STRATIGRAPHY OF THE UPPER DEVONIAN-LOWER MISSISSIPPIAN SHALE SEQUENCE IN THE EASTERN KENTUCKY OUTCROP BELTS

THESIS

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science at The University of Kentucky

By

DENNIS RAY SWAGER

Lexington, Kentucky

Director: Dr. Frank R. Ettensohn, Assist. Professor of Geology

Lexington, Kentucky

1978

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

STRATIGRAPHY OF THE UPPER DEVONIAN-LOWER MISSISSIPPIAN SHALE SEQUENCE IN THE EASTERN KENTUCKY OUTCROP BELT

by

Dennis Ray Swager

This thesis was well researched and well written. It is obvious - from the appendices alone - that much time was devoted to this effort.

The [illegible] in the appendices and the [illegible] throughout the text could prove to be valuable reference works in the future.

Especially helpful were the correlations between surface radioactive - stratigraphic units and subsurface units as determined by gamma ray logs.

Fig 10 showing correlations from eastern Kentucky into surrounding areas and relating works of previous research is also helpful.

Supporting fossil evidence - where available - helps lend credibility to the radio-stratigraphic - lithostratigraphic correlations.

____
Director of Thesis

____
Director of Graduate Studies

____
Date

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

THESIS

Dennis Ray Swager

The Graduate School

Univeristy of Kentucky

1978

ABSTRACT OF THESIS

STRATIGRAPHY OF THE UPPER DEVONIAN-LOWER MISSISSIPPIAN SHALE SEQUENCE IN THE EASTERN KENTUCKY OUTCROP BELTS

The Devonian-Mississippian black-shale sequence in the two eastern Kentucky outcrop belts has a characteristic internal stratigraphy which allows definition of three types of stratigraphic units. Six litho-stratigraphic, seven radioactive-stratigraphic and two biostratigraphic units are defined in this study, and are laterally extensive throughout the eastern Kentucky outcrop belts. The radioactive units can be correlated into the subsurface by comparison of gamma-ray logs with radioactivity profiles generated for outcrop exposures. Relative changes in radioactivity within continuous black-shale sequences are easily identified on radioactivity profiles, but are lithologically indistinguishable in the outcrop. As the shale sequence thins towards the southwestern parts of both outcrop belts, internal stratigraphic units also thin proportionally. Eventual pinch outs occur in the lower parts of the sequence as it onlaps the Cincinnati Arch in the east-central Kentucky outcrop belt.

Author's Name

Date

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

RULES FOR THE USE OF THESES

Unpublished theses submitted for the Master's and Doctor's degrees and deposited in the University of Kentucky Library are as a rule open for inspection, but are to be used only with due regard to the rights of the authors. Bibliographical references may be noted, but quotations or summaries of parts may be published only with the permission of the author, and with the usual scholarly acknowledgments.

Extensive copying or publication of the thesis in whole or in part requires also the consent of the Dean of The Graduate School of the University of Kentucky.

A library which borrows this thesis for use by its patrons is expected to secure the signature of each user.

Name and Address	Date

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

ACKNOWLEDGMENTS

Funding for this study was provided by the United States Department of Energy through the Morgantown Energy Research Center, Morgantown, West Virginia under contract number EY-76-C-05-5202. Financial support in the form of a two-year research assistantship was awarded the author by the Geology Department at the University of Kentucky which supported the research. Special thanks are extended to Dr. F. R. Ettensohn for his encouragement, leadership, advice, ideas and efforts throughout all phases of the research study. The author is indebted to Dr. Linda Provo Fulton, University of Cincinnati, Dr. Roy C. Kepferle, U.S. Geological Survey and Dr. Paul E. Potter, University of Cincinnati, for their help in outlining problems to be solved, methods to be used and stratigraphic information supplied for this study.

Thanks are extended to Mike Miller, John Goble and Don Chesnut for their assistance in the collection of field data and suggestions on operational methods.

Special thanks are extended to Dr. Frank R. Ettensohn, Dr. William C. MacQuown, Dr. William H. Dennen and Ed N. Wilson for editing the manuscript. The typing and editing skills of Catherine Swager are gratefully acknowledged. I also wish to thank Patricia Bryant and J. Les Booth respectively for typing the manuscript and drafting the figures.

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

TABLE OF CONTENTS

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

LIST OF FIGURES

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

LIST OF PLATES

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1973

INTRODUCTION

The Upper Devonian-Lower Mississippian, black-shale sequence in the east-central Kentucky outcrop belt, and in the Pine Mountain outcrop belt was studied during this project. The purpose of this project was to determine possible internal stratigraphy within this uniform black-shale sequence which would be useful for further exploitation of contained hydrocarbons, as well as for comparison and correlation with the better-known, black-shale sequences in adjacent states and the subsurface units of Provo (1977). This study is based on a detailed physical characterization of 18 black-shale sections in central and eastern Kentucky and Tennessee. These section descriptions are included in Appendices A-C.

The Devonian-Mississippian, black-shale sequence is a distinctive unit in both outcrop exposure and in subsurface cuttings and geophysical logs. Despite the distinctive nature of the sequence throughout the western Appalachian Basin, the internal stratigraphy of this unit was previously largely unknown in eastern Kentucky. Moreover, throughout parts of the Appalachian Basin these shales are important producers of natural gas (Avila, 1976). Hence, because of their widespread distribution, distinctive nature and economic potential, it is important that an internal stratigraphy be determined as a framework for geologic understanding and economic exploitation of these shales.

UGR File #2?
Dennis Ray Swager
Univ. of Kentucky
1978

LOCATION

The Devonian-Mississippian shale sequence outcrops in two distinct belts in eastern Kentucky. The largest of these is a northeast-southeast, arc-shaped outcrop belt on the east flank of the Cincinnati Arch from Lewis County to Cumberland County, Kentucky (Figure 1). This outcrop belt, occurs within the knobs or knobstone escarpment which forms the physiographic boundary between the Bluegrass region and the Appalachian Plateau. The sections in this belt range in thickness from more than 61 m (200 ft) to less than 9.2 m (30.0 ft).

