporte noted that "lack of cross-stratification and abundance of mud in the calcilutites does not demand deposition below wave base because not all shallow subtidal deposits need to be current agitated." Occasional storms may have agitated the bottom sediment, which could account for the intraclasts and erosional layers present within the Ross Limestone. Intraclasts may have been transported from the intertidal zone into the low to high intertidal environment represented by the Ross Limestone. If the Ross Limestone represents and environment very near to the tidal flat environment, it could be assumed that some subareal exposure may have occured, allowing for the formation of the intraclasts. Dunbar (1919) noted that at one outcrop (Dry Creek) in the extreme southern part of the state, the beds in the upper Ross Limestone were locally cross-bedded. This may indicate a transitional stage between the Ross Limestone and the Bear Branch facies.

The Bear Branch facies is a cross-bedded oolitic ironstone which is found in the upper Ross Limestone in central Hardin County. An oolitic ironstone is defined by Kimberley (1978) as being an iron-rich (more than 15%) sedimentary rock, in which hematite is present primarily as oolitic coatings on grains, but is also found as individual pellets and replacement or pore filling in fossil grains.

The ooids present in this study are superficial ooids, containing less than 5 laminations. This suggests that there was not optimal conditions for ooid accretion, such as continual motion of the water, but only minor aggitation.

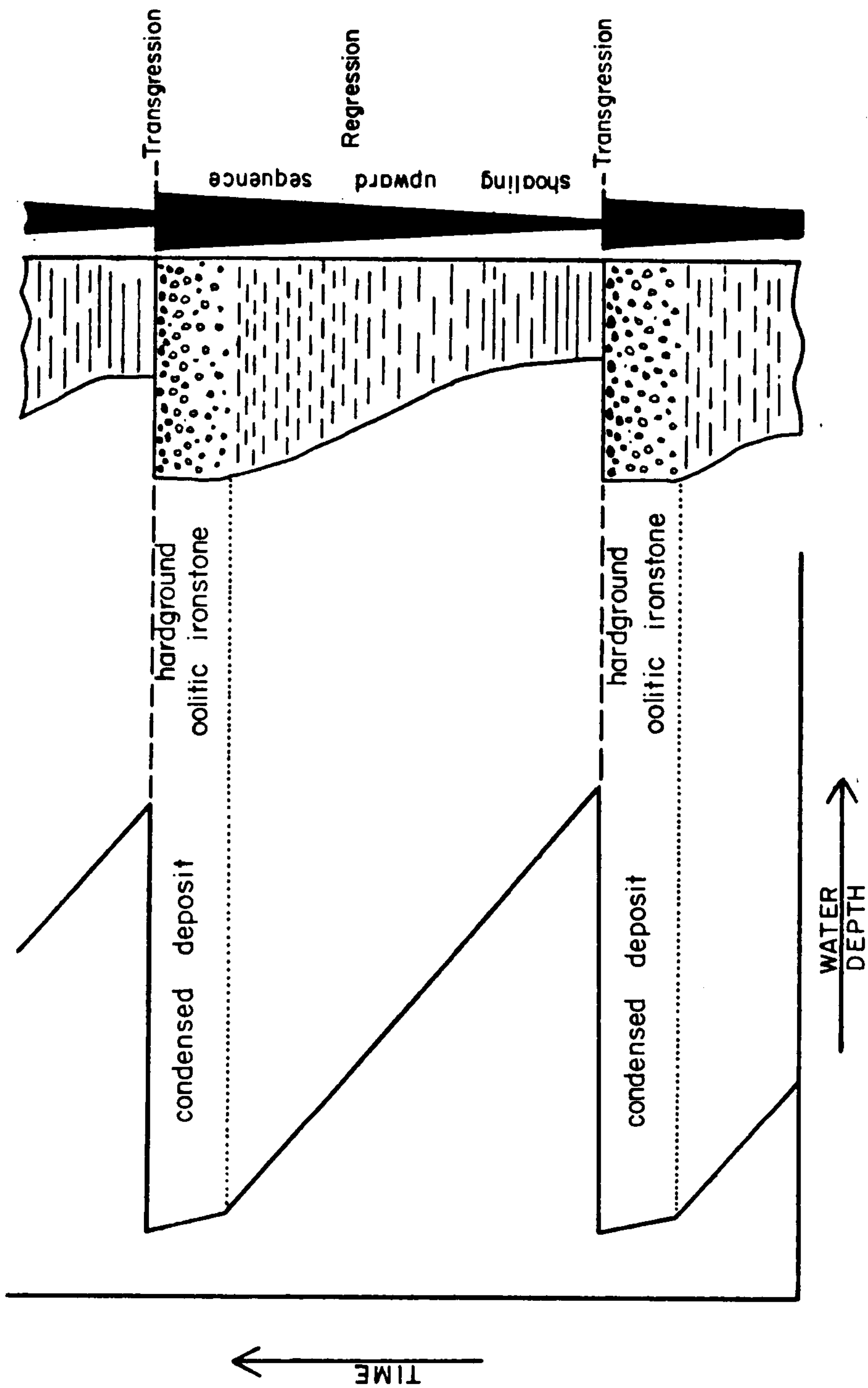
The origin of ferruginous ooids is a subject of debate; two main theories exist, although neither offer a good explanation of the geochemical, diagenetic, and other problems involved with the formation of oolitic ironstones. Kimberley (1979) supports the early idea of Sorby (1856) that the oolitic iron formations were originally beds of calcareous oolite, which were covered by mud and organic matter. Leaching of the iron from the mud by pore water resulted in ferruginization of the aragonite or calcite ooids.

In an SEM study of ironstone ooids, Bhattacharyya and Kakimoto (1982) showed that the internal fabric of the ooids is in a tangential-concentric orientation. The proposed method of formation of these ooids is a "snow balling" effect, in which the tangential fabric is produced by "mechanical accretion of already existing particulate matter on rolling nuclei." They suggested that clay (kaolinite) and hydrated iron oxides were mechanically accreted onto a nucleus, with early diagenetic reactions transforming the clays into ferric oxides. The formation of aragonite ooids by this "snow balling" has been proposed by Sorby (1879). This theory is generally rejected by most carbonate sedimentologists by means of minerological and textural evidence (Land, Behrens, and Frishman, 1979).

Reviewing the geologic record of oolitic ironstones, Van Houten and Bhattacharyya (1982) determined that oolitic ironstones were commonly formed when there was a mild climate, with widespread transgression of the continents causing much weathering, and tectonic stability accompanied by decreased detrial influx into shallow seas. They also proposed a facies model into which most of Phanerozoic ironstone deposits fit. Figure 17 shows that oolitic ironstone represents condensed deposits that usually occur at the end of a regressional sequence or at the beginning of a renewed trangression. They are said to accumulate in relatively low-energy (minor agitation by waves and tides) shallow marine environments. Some of the ooid beds were deposited in marine waters with abundant benthic fauna and normal salinity, whereas others developed in protected brackish lagoons with a less diverse and abundant fauna. The authors emphasized that the conditions given (such as water energy) for the formation of oolitic ironstones are "favorable but not necessary factors", with the most crucial factors being a mild climate, subdued tectonic activity and deep weathering.

In the Early Devonian, western Tennessee was situated between 10^{o} and 35^{o} S latitude (Bambach and Scotese, 1979; Heckel and Witzke, 1979) in an area of tectonic stability and

Figure 17. Facies model of oolitic ironstone-bearing shoaling-upward detrital sequence. Also showing the relation of prolonged regression and relatively rapid transgression (from Van Houten and Bhattacharyya, 1982, p.446).


Transgression
Regression
Transgression
shoaling upward sequence
hardground
oolitic ironstone
condensed deposit
hardground
oolitic ironstone
condensed deposit
WATER DEPTH
TIME

and widespread transgression (flooding) of the continent (Figure 18). With a high sparite to micrite ratio, cross-stratification, and a diverse and abundant fauna that is commonly fragmented and abraded, the Bear Branch facies can be classified as a shallow water, agitated, normal marine deposit.

Laporte's (1971) shallow subtidal facies was mentioned earlier as having two end members, a calcilutite/wackestone member (represented here by the Ross Limestone Member), and a calcarenite/grainstone member. The beds of grainstone show evidence of wave and current agitation and winnowing by such features as cross-stratification, high sparite-to-micrite ratios, disarticulated and fragmented skeletal grains and ooids. These grainstone beds also generally have a high fossil abundance and diversity. The Bear Branch facies, with all of the above characteristics, can be placed within this facies, as can the Coeymans Formation of New York. Although it probably was not a high energy deposit with reefs or bioherms, the Bear Branch environment was frequently agitated in order to produce the superficial ooids and cross-stratification.

The Ross Formation as a whole was deposited in a shallow epeiric sea (which deepened to the north) that probably extended to Oklahoma and to New York, but most

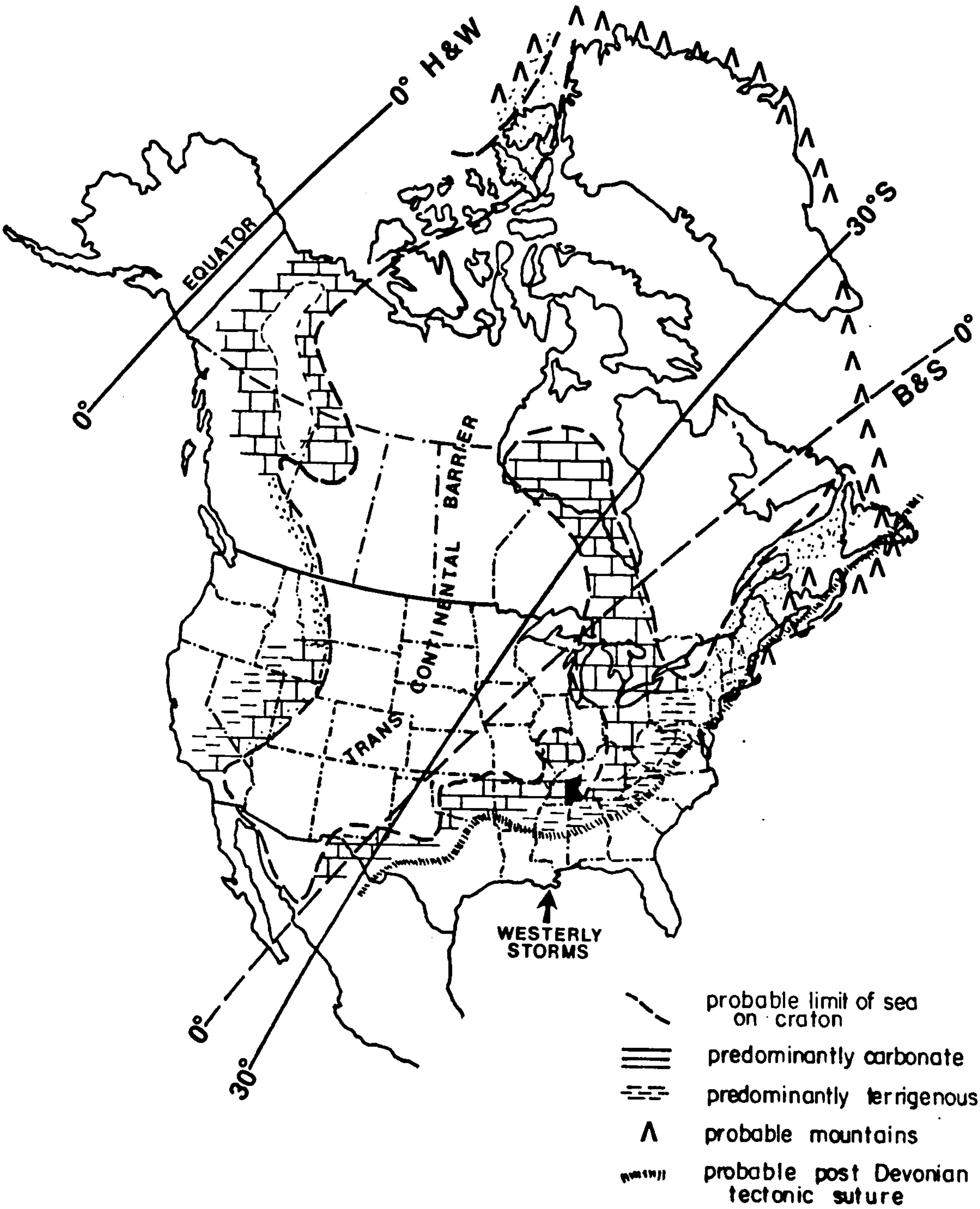
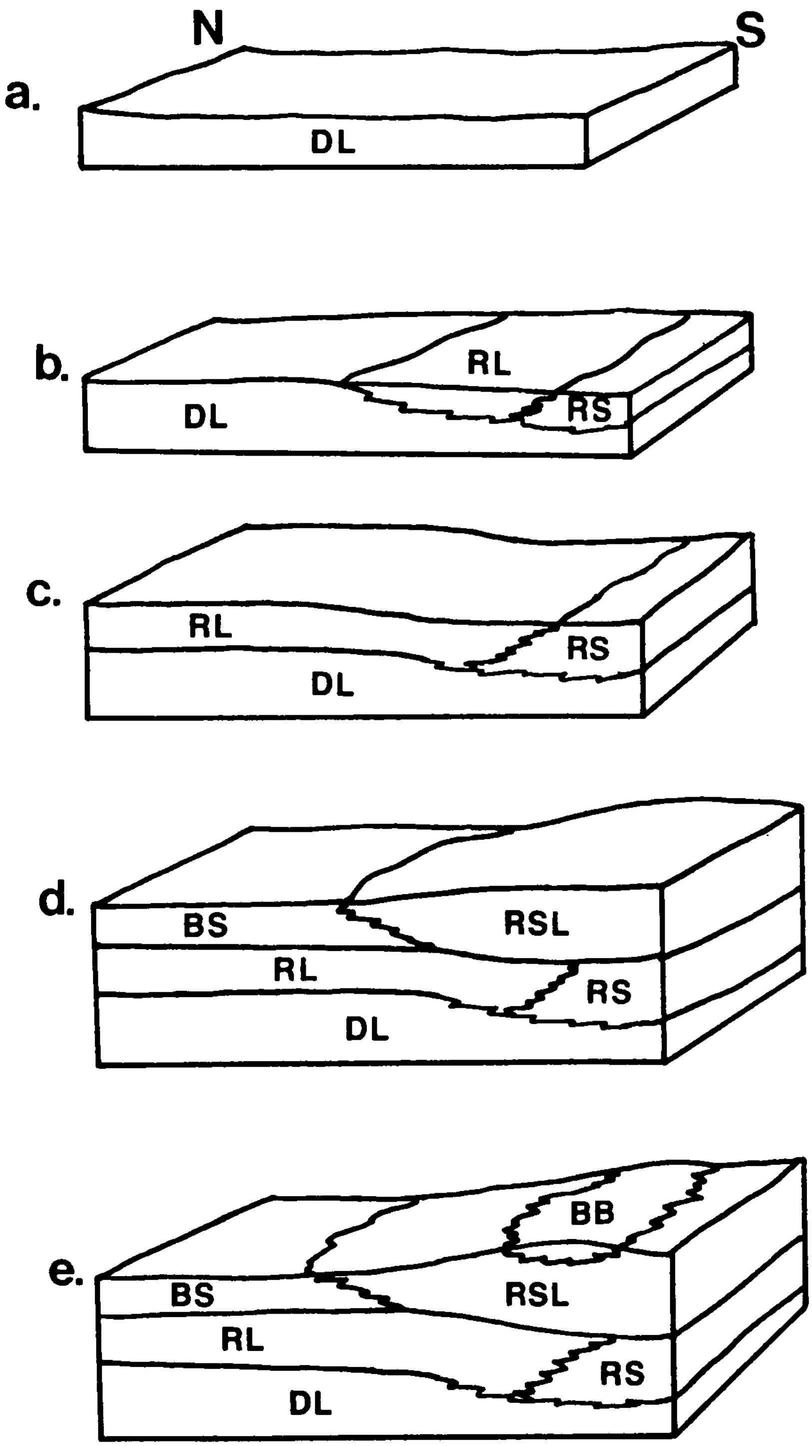