The second outcrop belt trends northeast-southwest from Pike County to Bell County in easternmost Kentucky (Figure 1). In this region, the black-shale sequence is exposed along the base of the Pine Mountain thrust block and acted as the incompetent unit along which most of the thrusting occurred. Therefore, the black shales in this outcrop belt are usually highly fractured and folded. The sections in this belt range in thickness from more than 260 m (850 ft) to less than 56 m (182 ft); this variation is largely due to faulting. The four cross sections shown in Figures 1, 4, 5, and 7 are based on sections from these two outcrop belts.

The location of each section from each outcrop belt is shown in Figure 1. More detailed locations with Carter Coordinates are provided in the introductory paragraphs of each description in Appendices A-C.

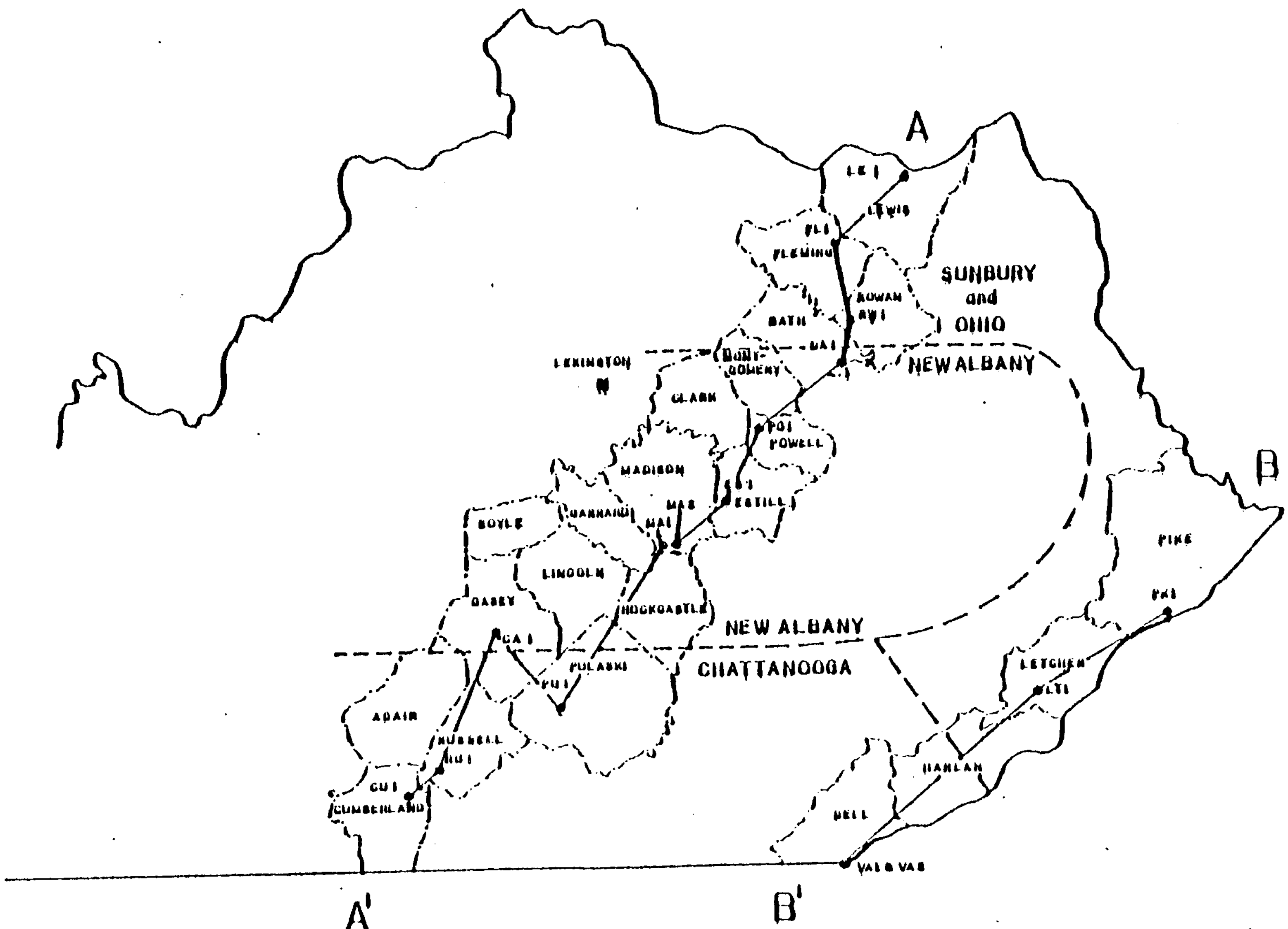


Figure 1. Location map of measured sections, lines of cross-section and U.S.G.S. formational terminology.

UGR File #25
Dennis Ray Swager
Univ. of Kentucky
1978

PROCEDURES

Each section was measured, described, sampled and photographed. Because these shales are commonly very radioactive, gamma-ray emmission levels were recorded at 0.8 m (2.5 ft) intervals along the vertical section with a scintillometer.

One of the most difficult parts of the study was locating suitable black-shale exposures. Accessible black-shale exposures were found by examining geologic quadrangle maps, consulting with knowledgable persons and driving through the Knobs area of eastern Kentucky looking for suitable outcrops.

Once suitable outcrops were located, a procedure suggested by Dr. Roy C. Kepferle and Dr. Paul E. Potter involving three traverses was used for outcrop characterization. On the first traverse, the section was measured with a Jacob's staff, Abney level and tape measure, where needed; each section was marked with brightly-colored flags of engineering tape at 1.5 m (5 ft) intervals. On the second traverse, each section was physically described, noting lithology, lamination character, sedimentary structures, grain size, color, burrows, fossils and occurrence of pyrite and phosphate nodules. Also on the second traverse, each section was sampled at 1.5 m (5 ft) intervals and at any intervening intervals where changes in lithologic character or other interesting features occurred. On the third traverse, radioactive emmission levels were recorded at 0.8 m (2.5 ft) intervals with a portable scintillation counter. After each section was described, the elevation at the base of the section was found with an altimeter adjusted to a nearby benchmark. Where the base of the section was covered, the elevation was taken at the base of the prominent Three Lick Bed. This information is easily entered into a computer system for regional analysis or comparison with subsurface data.

Based on these data collected in the field, two stratigraphic profiles were compiled for each section described. A lithologic column was first drawn for each section based on the field description of thickness, bedding, fossils and lithology. Both lithologic and biostratigraphic data are contained on these columns. A second profile was formed by plotting gamma-ray emmission levels against black-shale thickness above the base of the outcrop (Appendices A-C; see Ettensohn and others, 1978). This kind of profile reveals a persistent sequence of radioactive units which was first recognized by Provo (1977). The lithologic columns, section descriptions and radioactive profiles are included in Appendices A-C.

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

STRATIGRAPHIC NOMENCLATURE

Introduction

The Upper Devonian-Lower Mississippian black-shale sequence underlies much of the eastern and central United States. The sequence can be traced from Alabama to southern Canada and underlies some 500,000 square miles of the continent (Provo, 1977). In addition to being widespread, it is a very distinctive sequence in surface exposures, subsurface cuttings, gamma-ray logs and other geophysical logs. Therefore, over large parts of its distribution, the sequence has been mapped and subdivided for many years resulting in a staggering amount of data. Despite all this study, the black-shale sequence in eastern Kentucky is still not adequately understood or correlated.

Previous Studies

Stratigraphic subdivisions have been adopted for the black-shale sequence in many of the regions where it is found, and in many cases, these subdivisions do not directly correlate across regional boundaries. In the process of determining which subdivision and stratigraphic nomenclature should be used in eastern Kentucky it was necessary to examine all the stratigraphic nomenclature used in both this and surrounding regions. Figure 2 summarizes the most commonly used nomenclatures for the black-shale sequence in southern Ohio, southern Indiana, Tennessee, and Kentucky.

The formational nomenclature used in this study is the same as that used by the U.S. Geological Survey-Kentucky Geological Survey joint mapping program in Kentucky. This program used the Ohio, Sunbury, New Albany, and Chattanooga as formational names for the black-shale sequence in various parts of eastern Kentucky. However, no attempt was made during the program to subdivide these units or to make detailed correlations between them. Figure 1 shows the areal extend of the various black-shale formations in eastern Kentucky.

Many detailed reports on the stratigraphy of these formations already exist, but they are generally limited, regional studies. Campbell's study in 1946 was probably the first major stratigraphic study of this black-shale sequence. Campbell (1946) divided the New Albany Group of southern Indiana into formations and correlated these into central Kentucky. In the same paper, he divided the Chattanooga Shale of southern Kentucky and Tennessee into members. For comparison of his subdivisions refer to Figure 2. In a well-organized summary of the Devonian-Mississippian stratigraphy of Ohio, Hoover (1960) presents a generalized stratigraphic nomenclature for the Ohio Shale, as well as underlying and overlying units (Figure 2). Conant and Swanson (1961) provide a detailed stratigraphic study of the Chattanooga Shale and overlying Mississippian shales in Tennessee and southern Kentucky. Much of their stratigraphic nomenclature is based upon an earlier detailed study of the Devonian-Mississippian shale sequence in Tennessee by Hass (1956). Studies of the Chattanooga and New Albany Shales were conducted by Conant and Swanson (1961) and Lineback (1968). Lineback (1968) suggests a modified stratigraphic nomenclature for Indiana (Figure 2), but also discusses environments of depositon. Provo (1977) discussed the stratigraphy of the Devonian-Mississippian shale sequence in the central Appalachian Basin, and found seven internal stratigraphic units which she feels can be correlated over much of the basin. These stratigraphic studies and mapping by the joint U.S. Geological Survey-Kentucky Geological Survey