Figure 18. Generalized Lower Devonian lithofacies of North America (from Heckel and Witzke, 1979; Bambach and Scotese, 1979).

of the intervening areas are covered now by younger rocks. This would account for the uncertainty of the types of barriers present and the source of the terrigenous sediment. A brief summary of the deposition of the Decatur Limestone and the Ross Formation is given in figure 19 and described below.

The Decatur Limestone (Silurian to Early Devonian) was said by Reid (1983) to have been deposited in a shallow, high energy crinoidal sandbank environment in Late Silurian time (figure 19a). Terrigenous mud began to accumulate (Rockhouse Shale), concentrated to the south possibly in deeper water by means of a topographical high acting as a barrier. North of this barrier, the Rockhouse Limestone was deposited in only slightly deeper water (shallow subtidal) than the Decatur, with minor terrigeneous influx (figure 19b,c). Into the Early Devonian, the area to the south shallowed due to accumulating autochthonous carbonate sediment (Ross Limestone), which was deposited in a shelf lagoonal to tidal flat environment. At approximately the same time, water in the northern area became deeper with a greater influx of terrigenous mud (Birdsong Shale) (figure 19d). Shoaling, along with an increase in water circulation occurred to the south and the Bear Branch facies was deposited (figure 19e). This environment was agitated enough to coat grains for the

Figure 19. Block diagrams illustrating the suggested pattern of deposition of the Upper Silurian to Lower Devonian sequence in west-central Tennessee. A- Upper Silurian, b- Siluro-Devonian boundary, c-e - Lower Devonian. DL= Decatur Limestone, RL= Rockhouse Limestone, RS= Rockhouse Shale, RSL= Ross Limestone, BS= Birdsong Shale, BB= Bear Branch facies.


N
S
a.
DL
b.
RL
DL
RS
c.
RL
RS
DL
d.
BS
RSL
RL
RS
DL
e.
BB
BS
RSL
RL
RS
DL

formation of hematitic superficial ooids. Wilson (1949) interpreted the Bear Branch facies as being deposited in a basin (see figure 3, p.9) within the Ross Limestone. Sedimentological and petrological structures shows no evidence of deepening waters. Cross-bedding, superficial ooids, and other evidence suggest a shallow water deposit with a moderate water energy.

CHAPTER III

CONODONT BIOSTRATIGRAPHY AND PALEOECOLOGY

Introduction

The Silurian-Devonian boundary, by international definition, is marked by the base of the *Monograptus uniformis* Zone in bed 20 of the graptolite succession, at the type section in Klonk, Czechoslovakia. The *woschmidti* Zone, based on the first appearance of the conodont *Icriodus woschmidti*, can also be used as a working approximation for the base of the Devonian where graptolites are not present. At the type section in Czechoslovakia, *M. uniformis* and *I. woschmidti* first appear in the same bed, however, at other localities (USSR, Nevada) they do not correspond (Klapper, et. al., 1971). In Podolia, USSR, *I. woschmidti* occurs below the first appearance of the graptolite, and at Roberts Mountains, Nevada, the *M. uniformis* Zone was recognized 4 feet (1.2m) below the lowest occurence of *I. woschmidti* (Klapper, et. al., 1971). Murphy and Berry (1983) established by means of graphic correlation, that the western North American conodont and graptolite zones are approximately equivalent to the Czechoslovakian sequence.

The top of the Pridoli (Silurian) is marked by the *eosteinhornensis* Zone, containing the conodont *Ozarkodina remscheidensis eosteinhornensis*. This zone can be correlated with the *Monographtus transgrediens* Zone (graptolite) (Walliser, 1971).

The Early Devonian is divided into 11 conodont zones (Klapper and Johnson, 1980) (figure 20). The zones are based primarily on the western North American (Nevada) and European sequences. Eastern North American occurrences have not yet played a major part in developing this zonation.

In western North America, the lower part of the Lower Devonian is subdivided into six zones (Klapper, 1977; Klapper and Ziegler, 1979) (figure 21) based on collections from Nevada and the Yukon Territory. The bottom half of figure 21 shows the faunal sequence of the conodonts from Spain, with eight zones described. This sequence is considerably different from that of western North America, with only five species in common. Figure 18 shows an attempt to correlate between the two sequences, with only one strong correlation present, between the North American *Ozarkodina* n. sp. D and the Spanish d2a gamma zones (Klapper and Ziegler, 1979). The other zonal correlations are essentially arbitrary, because of the dissimilar faunas.

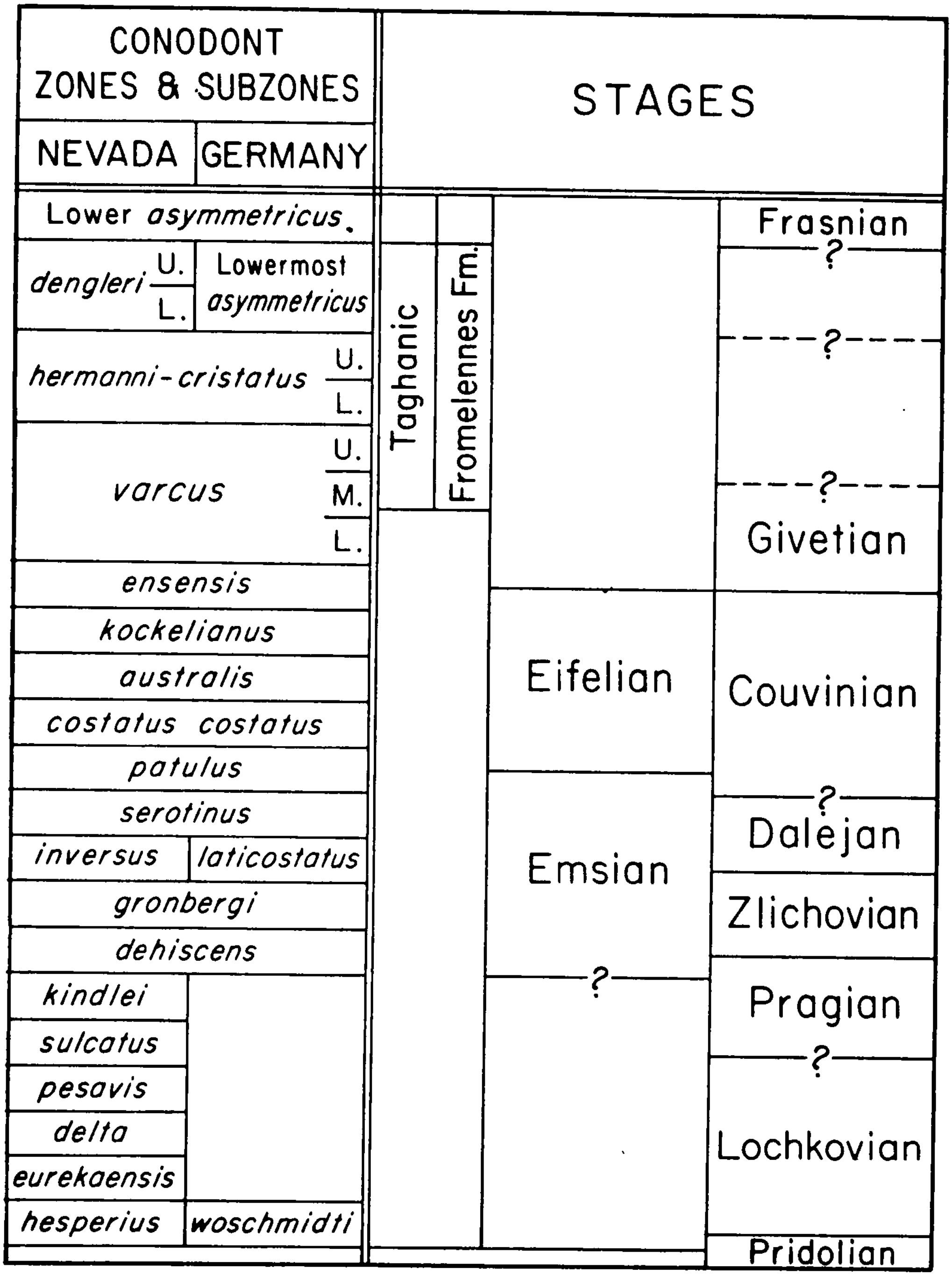
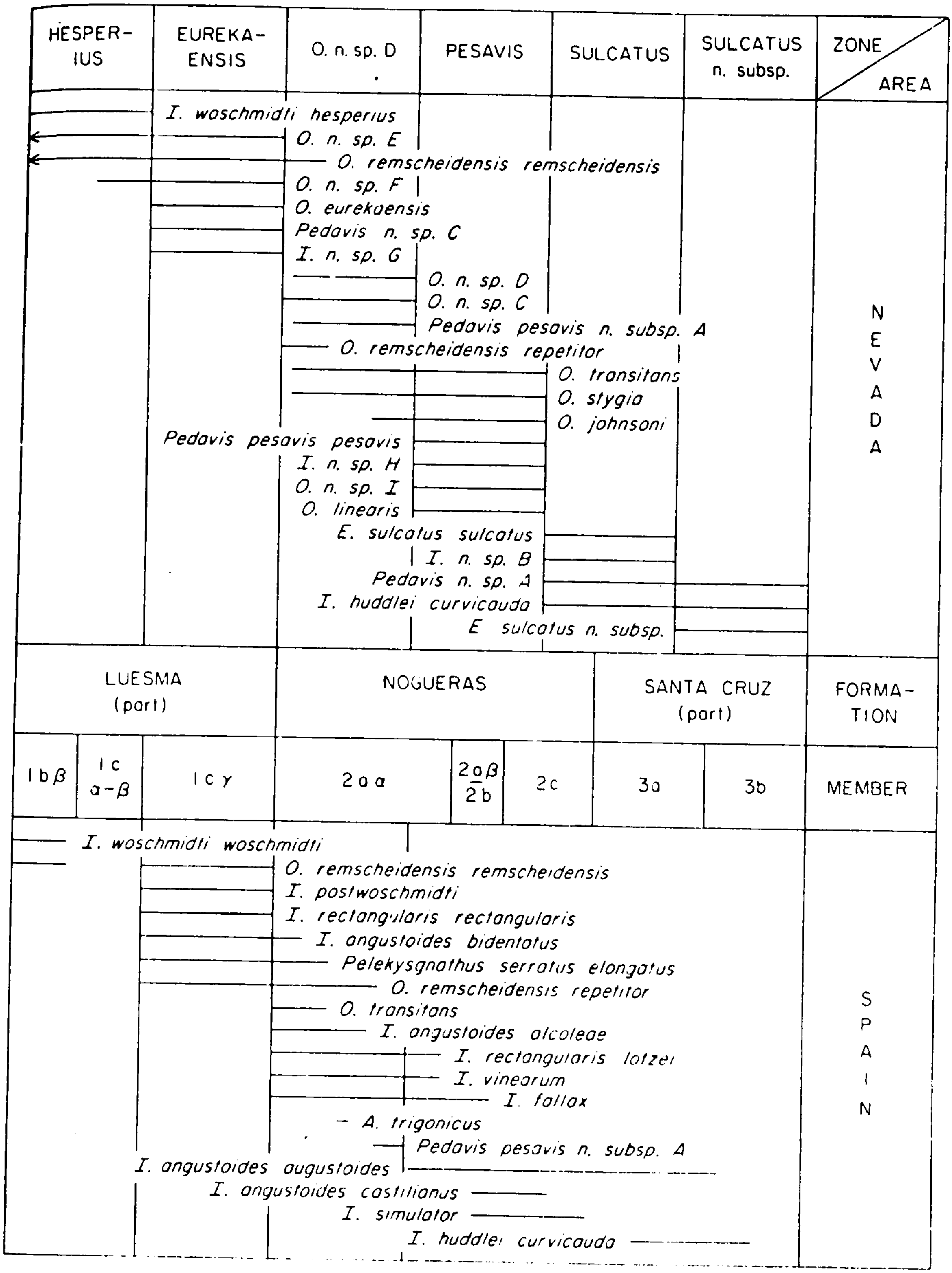


Figure 20. Correlation of latest Pridolian to earliest Late Devonian conodont zones and subzones with stages in Europe and North America (from Klapper and Johnson, 1980, p.403).

Figure 21. Comparison of conodont zonation for lower part of Lower Devonian in Nevada with dissimilar faunal sequence in Spain. Only firm correlation is in the *O.* n. sp. D. Zone with d2a gamma strata in Aragon; other Spanish faunas positioned essentially arbitrarily. *I.* = *Icriodus*, *O.* = *Ozarkodina*, *E.* = *Eognathodus*, *A.* = *Ancyrodelloides*. (from Klapper and Ziegler, 1979).



HESPERIUS
EUREKAENSIS
O. n. sp. D
PESAVIS
SULCATUS
SULCATUS n. subsp.
ZONE
AREA
I. woschmidti hesperius
O. n. sp. E
O. remscheidensis remscheidensis
O. n. sp. F
O. eurekaensis
Pedavis n. sp. C
I. n. sp. G
O. n. sp. D
O. n. sp. C
Pedavis pesavis n. subsp. A
O. remscheidensis repetitor
O. transitans
O. stygia
O. johnsoni
Pedavis pesavis pesavis
I. n. sp. H
O. n. sp. I
O. linearis
E. sulcatus sulcatus
I. n. sp. B
Pedavis n. sp. A
I. huddlei curvicauda
E sulcatus n. subsp.
NEVADA
LUESMA (part)
NOGUERAS
SANTA CRUZ (part)
FORMATION
I b β
I c α–β
I c γ
2 a α
2 a β 2 b
2 c
3 a
3 b
MEMBER
I. woschmidti woschmidti
O. remscheidensis remscheidensis
I. postwoschmidti
I. rectangularis rectangularis
I. angustoides bidentatus
Pelekysgnathus serratus elongatus
O. remscheidensis repetitor
O. transitans
I. angustoides alcoleae
I. rectangularis lotzei
I. vinearum
I. fallax
A. trigonicus
Pedavis pesavis n. subsp. A
I. angustoides augustoides
I. angustoides castilianus
I. simulator
I. huddlei curvicauda
SPAIN

Other localities mentioned in Klapper and Ziegler's summary of Devonian conodont zones, are conpared with these two main sequences. The Central Europe (Alps, Bohemia) and Eastern Australian sequences tend to correlate well with the western North American zones, whereas the Soviet Union sequences correlate with the Spanish zones. The present study involves the use of only the two lowest zones, the hesperius-woschmidti and eurekaensis zones, which will be described below.

Figure 22 lists the concdont fauna present in the woschmidti Zone-hesperius Zone. The woschmidti Zone best represents the conodont biostratigraphy in Eurasian sequences and in the northern Yukon. The "presumably correlative" hesperius Zone is applicable in most Cordilleran and Australian sections (Klapper and Johnson, 1980). It was noted that the eastern North American specimens of I. woschmidti could not be identified to subspecies, but were tentatively placed in the woschmidti Zone (Klapper and Johnson, 1980).

These two zones have been recognized at many localities, as noted in figure 22, although they contain the lowest diversity of all the Devonian conodont zones. Only six species are present between the two zones that are considered biostratigraphically useful, Ozarkodina remscheidensis remscheidensis being the subspecies present in both.

hesperius Zone - *woschmidti* Zone / SPECIES & SUBSPECIES	NEVADA	ROYAL CREEK, Y.T.	HART RIVER, Y.T.	NEW JERSEY	N.S.W. AUSTL.	SPAIN	CARNIC ALPS	RHENISH SLATE M.	PODOLIA
O. n. sp. E	X								
O. n. sp. F	X	X							
I. woschmidti hesperius	X	X			X				
O. r. remscheidensis	X	X	X	X	X	?	X	X	X
O. e. excavata	X	X					X		
I. w. woschmidti			X	?		X	X	X	X

Figure 22. Lower Devonian hesperius-woschmidti Zone (from Klapper and Johnson, 1980, p.415).

Just above the *hesperius* Zone in Nevada is the *eurekaensis* Zone, which "properly describes a segment of biostratigraphy in the Cordilleran area only" (Klapper and Johnson, 1980). The equivalent zone in Spain is the d1c gamma, which is only correlative with the Cordillerian sequence on the basis that it falls between the *woschmidti*-*hesperius* Zone and d2a gamma-delta Zone. In Podolia, the *postwoschmidti* and *eolatericescens* Zones presumably correlate with the d1c gamma Zone because *Icriodus* *postwoschmidti* ranges up into the *eolatericescens* fauna (Klapper and Johnson, 1980) and therefore would presumably correlate with the *eurekaensis* Zone of Nevada. Nineteen species of icriodontan and ozarkodinan conodonts are found within the *eurekaensis* and equivalent zones at 9 localities (figure 23).

Other biostratigraphic criteria used in the correlation of Lower Devonian rocks in North America include graptolites, brachiopods, ostracodes and corals. Berdan and others (1969) correlated several stratigraphic sections containing the Silurian-Devonian boundary in North America (figure 24). The base of the Devonian was determined by a number of species and genera from both Europe and North America, including the brachiopods *Podolella*, *Cyrtina* and *Schizophoria*, the graptolites *Monograptus* *uniformis*, *M*. spp.cf. *M*.

eurekaensis Zone & equivalents SPECIES & SUBSPECIES	NEVADA	ROYAL CREEK, Y.T.	E-C ALASKA	N.W.T.	SPAIN	CARNIC ALPS	KARAWANKEN	BARRANDIAN	PODOLIA
O. eurekaensis	X								
O. n. sp. E	X								
Pand. optima	?								
O. n. sp. F	X	X	X						
I. n. sp. G	X		?						
I. hadnagyi	X			X					
I. cf. *woschmidti*			X						
Pelek. n. sp.			X						
Pelek. csakyi				X					
Pedavis n. sp. C	X		X			?			
O. r. remscheidensis	X	X	X	X	X			X	
O. e. excavata	X	X	X					X	
O. stygia			X						
O. repetitor					X				X
I. postwoschmidti					X			?	X
I. r. rectangularis					X				
I. a. bidentatus					X				
Pelek. s. elongatus					X				
I. eolatericrescens									X

Figure 23. Lower Devonian eurekaensis Zone (after Klapper and Johnson, 1980, p.416).

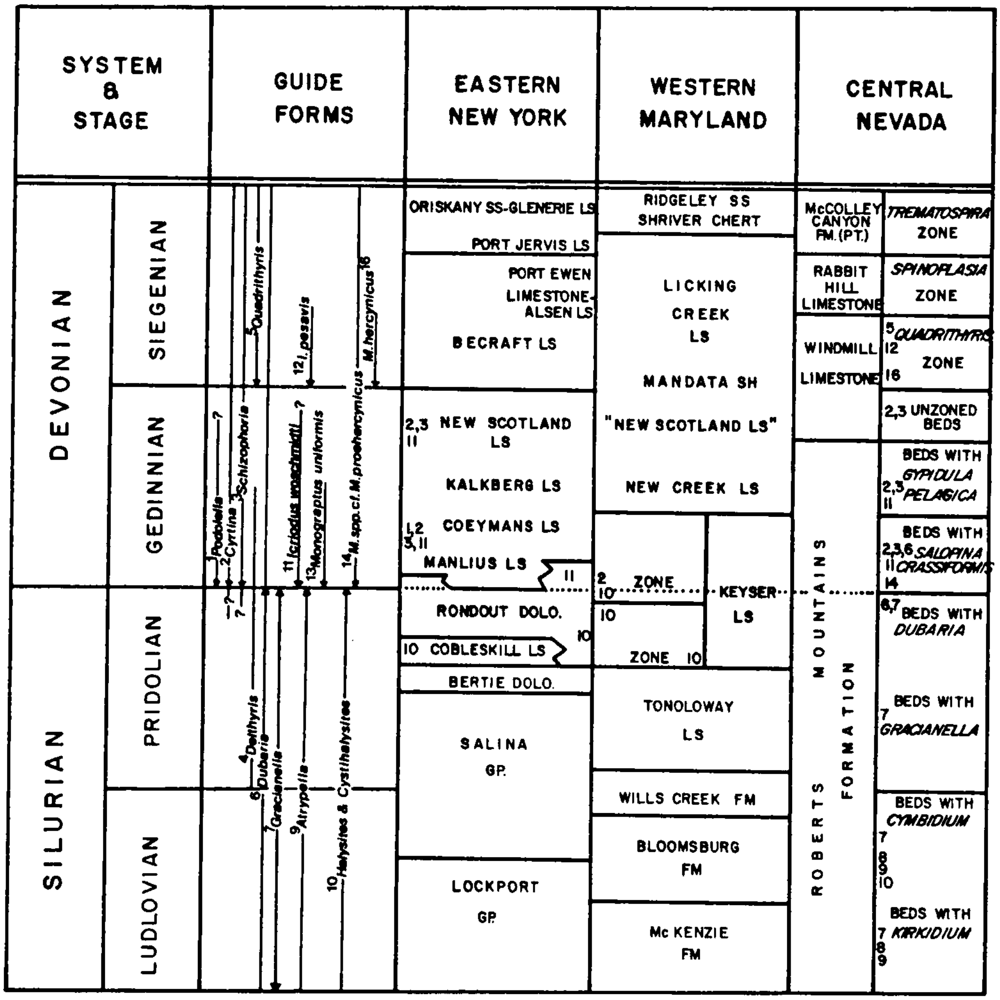


Figure 24. Correlation of New York, Maryland, and Nevadan sections containing the Siluro-Devonian boundary (after Berdan and others, 1969, plate 1).

praehercynicus, and M. aequbilis, along with the conodont I. woschmidti. The eastern New York section, which includes the Helderberg group (Manlius, Coeymans, Kalkberg and New Scotland Limestones) contains diagnostic Devonian brachiopods and conodonts. The base of the Devonian in western Maryland is based primarily on the presence of the brachiopod Cyrtina and the coral Favosites helderbergiae praecedens. In Nevada, the presence of the graptolite Monograptus cf. praehercynicus is regarded as being equivalent to the Monograptus uniformis Zone, which defines the base of the Devonian at the stratotype. Just above the first appearance of the graptolites are the conodonts I. woschmidti and Ozarkodina remscheidensis (their Spathognathodus). Brachiopods also are abundant in Nevada, with the fauna containing many diagnostic species.