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

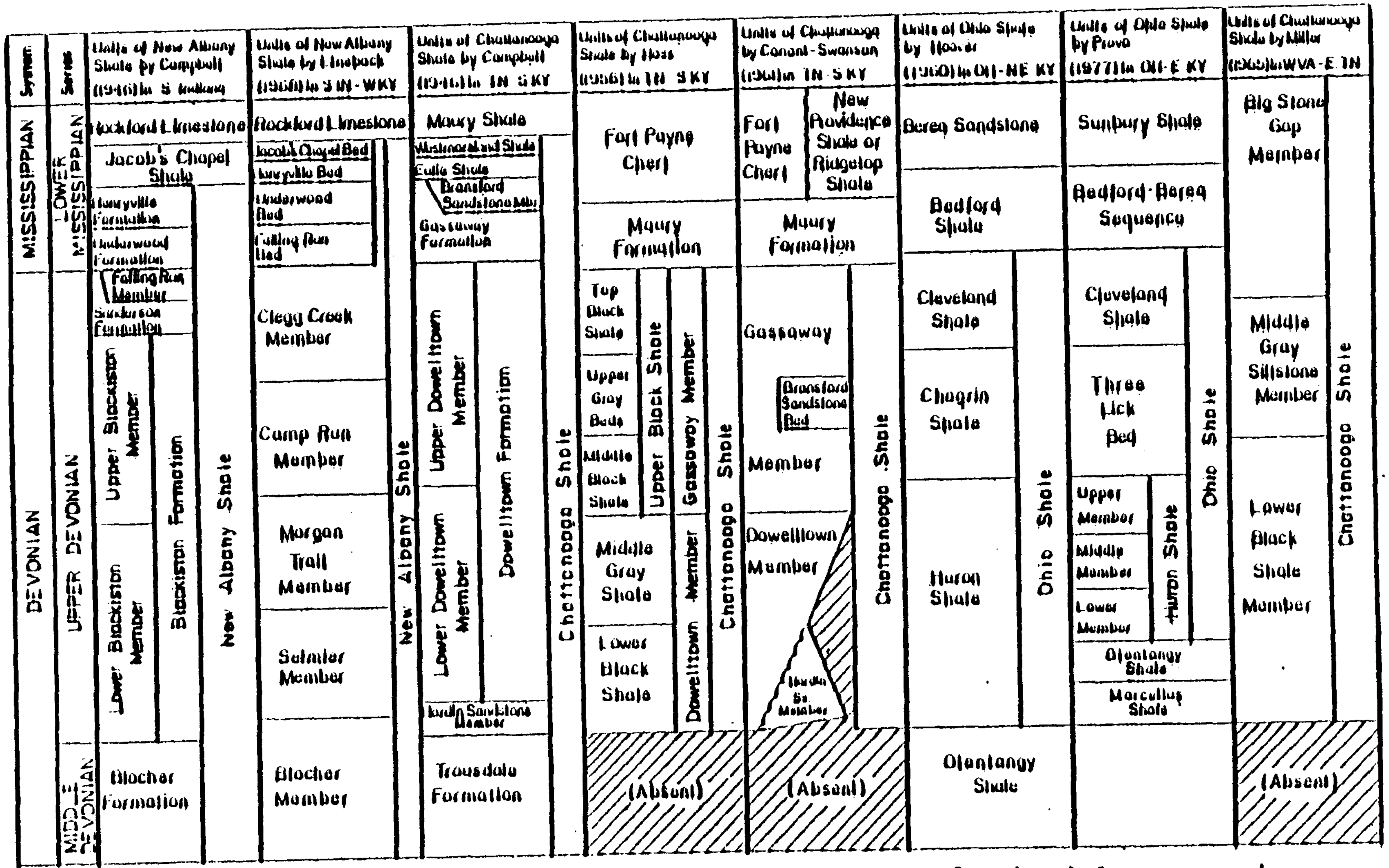


Figure 2. Comparison of frequently referenced stratigraphic nomenclature for the shale sequence in southern Ohio, southern Indiana, Kentucky and Tennessee.

mapping program provide the nomenclatorial framework used for the black-shale formations in this study. The actual correlation of various units within the Ohio, Chattanooga and New Albany Shales is discussed in the section on correlations.

Although only a few fossils commonly occur in the black shale, a number of studies have described them and their use in biostratigraphy, correlation, and interpretation of depositional environments. Various marine and terrestrial plant fossils are most abundant in the black shales. White and Stadnichenko (1923), Read (1936, 1937), Hoskins and Cross (1951), Winslow (1962), and Schwietering (1970) have described many of these plant fossils. Certain brachiopods are also locally common in these shales, and these have been described by Campbell (1946). Conodonts, which are very important for correlation and biostratigraphy in the black shales, have been described by Huddle (1933), Hass (1947, 1956), and Conant and Swanson (1961).

Black-shale petrographic studies are few in number and most have been done for economic purposes. Petrographic studies by Theissen (1925), Patchen and Larese (1975), and Harvey and others (1977) are the most notable.

The age of the shale sequence and its environment of deposition is another prominent problem dealt with in black-shale literature. Hoover (1960) refers to it as the black-shale problem. Placement of the Devonian-Mississippian boundary has been problematic and many authors, such as Swartz (1923), Savage (1930), Keyes (1938), Hass (1965), and Conant and Swanson 1961); Have addressed themselves to this topic. The depositional environments of the black shale sequence is also controversial, but can be divided into two schools of thought. The first school of thought maintains a deep-water origin; workers such as Rich (1951) and Lewis and Schwietering (1971) have supported this view. A second school of thought maintains a shallow-water origin, and this view has been supported by Stockdale (1939), Conant (1956), Swanson (1956) and Conant and Swanson (1961). More recent work on the depositional environment of these black shales suggests that depth is not necessarily the most critical factor in black-shale depositon, but rather, the formation of a thermally stratified water column. Such suggestions have been made by Lineback (1968), Griffith (1977), and Provo (1977).

Age of the Shale Sequence

In order to establish a basic stratigraphic framework in which to work, it was first necessary to define the approximate location of the Devonian-Mississippian boundary. Because it was not within this scope of this study to do detailed conodont biostratigraphy, in order to place this boundary, Biostratigraphic determinations made in the course of the U.S. Geological Survey-Kentucky Geological Survey joint mapping program were relied upon. Conodont studies by Huddle (1966, written communication) and later confirmations from Harris (1977, personal communication) indicate that the Ohio Shale in east-central Kentucky is entirely Late Devonian in age. The Ohio Shale outcrop along the northern part of the Pine Mountain outcrop belt is also assumed to be Late Devonian in age (Alvord, 1971). The Ohio Shale is overlain by the Bedford Shale or by both Bedford Shale and Berea Sandstone (Figure 3). The Bedford Shale is probably of combined Devonian and Mississippian age similar to the Louisiana Limestone of Illinois (Huddle, written communication, 1965). Although the Berea Sandstone has never been formally dated, it is traditionally assumed to be early Mississippian because it lies between the

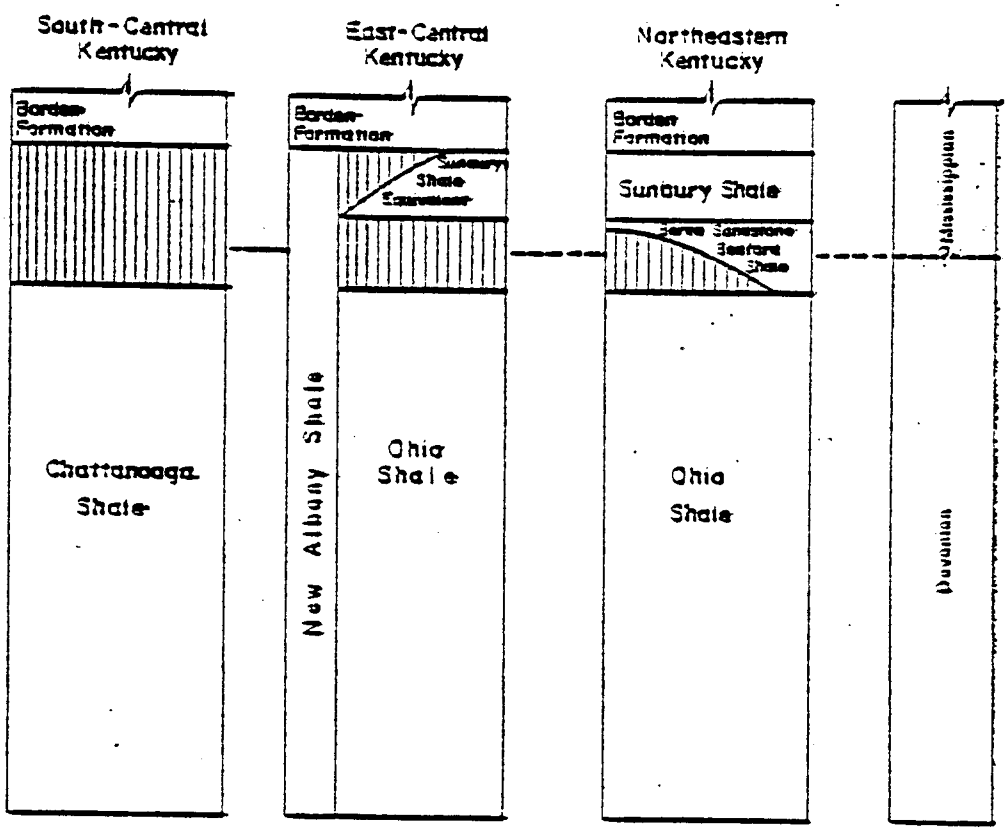


Figure 3. Chart showing the relationships of the Sunbury, Bedford, Berea, Ohio and New Albany Shale in eastern Kentucky.