Conodont Distribution

Each sample of the Decatur and Ross collected from each locality was processed and examined for conodonts. The specimens were then identified and are described in a later chapter (Systematic Paleontology). Table 2 gives the number of conodont elements belonging to each

Table 2. Distribution and abundance of elements per sample.

	SAMPLE NUMBER																						
	D1	D2	D3	D4	D5	RR1	RR2	RR3	RR4	RR5	RB1	RB2	RB3	RB4	RB5	RB6	RB7	RB8	RB9	RB10	RB11	RB12	RB13
Icriodus woschmidti	-	2	6	2	22	4	1	5	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Icriodus postwoschmidti	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pedavis sp.	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Panderodus unicostatus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Belodella silurica	2	1	1	1	3	-	-	-	-	-	2	-	-	-	-	2	-	-	5	-	5	-	-
Oulodus elegans	2	1	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Ozarkodina remscheidensis eosteinhornensis	2	1	14	1	9	-	-	-	-	-	2	-	1	3	1	-	-	-	-	1	-	-	-
Pseudooneotodus beckmani	3	6	-	-	4	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	5	-	-
TOTAL	9	11	21	4	39	6	1	6	2	1	4	0	1	3	1	2	0	0	5	1	10	0	1

species present for each sample. Figures 25 and 26 show the abundances of conodont elements per kilogram of dissolved sample at the Parsons Quarry and Olive Hill localities respectively. The conodont distribution for each locality will be discussed below, except for samples from the Bear Branch and Horse Creek localities which are barren. Discussions on the Silurian-Devonian boundary in Tennessee and paleoecology of conodonts follow.

Parsons Quarry

The Decatur Limestone contained by far a greater number of conodonts (83) than the Rockhouse Limestone and Birdsong Shale members together at Parsons Quarry. Icriodus woschmidti is present in all but the bottom sample of the Decatur (topmost 2.0m of the formation) and is quite abundant in the top sample PQD-5 (22 specimens). Ozarkodina remscheidensis eosteinhornensis is present in all Decatur samples, although many elements are poorly preserved or fragmental. Belodella silurica is also present in minor amounts in all samples, with sample PQD-5 exhibiting the greatest abundance among all five samples (3 specimens). Pseudooneotodus beckmani is present in 3 of the 5 samples, 6 of the 10 specimens recovered from the sample

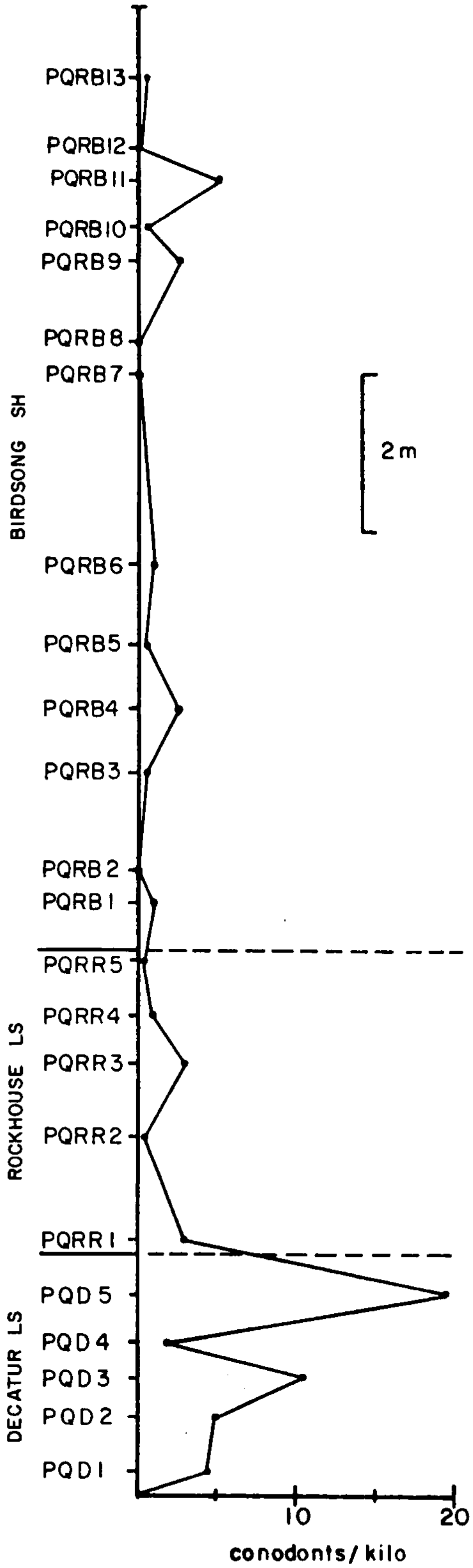


Figure 25. Percentage of conodont elements recovered per kilogram rock dissolved for Parsons Quarry.

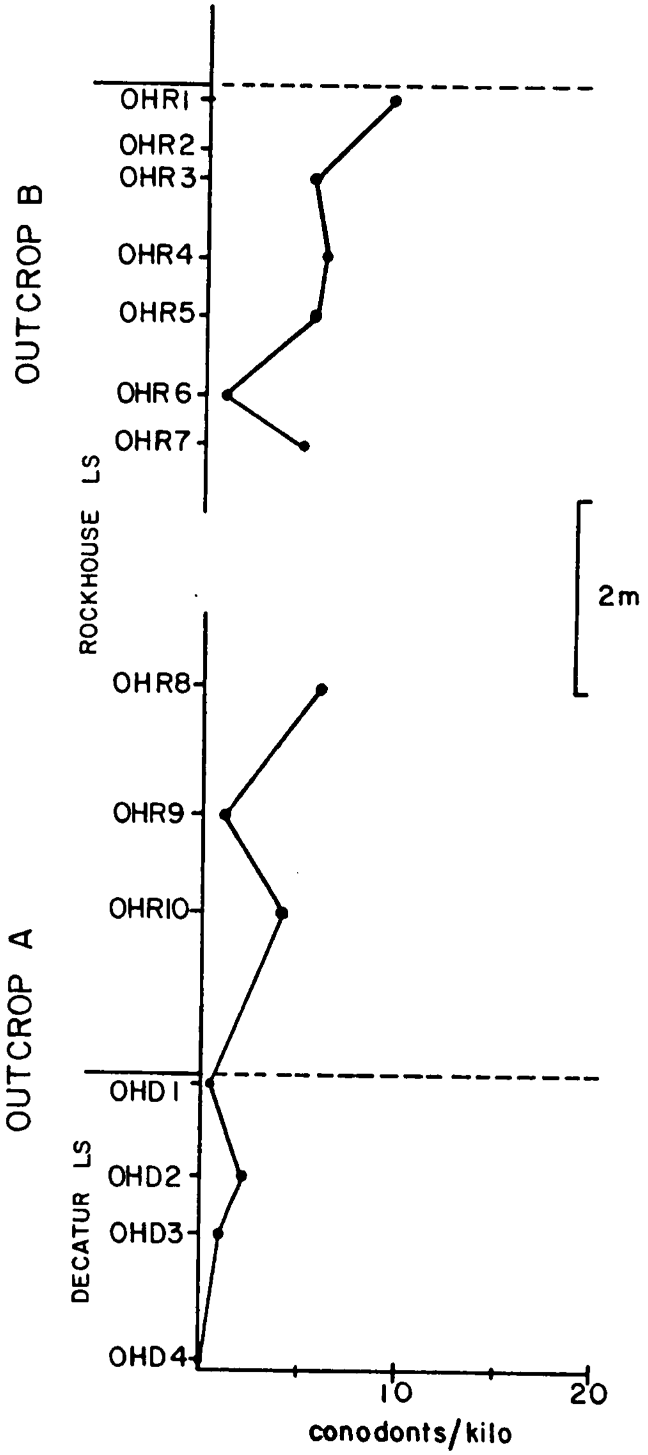


Figure 26. Percentage of conodont elements recovered per kilogram rock dissolved for Olive Hill.

PQD-2 were elements of this species. Oulodus elegans is present in the bottom two samples (PQD-1 and PQD-2), and a basal plate of Pedavis sp. is present in the uppermost Decatur (PQD-5).

The Rockhouse Limestone member contained only three species, two of which, P. beckmani and O. elegans were represented by only 1 and 2 specimens, respectively. I. woschmidti is present in all 5 samples, with the top two samples containing only a few (1-2) poorly preserved elements.

The Birdsong Shale member has a sparse population of conodonts, although 6 species are present throughout the section. The bottom of the Birdsong contains specimens of O. r. eosteinhornensis and B. silurica. Only a few elements were found of each. The middle Birdsong (samples PQRB-4 to PQRB-7) contains O. r. eosteinhornensis. The O. r. eosteinhornsnsis specimen represents the O. remscheidensis subspecies transitional to O. r. eosteinhornensis, as reported by Neff (1983). The upper Birdsong contains two samples (PQRB-9 and PQRB-11) that have 5 specimens of B. silurica apiece. PQRB-11 also contains 5 specimens of P. beckmani. Other samples contain O. r. eosteinhornensis (PQRB-10) and a fragmental Oulodus elegans element (PQRB-13). Four samples in the entire Birdsong were barren, three of these are found in the upper portion of the section.

Olive Hill

The Olive Hill section contains 5 species that were present in the Parsons Quarry section lacking only *Pedavis* sp. However, specimens were only found in the Decatur Limestone and Rockhouse Limestone member, with the overlying Ross Limestone member barren of conodonts.

The Decatur Limestone has a low abundance of conodonts, with only a few specimens of *O. r. eosteinhornensis* and one element of *Oulodus elegans*. Two coniform elements are also present, which are assigned to *Panderodus unicostatus*. Abundance increases upward into the Rockhouse, especially with *O. r. eosteinhornensis*, which is the most common species found. *I. woschmidti* is present throughout the Rockhouse (none found in the Decatur), but is most abundant at the top of the section (OHR-1). Many specimens of *I. woschmidti* were fragmental, making identification to the subspecies difficult, although it appeared certain that they all belonged to the same species. At least one sample (OHR-8) contains the subspecies *I. w. postwoschmidti*. *P. beckmani* is common throughout the section, showing greater abundance in the middle of the section (OHR-5, OHR-7). Fragments of *Oulodus elegans* are also present in two samples.

Biostratigraphy

As previously mentioned, the Silurian-Devonian boundary can be placed approximately at the first occurrence of the conodont Icriodus woschmidti (hesperius/woschmidti Zone). It was reported by McComb and Broadhead (1980) that the first appearance of I. woschmidti (from samples collected at Parsons Quarry) in west-central Tennessee occurs approximately 2 meters below the Ross Formation-Decatur Limestone contact. The Decatur was previously thought to be entirely Silurian in age, with the Rockhouse Devonian in age. The present study, at Parsons Quarry, also shows the first appearance of I. woschmidti at 2 meters below the Decatur-Ross boundary.

Farther south, at Olive Hill, an approximate boundary was placed within the lower part of the Ross Formation, with the first appearance of I. woschmidti occuring approximately 2.2 meters above the lithostratigraphic boundary between the Ross and Decatur. This would place the lower part of the Rockhouse in the Silurian, while the upper half would be of Devonian age.

Figure 27 shows the I. woschmidti first appearance datum (FAD) from Parsons Quarry to Olive Hill,

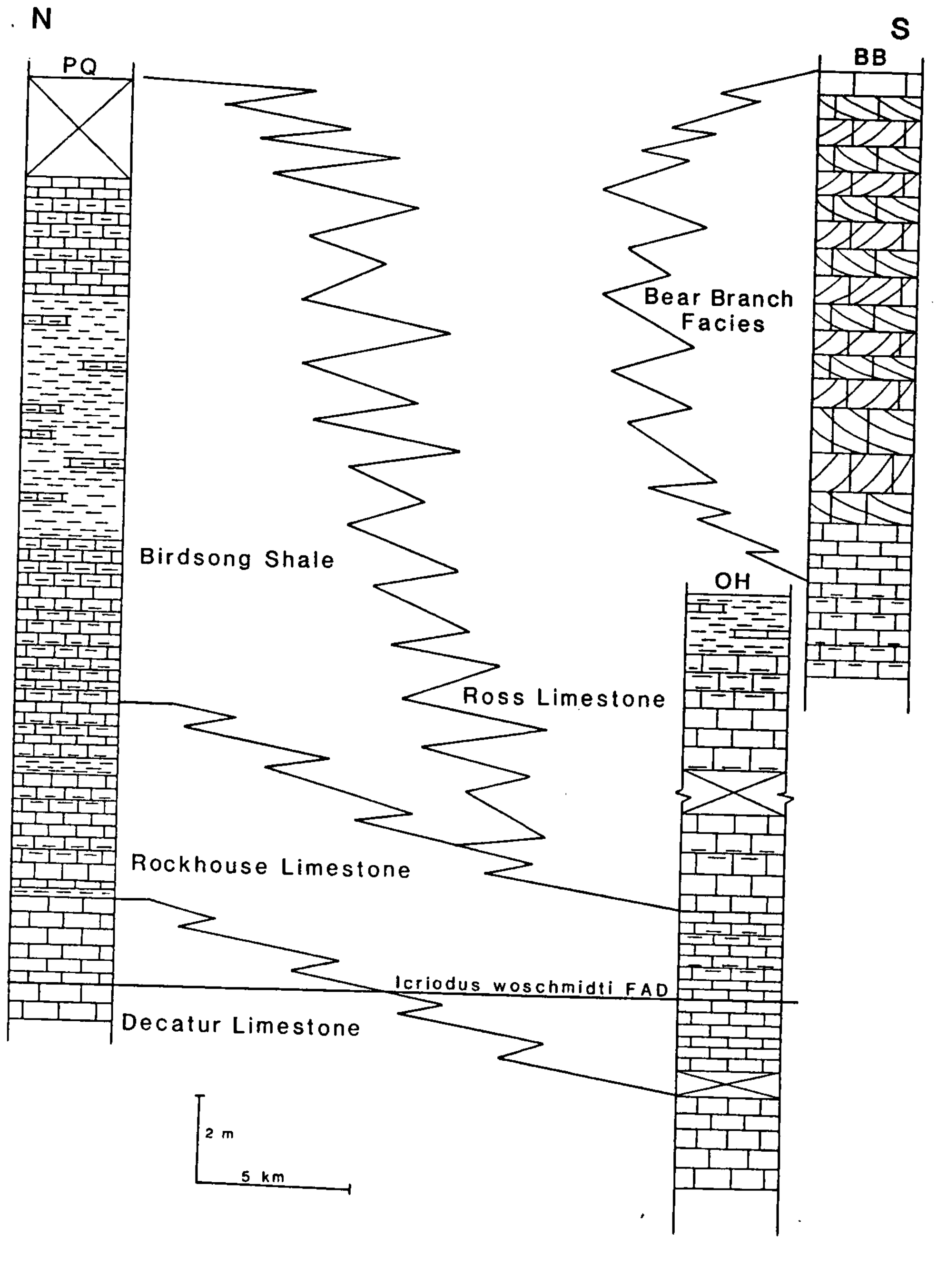


Figure 27. Lower Devonian correlations among the sections of the Ross Formation in western Tennessee. Icriodus woschmidti first appearance datum (FAD) marks the Siluro-Devonian boundary.

illustrating the time-transgressive nature of the facies present. From this it could be assumed that the more southern exposures are earlier in age than those to the north, which would suggest that the Rockhouse Shale, which is found in southern Hardin County, is at least partly, if not entirely Silurian in age. No conodonts were found to substantiate this.

The Rockhouse Shale member has been thought to be both Silurian and Devonian in age (see figure 1, page 3). In a preliminary ostracode study, Petersen (1972) claimed that the Rockhouse Shale has "definite Devonian affinities." Berry and Boucot (1970) placed it in the Silurian, based on Scyphocrinites and "Silurian" brachiopods (Merista and Dictyonella). An earlier study by Boucot and Johnson (1967) gave the lower part of the shale a Silurian age and the upper portion a Devonian one, based on the brachiopod fauna.

The Rockhouse Limestone member at Olive Hill contains a specimen of Icriodus postwoschmidti, which is characteristic of the eurekaensis Zone (d1c gamma of Spain) (see figures 21, p. 73 and 23, p. 79). This specimen was found in sample OHR-8, which is 4.0 m above the Decatur-Ross contact, and approximately 1.8 m above the first appearance of Icriodus woschmidti (2.2 m above the Decatur-Ross contact). Petersen (1972) also states that I. postwoschmidti is present in the Rockhouse

Limestone (his Alley Bluff Limestone), although no explanation of where it was found within the unit or localities it was recovered from was given.

Gilbert Klapper (personal communication, 1986) stated that the conodont specimens collected were definitely not like those of the Nevada sequence of Western North America (see figure 20, p. 72), but were characteristic of specimens collected in Oklahoma, in what he called the "southern continent sequence". Icriodus postwoschmidti was said to be present in the Oklahoma sections and is characteristic of this sequence.

Conodont Paleoecology

Previous studies on conodont paleoecology are limited, due to the nearly ubiquitous nature of conodont elements in marine sedimentary rocks. Most studies attempted to determine if the conodont animal was pelagic, benthic or both in nature based upon inferences derived from to distributional patterns (Seddon and Sweet, 1971; Barnes and Fahraeus, 1976; Klapper and Barrick, 1978). The present discussion will attempt to give a plausable explanation of the differences between the composition and abundance of conodont specimens of the Ross and Decatur Formations.

It was mentioned earlier (chapter 2) that the Decatur-Ross sequence is similar to the Helderberg sequence of New York. The Coeymans Limestone and the Decatur Limestone are both thought to represent a shallow subtidal crinoidal facies, deepening to shallow sublittoral waters of the Kalkberg-Rockhouse Limestones and New Scotland-Birdsong Limestones, respectively. In contrast, the Ross Limestone represents a shallow lagoonal environment similar to that of the Manlius Formation, and the Bear Branch represents a slight increase of the energy level to that of a shoal water environment.

Neff (1983) stated that *Ozarkodina remscheidensis eosteinhornensis* inhabited an open marine subtidal environment in the Upper Silurian of eastern Tennessee. In New York, *O. remscheidensis* and *Icriodus woschmidti* were generally abundant in the "crinoidal meadow" (shallow subtidal) environment of the Coeymans Formation (Barnett, 1971). This also seems to be the case in the present study with the greatest abundance of *O. r. eosteinhornensis* occuring in the Decatur and Rockhouse Limestones, both of which are shallow subtidal deposits.

A study by Barnett (1971) analyzed the environmental distribution of Icriodus woschmidti and Ozarkodina remscheidensis (his Spathognathodus) within the upper Cayugan and Helderbergian strata of New York and vicinity. One observation noted was that conodonts were abundant in the shallow sublittoral environments of the Kalkberg, decreasing in abundance up section into the deep sublittoral New Scotland. This suggests that conodonts were less abundant in the deeper waters of the sublittoral environment. Because these deeper environments contain an overabundance of terrigenous silt and argillaceous material with very rapid deposition, it is possible that the number of actual conodont bearing animals may have been the same as in shallower deposits with slower deposition. However Barnett stated (1971, p.290)

> If this were the case, an area such as Cornwall, New York, where the Upper Kalkberg-New Scotland interval is only 50 feet thick, should yield conodont abundances higher than along the main outcrop belt where this approximate time interval is represented by about 155 feet of strata. However, samples collected there were completely barren. . . . Therefore, . . . it can be concluded that the relative abundance of conodonts from each rock unit generally reflects the abundance of living conodont bearing animals in each of the various environments.

This distributional pattern is also present in the Rockhouse-Birdsong sequence at Parsons Quarry which also represents a deepening sublittoral environment. The Rockhouse Limestone contains a moderate abundance of elements, with decreasing abundance stratigraphically higher into the Rockhouse, some samples being completely barren.

The conodont Icriodus is said to be a pelagic organism, and is thought to be present in the upper photic zone (Seddon and Sweet, 1971). The absence or rarity of Icriodus or conodonts in general in the deeper environments have been used as evidence for a benthic mode of life for these conodonts (Klapper and Barrick, 1978). A study by Babcock (1977) showed that the abundance and diversity of conodont elements decreased in a basinward direction from the Permian Reef Complex, west Texas. Decreasing food supply in this basinward direction was given as the probable cause for this trend. Food supply along with other environmental factors that control all biotoa present may also be the reasons for the decreasing trend present in this study.

The Manlius Formation of New York contained abundant conodont specimens in the sublittoral lagoonal environment, but these were rare in the lower littoral lagoonal environment, and absent in the upper littoral lagoonal environment (Barnett, 1971). This indicates a decrease in abundance in nearshore environments. The Ross Limestone, which represents a shallow lagoonal environment is barren of conodonts, which could indicate an upper littoral environment. It was also noted by Barnett that I. woschmidti was restricted to the crinoidal banks and sublittoral environments of the Coeymans and Kalkberg formations. This form is not found in lagoonal rocks, whereas O. remscheidensis was found in all environments (figure 28).

O. r. eosteinhornensis was noted by Neff (1983) to inhabit the open marine subtidal environments of the Sneedville Formation (Upper Silurian), but specimens were also recovered from intertidal channel facies (subtidal lagoonal biopelmicrite), indicating that they were washed ashore. O. r. remscheidensis, as well as O. r. transitional remscheidensis and O. r. transitional eosteinhornensis, was present in throughout the section studied in lagoonal, intertidal and nearshore shallow marine facies.

The Bear Branch facies also was completely barren of conodonts, although shoal water environments are generally thought of as being favorable for their presence. The abundance of hematite, which is thought to represent abundant weathering of clays, might have inhibited the presence of conodont animals in this facies, although this probably is not likely because the shelly fauna present is quite diverse. Possibly, because most of the hematite occurs as oolitic coating

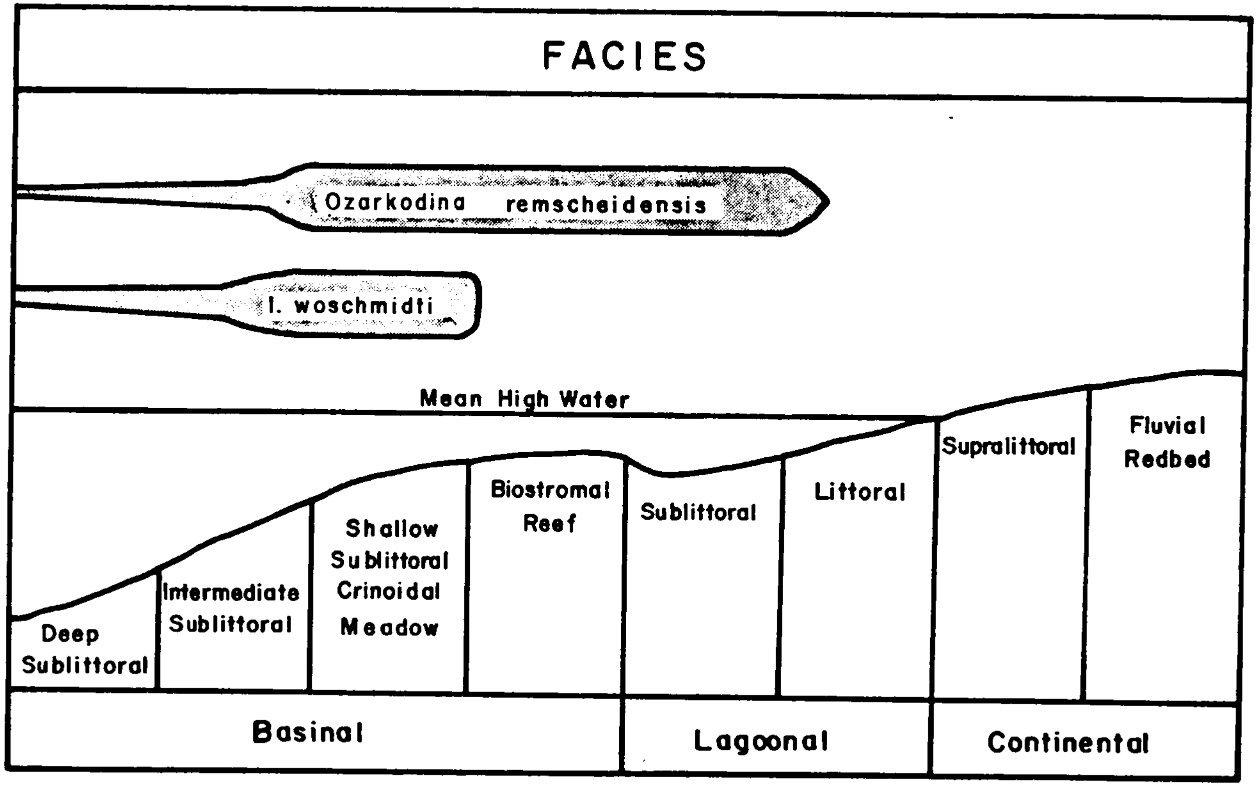


Figure 28. Schematic showing the distribution of late Cayugan and Helderbergian environments and the relative abundance of the conodont species <u>Ozarkodina remscheidensis</u> and <u>Icriodus woschmidti</u> (after Barnett, 1971, p.279).

or pore fillings in fossil fragments, the iron could have coated conodont specimens making them impossible to recognize.