Bedford Shale, the upper part of which is most likely Mississippian, and the Sunbury Shale, which is definitely Mississippian. The black Sunbury Shale contains an abundant conodont fauna which indicates an early Mississippian age (Huddle, written communication, 1966).

Southward along the outcrop belt, both the Bedford and Berea thin and are completely absent in east-central Kentucky (Peck, 1967; Weir, 1976), so that Mississippian black shales equivalent to the Sunbury directly overlie Devonian black shales equivalent to the Ohio Shale. At this point on the outcrop belt where Devonian and Mississippian black shales are no longer separated by intervening formations, the black-shale sequence is called the New Albany Shale. Paleontology also suggests that the lowermost portions of the New Albany Shale are Middle Devonian in age (Lewis, 1971).

Farther south along the east-central Kentucky outcrop belt, conodont studies also indicate that black shales of Mississippian age pinch out, leaving a black-shale sequence entirely late Devonian in age. This sequence is called the Chattanooga Shale. However, along the southern part of the Pine Mountain outcrop belt, the Chattanooga Shale is both Mississippian and Devonian in age (Miller, 1965). Further details on these ages are provided by the following authors:

a) Ohio-Bedford-Sunbury sequence (Hoover, 1960; Provo, 1977).

b) New Albany (Campbell, 1946; Lineback, 1968).

c) Chattanooga in east-central Kentucky (Hass, 1956; Conant and Swanson, 1961).

d) Chattanooga in Pine Mountain (Swartz, 1923; Miller, 1965).

It is important to note that there is still much controversy regarding the exact age of the Devonian-Mississippian black-shale sequence from place to place and by no means will this study solve all of these problems.

One problem which should be clarified further is that of nomenclature. The names of the stratigraphic subdivisions used in Figure 2 refer to particular type localities. Although the names are typically used beyond type localities to indicate homotaxial units, they are not necessarily wholly correlative in a time-stratigraphic or rock-stratigraphic sense. In order to facilitate rock-stratigraphic correlation within the uniform black-shale sequences of the Ohio, New Albany and Chattanooga Shales, an internal stratigraphy needs to be found in these sequences. The internal stratigraphic units discussed in the next part of this study are used for correlation.

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

INTERNAL STRATIGRAPHY

Introduction

The Upper Devonian-Lower Mississippian black-shale sequence in eastern Kentucky consists predominantly of two lithologies. The most common lithology is a brownish-black, organic-rich shale. A second lithology consists of lesser amounts of greenish-gray, organic-deficient shale. Cone-in-cone limestone (Plate 1), dolomites and sandstones occur locally in very small quantities. At the RU-1 locality, a very unusual, 2.5 cm (1 in) lens of coal was found. The predominant black and green shales generally occur in a persistent vertical sequence which is discussed in this section.

In addition to lithologic sequence, it has been found that the radioactive emmission levels along an outcrop section varies vertically in a consistant fashion. Most of the radioactivity in these shales comes from uranium and thorium in close association with organics. When radioactive profiles from the outcrop are compared with gamma-ray logs from the subsurface, a similarity in the pattern of emmissions is noted. These patterns were first noted by Provo (1977). The discovery of similar patterns from radioactivity profiles of surface exposures has enabled the definition of radioactive units and internal correlation between the surface and subsurface. These radioactive units form the basis of the internal stratigraphic framework discussed herein.

The consistent presence of certain fossils in parts of the shale sequence also provide some stratigraphic control. The persistent presence of these fossils at certain stratigraphic horizons is the basis for the two biostratigraphic zones discussed in this section.

In order to show the stratigraphic relationships of the Ohio, New

Albany and Chattanooga Shales, it is first necessary to define an internal stratigraphy that is correlative throughout eastern Kentucky. This internal stratigraphy is based upon the outstanding easily identified physical characteristics of the shale sequence. In this case, lithology, radioactivity and paleontology provide the best means of understanding stratigraphic relationships. Each of these areas will be discussed in detail below.

Although some prefer to differentiate this sequence on the basis of age, where possible, it is discussed here as a whole. In other words, when the term shale sequence is used here it refers to both the Devonian and Mississippian black shales as well as the green shales and siltstones contained between and within the black shale sequence.

Lithostratigraphy

The stratigraphic nomenclature discussed previously was largely based on lithology. During the study of the shale sequence for this report, lithology was also a major factor in determining internal stratigraphy because the lithologic units persist in the same order throughout the sections measured in eastern Kentucky. This persistance is shown in Figures 4 and 5.

The uppermost lithostratigraphic unit in the shale sequence is the Lower Mississippian, Sunbury black shale. It is herein called the uppermost black-shale member (Figure 10). This unit is present in the LE 1, FL-1, RW-1, BA-1 and LT-1 sections (Appendices A and B) and ranges from 4.4 m (14.3 ft) to 7.3 m (24.0 ft) thick. It is characteristically a laminated brownish-black, organic-rich shale. It commonly contains phospate and pyrite nodules as well as inarticulate Lingula and Orbiculoidea brachipods. It is a distinctive unit in outcrop because it typically forms a massive ledge overhanging the less resistant Bedford Shale. This shale, like some of the lower black shales, exhibits a distinctive weathering pattern termed "couplet weathering" by Dr. Paul E. Potter (personal communication, 1976). The term "couplet weathering" refers to equidistantly spaced alternating resistant and reentrant beds a few centimeters thick which occur in weathered vertical sections.