CHAPTER IV

SYSTEMATIC PALEONTOLOGY

Conodont specimens were identified using the descriptions of Klapper and Philip (1971, 1972), Barrick (1977), Barrick and Klapper (1976), Serpagli (1983), and Ziegler et al. (1981). Figured specimens were photographed by scanning electron micrography (see Appendix C). All specimens recovered are in the paleontological collections of the Department of Geological Sciences of the University of Tennessee, Knoxville.

Order Conodontophorida Eichenberg, 1930

Superfamily Prioniodontacea Muller and Muller, 1957

Family Icriodontidae Muller and Muller, 1957

Icriodus Branson and Mehl, 1938

Icriodus woschmidti Ziegler, 1960

(Plate 1, figures 1-7, 9-14)

The multielement apparatus of this species as described by Serpagli (1983) consists of icriodontan (Pa), ramiform, and acodinan elements (figure 29). The platform exhibits 5-7 transverse ridges, as opposed to three longitudinal rows of nodes in other species of

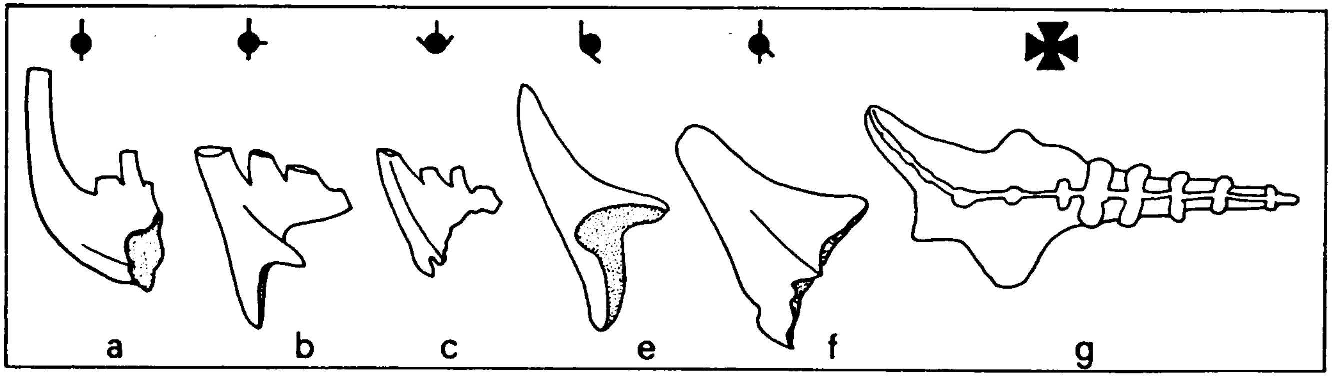


Figure 29. Structure of <u>Icriodus</u> <u>woschmidti</u> <u>woschmidti</u> skeletal apparatus. <u>Elements</u> are arranged in both a first or ramiform (a-c) and second transition series (e-g) (Serpagli, 1983).

Icriodus. The ramiform elements are of three different morphotypes (a, b, c) each containing several denticles and a larger cusp. The a morphotype is a slightly asymmetrical element with a denticulated posterior process; b morphotype is similar to a, but possesses a lateral costa; c morphotype is nearly symmetrical with two ridges. The acodinan elements are coniform and exhibit two morphotypes; e morphotype is an asymmetrical cone with anterior and posterior edges; f morphotype is moderately asymmetrical with 2-3 sharp costae, one of which may or may not have denticles.

Distribution- This species is considered to be truly cosmopolitan, occuring throughout Europe, Asia, Australia, and North America. Its first occurrence is commonly used as a working approximation for the Silurian-Devonian boundary, in that it closely corresponds with the base of the Monograptus uniformis Zone. All three element types of the apparatus were recovered from the Decatur Limestone, Rockhouse Limestone (samples PQD2-5, PQRR1-5, OHR1-9).

Material- 80 specimens. The platform element is the most abundant form present (64 specimens) with only two ramiform elements and 14 cones recovered.

Icriodus postwoschmidti Mashkova, 1968

The multielement apparatus of this species is not known, but because the platform element closely resembles that of I. woschmidti, it is thought that the apparatus is similar to that species. The only recorded element is the platform (Pa) element, which is described as having an expanded basal cavity, with tuberculiferous, lateral projections. The posterior-most denticle of the median axis is also larger than the main cusp (Ziegler et al., 1981). The main platform contains three rows of nodes, instead of the transverse ridges as seen in I woschmidti.

Distribution- I. postwoschmidti is found in the USSR, Spain, Turkey and in North America (Oklahoma). It can be used as a marker for the eurekaensis Zone, because the postwoschmidti Zone of Podolia (USSR) correlates with the d1c gamma strata of Spain, which in turn correlate with the eurekaensis Zone (Klapper and Johnson, 1980). I. postwoschmidti was recovered from the Rockhouse Limestone only at Olive Hill in the present study (samples OHR-8, OHR-4).

Material- 3 specimens. Although only a few specimens were positively identified, it may be present in greater numbers because it is difficult to distingush from the platform elements of I. woschmidti when the specimens are fragmented.

Pedavis Klapper and Philip, 1971

Pedavis sp. E Broadhead and McComb, 1983

(Plate 1, figure 9)

The multielement apparatus of the genus consists of a pesaviform element, a sagittodontan (Sc) and costate cone (M) (Klapper and Philip, 1972). The Sc (ramiform) and M (coniform) elements represent the ramiform and cone elements respectively of I. woschmidti. The one specimen recovered is the basal material belonging to a platform element. It is characterized by three accessory processes that emerge from the posterior end of the main platform. Broadhead and McComb (1983) noted that the Pa elements of Pedavis are similar to those of Icriodus, and that Icriodus rapidly evolved from Pedavis during the Late Silurian.

Distribution- As mentioned above, only one specimen was recovered from the upper Decatur Limestone at Parsons Quarry. Broadhead and McComb (1983) reported this species to occur only in the Rockhouse Limestone. (Sample PQD-5).

Material- 1 specimen.

Superfamily Panderodontacea Lindstrom, 1970

Family Panderodontidae Lindstrom, 1970

Panderodus Ethington, 1959

Panderodus unicostatus Branson and Mehl, 1933

The multielement apparatus consists of simple, panderodontiform cone elements (M, Sa, Sb, Sc) (Barrick, 1977). All elements contain at least one groove along the side of the cone except for the M element which may have none. The Sa element has a triangular cross-section with two grooves, the Sb can have either one or two grooves; and the Sc element has one groove. The elements of *P. unicostatus* have been noted by Cooper (1976) to be widely variable in that there are elements that are slender and thin-walled as well as more robust, thicker-walled elements.

Distribution- Two specimens were recovered from the Decatur Limestone at Olive Hill (sample OHD-3).

Material- 2 specimens.

Family Belodellidae Khodalevich and Tschernich, 1973

Belodella Ethington, 1959

Belodella silurica Barrick, 1977

(Plate 1, figure 15)

The apparatus of this species is composed of slender, simple cones, that have a large basal cavity, but without any basal expansion. The M element has a biconvex cross-section; Sa element has symmetrical triangular cross-section; Sb element a asymmetrical, triangular cross-section; and Sc a strongly asymmetrical, lenticular cross-section (Barrick, 1977). The transition series elements (Sa, Sb, Sc) elements contain many fused denticles.

Distribution- This species was first described from the Silurian of Oklahoma and is also present throughout Europe and North America. It was recovered throughout the Decatur Limestone and in the upper Birdsong Shale at Parsons Quarry (samples PQD1-5, PQRB-1, PQRB-9, PQRB-11).

Material- 17 specimens, nine of which are M elements and eight are Sc elements.

Superfamily Hibbardellacea Muller, 1956

Family Hibbardellidae Muller, 1956

<u>Oulodus</u> Branson and Mehl, 1933

<u>Oulodus</u> <u>elegans</u> (Walliser, 1964)

(Plate 1, figures 21-22)

This multielement apparatus consists of aversiform (Pb), neoprioniodontan (M), ligonodinan (Sc), ortuform (Sb), and hibbardellan or detortiform (Sa) elements. The Pb element contains a large, round cusp with smaller, less robust denticles, and a small basal cavity. The M element also has a small basal cavity with larger denticles and cusp. The Sc element has a small, shallow basal cavity and robust denticles and cusp (Klapper and Philip, 1971).

<u>Distribution</u>- This species is present in minor amounts throughout the two sections, being found primarily in the Decatur and Rockhouse Limestones (samples PQD-1, PQD-2, PQRR-1, OHD-1, OHR-7, OHR-10).

<u>Material</u>- 7 specimens. The Pb element is the most abundant, with four specimens recovered. Only two M elements and one Sa element were found.

Superfamily Polygnathacea Bassler, 1925

Family Polygnathidae Bassler, 1925

Ozarkodina Branson and Mehl, 1933

Ozarkodina remscheidensis eosteinhornensis Walliser, 1964

(Plate 1, figures 18-20, 23)

The multielement apparatus of this species consists of spathognathodontiform (Pa), ozarkodiniform (Pb), neoprioniodotiform or synprioniodiniform (M) elements and a symmetry transition series (Sa, Sb, Sc). The platform element consists of a blade that contains denticles of uniform height and a basal cavity that is heart-shaped in outline (Ziegler, 1981). The Pb elements have a small basal cavity and a relatively large cusp. The M and transition series elements are denticulated blades that are easily broken and difficult to distinguish.

Distribution- O. r. eosteinhornensis is present in sections throughout Europe and North America. It is characteristic of the eosteinhornensis Zone, which is the uppermost zone of the Pridoli (Silurian). The present study contains specimens throughout the Decatur, Rockhouse Limestone and Birdsong Shale at both Parsons Quarry and Olive Hill (samples PQD1-5, PQRB-1, PQRB-3,

PQRB-4, PQRB-5, PQRB-10, OHD-2, OHR1-10).

Material- 73 specimens. The platform element is the most abundant with 56 specimens recovered, with eight Pb, four M, and five S elements present.

Superfamily Unknown

Family Unknown

Pseudooneotodus Drygant, 1974

Pseudooneotodus beckmani Bischoff and Sannemann, 1958

(Plate 1, figures 16-17)

This is a simple cone species characterized by short, stout cones. They have a deep basal cavity, with walls that thicken toward the apex. This species is characterized by a single denticle (Barrick, 1977). The apparatus of P. beckmani is unknown.

Distribution- This species is known to occur in Russia, Spain and Oklahoma. It is found throughout the study area in the Decatur Limestone, Rockhouse Limestone, and Birdsong Shale at Parsons Quarry and Olive Hill (samples PQD-1, PQD-2, PQD-5, PQRR-3, PQRB-11, OHR-1, OHR-3, OHR-5, OHR-7, OHR-9, OHR-10).

Material- 42 specimens.

CHAPTER V

SUMMARY AND CONCLUSIONS

1. The Ross Formation consists of five members. The Rockhouse Limestone Member is a fossiliferous grainstone to packstone with minor shale partings. It is overlain to the north by the Birdsong Shale Member, a fossiliferous packstone to wackestone interbedded with fossiliferous shale, and to the south by the sparsely fossiliferous, dense, recrystallized lime mudstone of the Ross Limestone Member to the south. The Rockhouse Shale Member, a gray, moderately fossiliferous shale with minor carbonate beds (of Ross Limestone lithology), underlies the Ross Limestone Member further south. The Bear Branch facies, a cross-bedded, hematitic grainstone, is found in the upper Ross Limestone.

2. The northern facies, previously studied by Reid (1983) represents a deepening sequence, from the moderately shallow subtidal environment of the Rockhouse Limestone, to the deeper, sublittoral environment of the Birdsong Shale. To the south, however, the Ross Formation represents a shallowing upward sequence, from the Rockhouse Shale to the quiet, shallow-subtidal to lagoonal environment of the Ross Limestone. A small localized area in the Ross Limestone was subjected to an

increase in water circulation along with abundant weathering of nearby clays to produce the hematitic ooids and abundant bioclastic debris of the Bear Branch facies.

3. The Silurian-Devonian boundary is approximately marked by the first appearance of the conodont Icriodus woschmidti (hesperius-woschmidti Zone). At Parsons Quarry, the boundary is approximately 2.0 m below the Decatur-Ross contact, while at Olive Hill, it is approximately 2.2 m above the contact. This places the Silurian-Devonian boundary approximately 2.0m down into the Silurian Decatur Limestone at Parsons Quarry, while at Olive Hill, the boundary is placed approximately 2m up into the Rockhouse Limestone.

4. Icriodus postwoschmidti marks the occurrence of the next higher conodont zone, the eurekanensis Zone (Nevada) or the d1c gamma Zone (Spain).

5. Conodont abundance decreases up section, from the shallow-subtidal facies of the Decatur and Rockhouse limestones, to the deeper sublittoral facies of the Birdsong Shale. Conodonts are absent from the lagoonal deposits of the Ross Limestone and the hematitic Bear Branch.

LIST OF REFERENCES

LIST OF REFERENCES

Amsden, T. W. 1958. Stratigraphy and paleontology of the Hutton Group in the Arbuckle Mountain region. Part II--Haragan articulate brachiopods. Oklahoma Geological Survey, Bulletin 78, 189p.

________. 1958b. Stratigraphy and paleontology of the Hunton Group in the Arbuckle Mountain region. Part V--Bois d'Arc articulate brachiopods. Oklahoma Geological Survey, Bulletin 82, 110p.

________. 1960. Stratigraphy and paleontology of the Hunton Group in the Arbuckle Mountain region. Part VI--Hunton stratigraphy. Oklahoma Geological Survey, Bulletin 84, 311p.

________. 1962. Silurian and Early Devonian carbonate rocks of Oklahoma. American Association of Petroleum Geologists, Bulletin 46: 1502-1519.

Bambach, R. K., C. Scotese, and A. Ziegler. 1980. Before Pangea: The geographies of the Paleozoic world. American Scientist, 68:26-38.

Barnes, C. R., and L. Fahraeus. 1976. Provinces, communities and the proposed nektobenthic habit of Ordovician conodontoporids. Lethaia, 8:133-149.

Barnett, S. G. 1971. Biometric determination of the evolution of Spathognathodus remscheidensis: a method for precise intrabasinal time correlations in the northern Appalachians. Journal of Paleontology, 45:274-300.

Barrick, J. E. 1977. Multielement simple-cone conodonts from the Clarita Formation (Silurian), Arbuckle Mountains, Oklahoma. Geologica et Paleontologica, 11:47-68.

________ and G. Klapper. 1976. Multielement Silurian (late Llandoverian-Wenlockian) conodonts of the Clarita Formation, Arbuckle Mountains, Oklahoma, and phylogeny of Kockelella. Geologica et Paleontologica, 10:59-100.

Berdan, J. M., W. Berry, A. Boucot, G. Cooper, D. Jackson, J. Johnson, G. Klapper, A. Lenz, A. Martinsson, W. Oliver, Jr., L. Richard, and R. Thorsteinsson. 1969. Siluro-Devonian boundary in North America. Geological Society of America Bulletin, 80:2165-2174.

Berry, W. B. N., and A. J. Boucot (eds.). 1970. Correlation of the North American Silurian rocks. Geological Society of America Special Paper, 102:1-289.

Bhattacharyya, D. P. and P. K. Kakimoto. 1982. Origin of ferriferous ooids: an SEM study of ironstone ooids and bauxite pisoids. Journal of Sedimentary Petrology, 52(3):849-857.

Broadhead, T. W. and R. McComb. 1983. Paedomorphosis in the conodont family Icriodonitdae and the evolution of Icriodus. Fossils and Strata, 15:149-154.

________, N. Neff, and S. Reid. 1983. Sedimentary history and biostratigraphy of Late Silurian-Early Devonian of the Southern Appalachians and southeastern craton. In Appalachian Basin Industrial Associates, J. E. Robinson and C. Newton (eds.), program-fall meeting, 5:23-27.

Boucot, A. J., and J. G. Johnson. 1967. Palaeogeography and correlation of Appalachian Province Lower Devonian sedimentary rocks. Tulsa Geological Society Digest, 35:35-87.

Cooper, B. J. 1976. Multielement conodonts from the St. Clair Limestone (Silurian) of southern Illinois. Journal of Paleontology, 50:205-217.

Cooper, G. A., C. Butts, K. E. Caster, G. H. Chadulick, W. Goldring, E. M. Kindle, E. Kirk, C. W. Merriam, F. M. Swartz, P. S. Warren, A. S. Warthin, and B. Willard. 1942. Correlation of the Devonian sedimentary formations of North America. Geological Society of America, Bulletin, 53:1729-1794.

Dunbar, C. O. 1919. Stratigraphy and correlation of the Devonian of Western Tennessee. Tennessee Division of Geology, Bulletin 21, 127p.

Foerste, A. F. 1903. Silurian and Devonian limestones of West Tennessee. Journal of Geology, 11:554p.

Heckle, P. H. 1972. Recognition of ancient shallow marine environments, p. 226-286. In J. K. Rigby and W. K. Hambllin (eds.), Recognition of Ancient Sedimentary Environments. Society of Economic Paleontologists and Mineralogists, Special Publication, 16.

Heckel, P. H. and B. J. Witzke. 1979. Devonian world paleogeography determined from distribution of carbonates and related lithic paleoclimatic indicators. Special Papers in Paleontology, 23:99-123.

Irwin, M. L. 1965. General theory of epeiric clear water sedimentation. American Association of Petroleum Geologists, Bulletin, 49:445-459.

Johnson, J. G., and M. A. Murphy. 1969. Age and position of Lower Devonian graptolite zones relative to the Appalachian standard succession. Geological Society of America Bulletin, 80:1275-1282.

Kimberley, M. M. 1978. Paleoenvironmental classifications of iron formations. Economic Geology, 73:215-229.

Kimberley, M. M. 1979. Origin of oolitic iron formations. Journal of Sedimentary Petrology, 49:111-132.

Klapper, G. 1977. Lower-Middle Devonian boundary conodont sequence in central Nevada, with contributions by D. B. Johnson. In Murphy, M., Berry, W., and Sandberg, C. (eds.) Western North America: Devonian. University of California, Riverside Geology, 22:401-406.

________, C. Sandburg, C. Collinson, J. Huddle, R. Orr, L. Rickard, D. Schumacher, G. Seddon, and T. Uyeno. 1971. North American Devonian conodont stratigraphy. Geological Society of America, Memoir, 127:285-314.

________, and G. Philip. 1971. Devonian conodont apparatuses and their vicarious skeletal elements. Lethaia, 4:429-452.

________, and ________. 1972. Familial classification of reconstructed Devonian conodont apparatuses. In M. Lindstrom and W. Ziegler (eds), Symposium on conodont taxonomy. Geologica et Palaeontologica, SB1:97-114.

________, and J. E. Barrick. 1978. Conodont ecology: pelagic versus benthic. Lethaia, 11:15-23.

________ and W. Ziegler. 1979. Devonian conodont biostratigraphy. In The Devonian system. House, M. R. (ed.). Special Papers in Paleontology (London), 23:199-224.

________ and J. Johnson. 1980. Endemism and dispersal of Devonian conodonts. Journal of Paleontology, 54(2):400-455.

Laporte, L. F. 1969. Recognition of a transgressive carbonate sequence within an epeiric sea, Helderberg Group (Lower Devonian) of New York State. Society of Economic Paleontologists and Mineralogists, Special Publication #14, pp.98-118.

________. 1971. Paleozoic carbonate facies of the central Appalachian shelf. Journal of Sedimentary Petrology, 41:724-740.

Lundin, R. 1968. Ostracodes of the Haragan Formation (Devonian) in Oklahoma. Oklahoma Geological Survey, Bulletin, 116:1-121.

McComb, R. and T. W. Broadhead. 1980. Silurian-Devonian boundary correlation in Eastern United States. Geological Society of America, Abstracts with Program, 12:479.

Murphy, M. and W. Berry. 1983. Early Devonian conodont-graptolite collation and correlations with brachiopod and coral zones, central Nevada. American Associations of Petroleum Geologists, 67:371-379.

Neff, N. 1983. Stratigraphy, depostional environments, and paleoecology of the Upper Silurian (Pridoli) Sneedville Formation in Hancock County, Tennessee. Unpublished masters thesis, University of Tennessee, Knoxville, 201p.

Petersen, L. E. 1972. Ostracodes and stratigraphy of the Birdsong Formation (Devonian) of western Tennessee. Unpublished Master's thesis, Arizona State University, 192p.

Porrenga, D. H. 1967. Glauconite and chamosite as depth indicators in the marine environment. Marine Geology, 5:495-501.

Reid, S. 1983. Petrology, paleodepositional environments, and paleoecology of the Lower Devonian Ross Formation, west-central Tennessee. Unpublished Master's thesis, University of Tennessee, Knoxville, 143p.

Rickard, L. V. 1962. Late Cayugan (Upper Silurian) and Helderbergian (Lower Devonian) stratigraphy in New York. New York State Museum and Science Service, Bulletin, 386, 157p.

Seddon, G. and W. C. Sweet. 1971. An ecologic model for conodonts. Journal of Paleontology, 45:869-880.

Serpagli, E. 1983. The conodont apparatus of _Icriodus woschmidti woschmidti_ Ziegler. Fossils and Strata, 15:155-161.

Shaw, A. B. 1964. Time in stratigraphy. McGraw-Hill, Inc. New York, 365p.

Sorby, H. C. 1856. On the origin of the Cleveland Hill ironstone. Geological and Polytechnic Society, West Riding of Yorkshire Proc., 3:457-461.

Van Houten, F. B. and D. P. Bhattacharyya. 1982. Phanerozoic oolitic ironstones-Geologic record and facies model. Annual Review of Earth Planetary Science, 10:441-457.

Walker, L. G. and G. N. Pruitt. 1975. Devonian and Silurian at the Vulcan Materials Company, Parsons Quarry, p11-15. _In_ R. G. Stearns (ed.), Field Trips in West Tennessee. Tennessee Divisions of Geology, Report of Investigations #36.

Wilson, C. W. Jr. 1935. The ostracode fauna of the Birdsong Shale, Helderberg, of western Tennessee. Journal of Paleontology, 9:629-646.

APPENDIXES

APPENDIX A

MEASURED SECTION AT OLIVE HILL

Section is located along State Highway 64, in Olive Hill, Hardin County.

Unit	Thickness Meters	Thickness Cum.	Description
Section A			
O1A	2.9	2.9	DECATUR LIMESTONE. Tan to pinkish gray, coarse- to medium-grained, medium- to thickly-bedded echinodermal grainstone to packstone. Predominately echinoderm grains with impunctate brachiopods, fenestrate, ramose and encrusting bryozoans, ostracodes and trilobites. Much of the unit was covered. Micrite content decreases towards top of unit. SAMPLES: OHD-4 (0.0 m at base), OHD-3 (2.3 m), OHD-2 (2.9 m), OHD-1 (2.9 m)
O2A	1.4	4.3	COVERED INTERVAL. The contact between the Decatur Limestone and the Ross Formation is thought to be close to the bottom of this unit.
O3A	1.4	5.7	ROCKHOUSE LIMESTONE MEMBER OF ROSS FORMATION. Medium- to thinnly-bedded, tannish to medium gray, coarse-grained grainstone and minor shale partings. Minor glauconite. Much of the unit is covered. Echinoderm grains, encrusting and ramose bryozoans, and impunctate brachiopods dominate with rare ostracodes and trilobite and fenestrate bryozoans. SAMPLES: OHR-10 (4.6 m),OHR-9 (5.6 m)

O4A	0.8	6.5	COVERED INTERVAL.
O5A	1.2	7.7	Medium gray, medium- to thinnly-bedded, glauconitic grainstone and gray, fissile shale interbeds. Fossils include echinoderm grains, encrusting, ramose and fenestrate bryozoans, pseudopunctate and impunctate brachiopods, ostracodes and trilobites. Glauconite and silica replacement of the fossil allochems is present. Articulation of ostracode valves is common. SAMPLE: OHR-8 (6.9 m)

Section B

O6B	1.8	1.8	Medium gray, medium- to thinnly-bedded, glauconitic grainstone/packstone and interbedded shale. Micrite content decreases up section. Dominantly bryozoans (all types), impunctate and pseudopunctate brachiopods, ostracodes and rare trilobites. Abundant articulated ostracode valves. SAMPLES: OHR-7 (0.3 m), OHR-6 (0.8 m), OHR-5 (1.6 m)
O7B	0.2	2.03	Fissile gray shale with limestone nodules.
O8B	1.8	3.8	Medium-gray, coarse-grained, medium- to thinnly-bedded, cross-bedded, glauconitic grainstone. Minor shale partings are present throughout the unit. Abundant silica replacement. Weathered outcrop is extremely fossiliferous. High faunal diversity includes echinoderm grains, bryozoans (ramose, encrusting and fenestrate), brachiopods (all types), ostracodes, trilobites, bivalves and rare dasyclad algae. Ostracode valves are commonly articulated.