The next lower lithostratigraphic unit consists of the Mississippian Berea Sandstone and the Devonian-Mississippian Bedford Shale, named by Newberry (1870). The Berea is composed of sandstone and siltstone beds with minor greenish-gray, organic-deficient shale lenses, and the Bedford is characteristically composed of greenish-gray, organic-deficient shale with minor amounts of phosphate and pyrite nodules. The Bedford-Berea sequence is found in the LE-1, FL-1, RW-1, BA-1, LT-1, and PK-1 sections (Appendices A and B) and ranges from 3.1 m (10.0 ft) to 18.6 m (60.0 ft) thick. A comprehensive study of the relationships and age of the Bedford-Berea sequence is summarized by deWitt (1951, 1970). This sequence is herein called the green shale and light siltstone lithostratigraphic unit (Figure 10). This lithostratigraphic unit is easily recognized in outcrop because it is light-colored and forms a reentrant between the dark-colored resistant shale ledges of the overlying Sunbury and the underlying Ohio Shales. The Bedford-Berea sequence is present along the east-central Kentucky outcrop belt just north of PO-1 section and along the Pine Mountain outcrop belt south to the LT-1 section. The Bedford-Berea thins southward and is absent south of the BA-1 section (Figure 4). Therefore, where the Bedford-Berea sequence exists, it separates the similar lithologies of the Mississippian Sunbury Shale and the Devonian Ohio Shale, but where the Bedford-Berea sequence is missing,

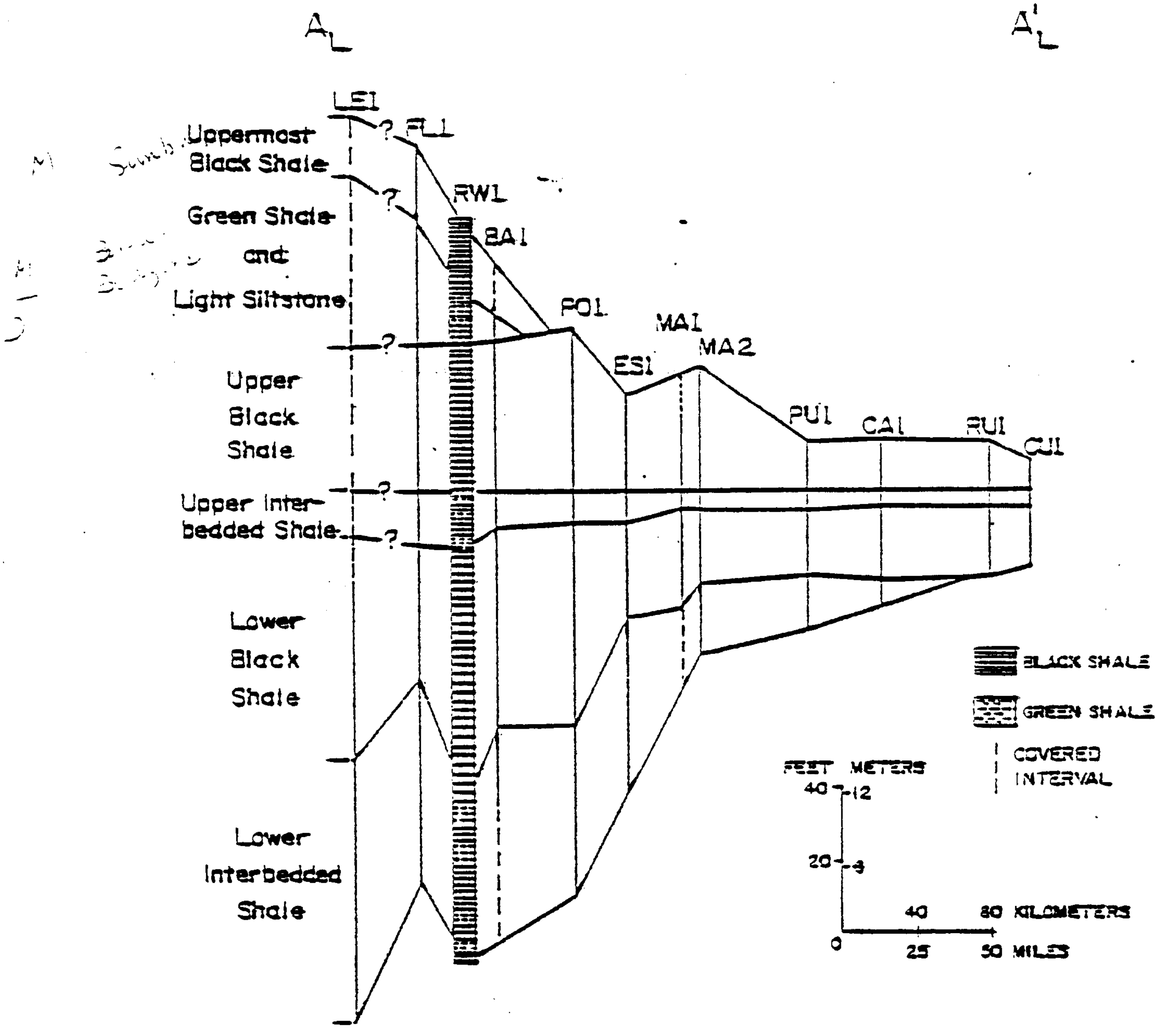


Figure 4. Schematic cross-section along the east-central Kentucky outcrop belt showing internal lithostratigraphic units (the lithologic drawing of the RW-1 reference section is included for clarity).

the contact between the Sunbury Shale equivalent and the Ohio Shale equivalent is lithologically indistinguishable. This combined Mississippian-Devonian, black-shale sequence is called the New Albany Shale. Although lithology offers no aid in distinguishing Mississippian and Devonian black shale, the radioactivity profiles discussed in a later section will readily do this.

Underlying the Bedford-Berea sequence is a unit of Upper Devonian age composed entirely of black shale. It is designated herein the upper black-shale member. This upper black shale can be seen in all the measured sections (Appendices A and B) except in the FL-1 section (Appendix A) where it was covered. The unit ranges from 34.1 m (110.0 ft) to 3.1 m (10.0 ft) thick, and thins to the southwest in both outcrop belts (Figures 4 and 5). It is characteristically a brownish-black, laminated, organic-rich shale and contains abundant phosphate nodules, Lingula and pyrite nodules. It characteristically forms steep ledges with "couplet weathering" and is easily distinguished in outcrops.

Underlying the upper black-shale member is the upper interbedded member called the Three Lick Bed by Provo and others (1977). This unit is also persistent throughout eastern Kentucky as shown in Figures 4 and 5. It is found in all measured sections except the Fl-1 section (Appendix A) where it was covered. This unit ranges from 0.9 m (3 ft) to 43.4 m (140.0 ft), but characteristically is only 0.9 m (3.0 ft) to 4.7 m (15.0 ft) thick (refer to Figure 4). The upper interbedded member generally consists of three greenish-gray, organic-deficient shales interbedded with two brownish-black laminated, organic-rich shales. Each of the beds is generally less than 1.0 m (3.2 ft) thick. The green shales in this unit commonly contain Lingula, vertical Lingula burrows, and some

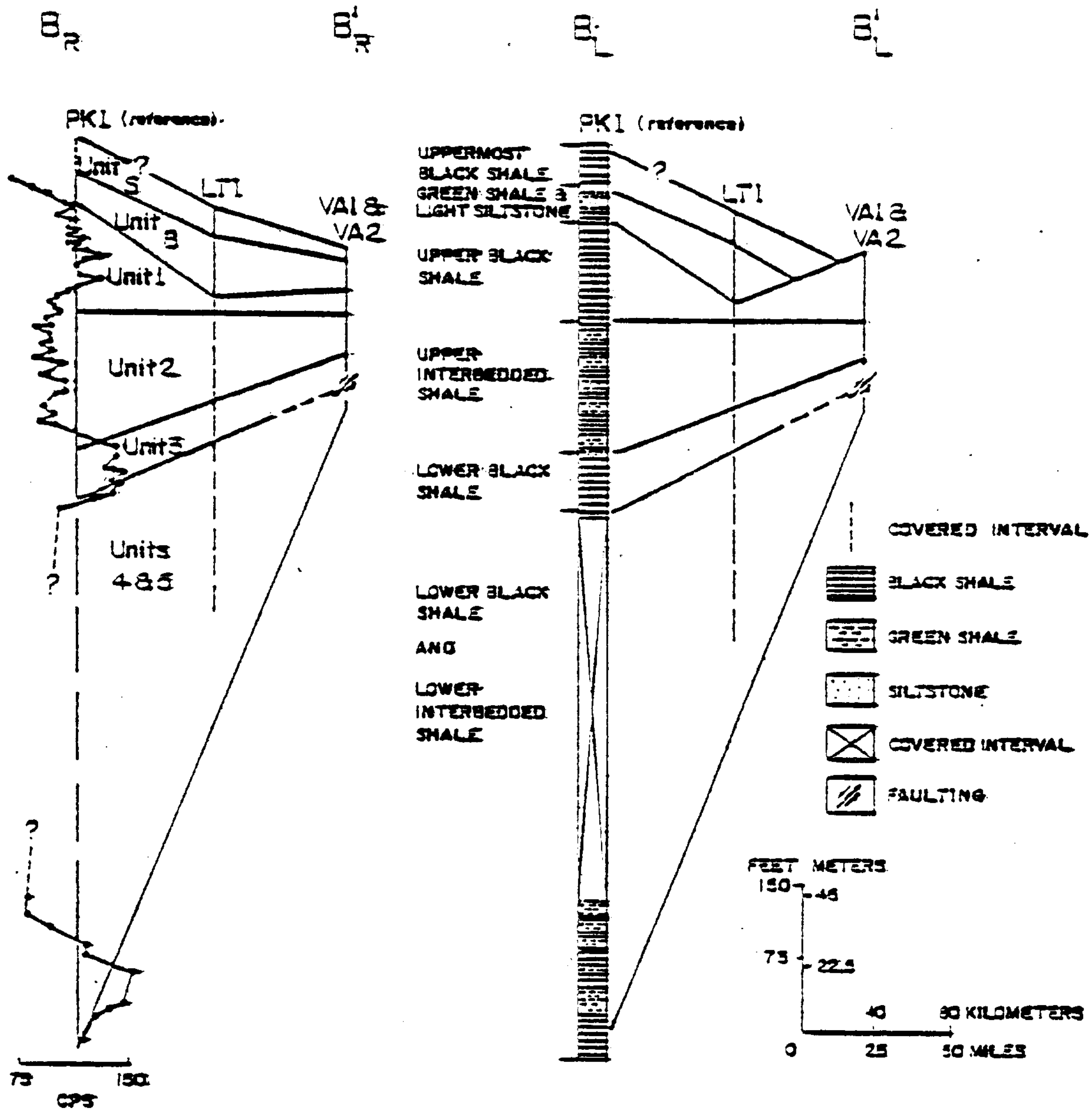


Figure 5. Schematic cross-section along the Pine Mountain outcrop belt showing internal radioactive-stratigraphic and lithostratigraphic units as compared to the PK-1 reference section.

unidentified horizontal burrows. The black shales, except for their thinness, are typical of other black shales in the sequence. This unit is easily distinguished in outcrop because the interbeds of green shale form three small reentrants. This unit also thins to the southwest as shown in Figure 5.

A lower black-shale unit underlies the Three Lick Bed, and parts of this unit can be seen throughout eastern Kentucky (Figures 4 and 5). This unit ranges from 4.7 m (15.0 ft) to more than 21.7 m (70.0 ft) thick. The lower black shale contains brownish-black, laminated, homogeneous, organic-rich shale as well as pyrite nodules, bedded pyrite, and discontinuous cone-in-cone limestones. The unit also contains the pelagic alga Foerstia and the large spore Tasmanites. The unit is also persistent throughout eastern Kentucky, although the lowermost part of the unit is not present in the CU-1 section where the entire shale sequence thins as it onlaps the Cincinnati Arch (Figure 4, Appendix A, section CU-1).

Underlying the lower black shale is the lower interbedded unit which contains brownish-black, organic-rich shale interbedded with greenish-gray dolomitic shales. This unit varies from 2.2 m (7.0 ft) to more than 21.7 m (70.0 ft) thick. This lithostratigraphic unit is also persistant throughout most of eastern Kentucky, except in the CA-1, RU-1 and CU-1 sections in southern east-central Kentucky (Appendix A and Figure 4). The entire black-shale sequence thins and this unit seems to pinch out as the sequence onlaps the Cincinnati Arch in Casey County, Kentucky (Figure 4). This unit contains abundant pyrite nodules, bedded pyrite and Tasmanites. In the LE-1 section (Appendix A), large carbonate concretions (up to 2.5 m (8.0 ft) in diameter) were found in this unit.