			SAMPLES: OHR-4 (2.2 m), OHR-3 (3.0 m), OHR-2 (3.3 m), OHR-1 (3.8 m)
O9B	0.3	4.1	CONTACT. Gray shale marking top of the Rockhouse Limestone member and bottom of the Ross Limestone member.
O10B	1.0	5.1	ROSS LIMESTONE MEMBER OF ROSS FORMATION Dark gray, weathering to yellowish brown, medium- to thinnly bedded, fine-grained dense limestone with shale partings. Abundant quartz. Rare fossil allochems includes encrusting and ramose bryozoans, echinoderm grains, ostracodes, brachiopods and trilobite fragments. Burrows (vertical and horizontal) are abundant. Laminations and intraclasts are present. SAMPLES: OHRL-1 (4.3 m), OHRL-2 (5.0 m)

Section C

O11C	2.3	2.3	Dark gray, fine-grained, medium- to thinnly-bedded, dense, quartz-rich limestone. Weathered outcrop shows bryozoans, corals, brachiopods and echinoderms. Few bryozoans (encrusting and cryptostomes), ostracodes, brachiopods, corals and trilobites. Abundant bioturbation. SAMPLES: OHRL-7 (0.1 m), OHRL-6 (0.6 m), OHRL-5 (1.0 m), OHRL-4 (1.3 m), OHRL-3 (2.2 m)
O12C	1.7	4.0	Interbedded shale and nodular limestone.

MEASURED SECTION AT BEAR BRANCH

Section is located 2 miles east-south-east of Olive Hill on Bear Branch, a tributary of Indian Creek, Hardin County.

Unit	Meters	Cum. m.	Description
B1	1.2	1.2	ROSS LIMESTONE MEMBER OF ROSS FORMATION Medium- to thinnly-bedded, medium- to fine grained, bluish gray grainstone with shale partings. Abundant glauconite and hematite. Quartz is present in minor amounts. Horizontal burrows are present. Brachiopods (all types), ostracodes, echinoderm grains and trilobite fragments are common. Bryozoans (ramose and encrusting) and bivalves rare. Articulation of small brachiopods common. SAMPLES: BBR-8 (0.0 m at base), BBR-9 (0.6 m)
B2	1.8	3.0	CONTACT. Gradational contact between the Ross Limestone member and the Bear Branch facies. Contains medium to thinnly bedded interbedded hematite and bluish limestone. Fossilifereous on weathered outcrop (dominately brachiopods and corals). No sample was obtained.
B3	3.1	6.1	BEAR BRANCH FACIES OF ROSS FORMATION. Massive fossiliferous hematitic limestone. It was not possible to obtain a sample from this unit.
B4	1.7	7.8	Cross-bedded laminations of hematite and reddish-gray, coarse-grained grainstone. Weathered outcrop shows layers that are profusely fossiliferous. Fossils present include echinoderm grains, pseudopunctate brachiopods, bryozoans (encrusting ramose and fenestrate), ostracodes, trilobites, inpunctate brachiopods and rare bivalve fragments. SAMPLES: BB-7 (6.9 m), BB-6 (7.5 m)

B5	4.0	11.8	Medium- to thickly-bedded, cross-bedded, hematite and coarse- to medium-grained grainstone. Abundant micrite at bottom of unit. Hematite occurs as oolitic coatings, pellets and replaced fossils. Echinoderm grains, brachiopods (all types), bryozoans (encrusting, fenestrate and ramose), trilobites, and ostracodes are present with rare bivalve fragments. SAMPLES: BB-5 (8.6 m), BB-4 (9.6 m), BB-3 (10.8 m), BB-2 (11.2 m)
B6	2.0	13.8	Medium- to thickly-bedded, coarse-grained grainstone and hematite stringers. Hematite content decreases up section. Abundant large, articulated echinoderms, impunctate and pseudopunctate brachiopods, and ostracodes valves. Minor trilobite fragments and rare bryozoans. SAMPLES: BB-1 (12.8 m)
B7	0.3	14.1	CONTACT. Interbedded coarse-grained, pinkish, fossiliferous limestone (Flat Gap Limestone) and greenish-gray to reddish-tan coarse-grained crinoidal limestone with hematitic stringers.

APPENDIX B

Table B-1. Constituent particle analysis (rock volume percent) of selected thin sections.

	Echinoderms	Bryozoans	Trilobites	Brachiopods	Ostracodes	Unidentified	Spar	Micrite	Hematite	Glauconite	Dolomite
OHD-2	36.0	7.0	2.7	6.3	2.0	0	45.3	0.7	0	0	0
OHR-1	29.0	10.7	3.7	17.3	2.7	0	32.0	0	0	4.0	0.7
OHR-10	31.7	17.3	0	18.0	2.0	0	30.0	0	0	0	0
BB-1	35.3	2.7	5.7	5.7	0	0	44.0	0.7	6.0	0	0
BB-4	24.0	17.7	4.7	5.7	0	0	17.7	0	30.3	0	0
BB-6	23.7	2.0	8.0	8.7	0	0.3	25.3	0	32.0	0	0
BBR-9	16.3	14.0	15.0	11.7	4.0	0	32.7	0.3	5.3	0.7	0

APPENDIX C

PLATE 1

Conodonts of the Decatur and Ross Formations.

1-7. *Icriodus woschmidti* Ziegler, 1960

1. Pa element, X50. PQRR-1.
2. Pa element, X50. PQD-5.
3. Pa element, X50. OHR-1.
4. Pa element, X50. OHR-4.
5. Pa element, X50. PQRB-6.
6. Pa element, X50. OHR-1.
7. Pa element, X50. OHR-1.

8. *Pedavis* sp. E. Broadhead and McComb, 1983

8. Basal plate, X50. PQD-5.

9-14. *Icriodus woschmidti* Ziegler, 1960

9. Ramiform element, *c* morphotype, X50. PQRB-6.
10. Cone element, *e* morphotype, X50. PQRR-1.
11. Cone element, *e* morphotype, X50. OHR-4.
12. Cone element, *d* morphotype, X50. PQD-1.
13. Cone element, *d* morphotype, X50. PQRR-3.
14. Cone element, *e* morphotype, X50. PQD-5.

15. <u>Belodella</u> <u>silurica</u> Barrick, 1977

15. M element, X50. PQD-5.

16-17. <u>Pseudooneotodus</u> <u>beckmani</u> Bischoff and Sannemann, 1958

16. X50, PQD-5.

17. X50. PQD-5.

18-20. <u>Ozarkodina</u> <u>remscheidensis</u> <u>eosteinhornensis</u> Walliser, 1964

18. Pb element, X50. OHR-4.

19. Pb element, X50. OHR-4.

20. Pb element, X50. OHR-1.

21-22. <u>Oulodus</u> <u>elegans</u> (Walliser, 1964)

21. Sc element, X50. OHD-2.

22. Pb element, X50. PQD-1.

23. <u>Ozarkodina</u> <u>remscheidensis</u> <u>eosteinhornensis</u> Walliser, 1964

23. Pb element, X50. OHR-4.

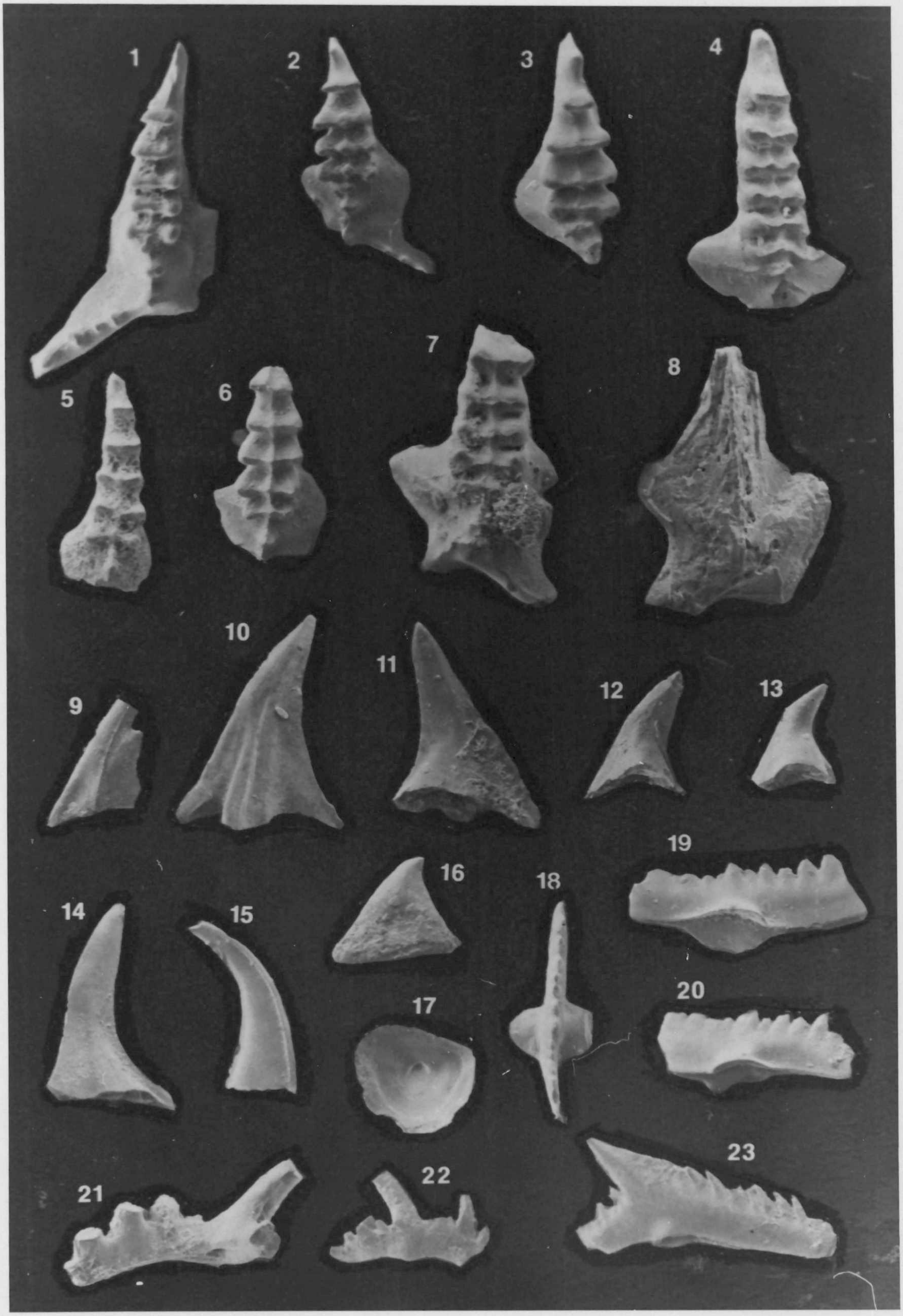


Plate 1.

VITA

Deborah Ann Capaccioli was born in Davenport, Iowa, on July 24, 1958. She attended high school in Mt. Vernon, Iowa, graduating in 1976. In August, 1977, she attended Rockford College, Rockford, Illinois, transferring to the University of Iowa, Iowa City after one year where she recieved her B.A. in Botany and Geology in July, 1983. She enrolled in the graduate program at the University of Tennessee in September, 1983 and recieved her M.S. in March, 1987. Deborah plans to move to New Orleans, Louisiana, where is awaits future employment.