In the outcrop of eastern Kentucky, the lower interbedded unit is the lowermost lithostratigraphic unit of the Upper Devonian black-shale sequence which can be correlated throughout this region. Photographs of the lithostratigraphic units described above are shown in Plate 2, and photographs of particular fossils, nodules and sedimentary features are shown in Plate I.

Two localized lithostratigraphic units were described at the base of the Upper Devonian section in parts of the east-central Kentucky outcrop belt. In the PO-1 and ES-1 sections, the Duffin Sandstone Member underlies and intertongues with the lower interbedded unit of each section. The Duffin is characterized by interbedded dolomites, dolomitic shales, dolomitic sandstones and black shales. The unit ranges from only a few centimeters to 7.8 m (25 ft) thick and unconformably overlies an irregular exposures surface on the Boyle Dolomite. It commonly contains flow rolls which were noted in the ES-1 section (Appendix A). Some unusual Boyle-Duffin-Ohio (New Albany) relationships are discussed by McFarlan and White (1952).

In the CA-1 and RU-1 sections (Appendix A), a basal sandstone or "lag zone" called the Kiddville layer is present. This layer contains pebbles of chert, phosphate and black shale in a matrix of iron-rich, quartzose sandstone. This unit is commonly less than 1.0 m (3.2 ft) thick. Again, this lithostratigraphic unit is very localized and lies unconformably on Ordovician strata.

The above generalized descriptions of these lithostratigraphic units characterize the sections measured in eastern Kentucky. For more complete descriptions and examples of each unit, refer to the outcrop descriptions in Appendices A and B.

PLATE 1

Figure 1 Plan view of cone-in-cone limestone structure (magnification X0.5).

Figure 2 Cross-sectional view of cone-in-cone limestone (structure (magnification X1).

Figure 3 Phosphate nodules (magnification X0.5).

Figure 4 Foerstia thalli (Protosalvinia fucata) (magnification X2).

Figure 5 Foerstia fruiting body (Protosalvinia ravenna) (magnification X3).

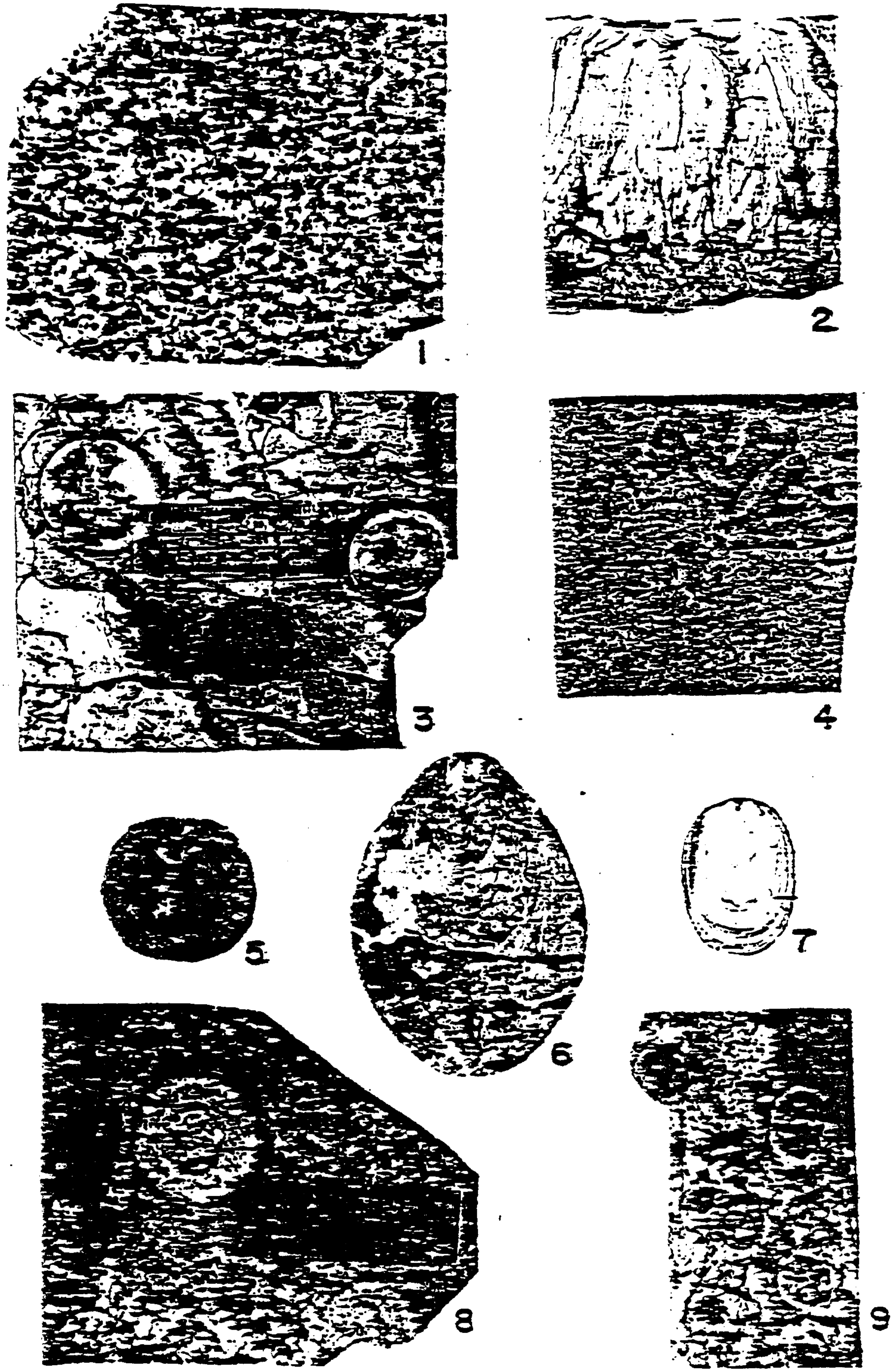
Figure 6 Lingula sp. (cf. L. spatulata, Vanuxem) (magnification X1.5).

Figure 7 Lingulipora sp. (cf. L. williamsana, Girty) (magnification X2).

Figure 8 Pyrite nodules in plan view (magnification X0.5).

Figure 9 Pyrite framboids in plan view (magnification X0.7).

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978



UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

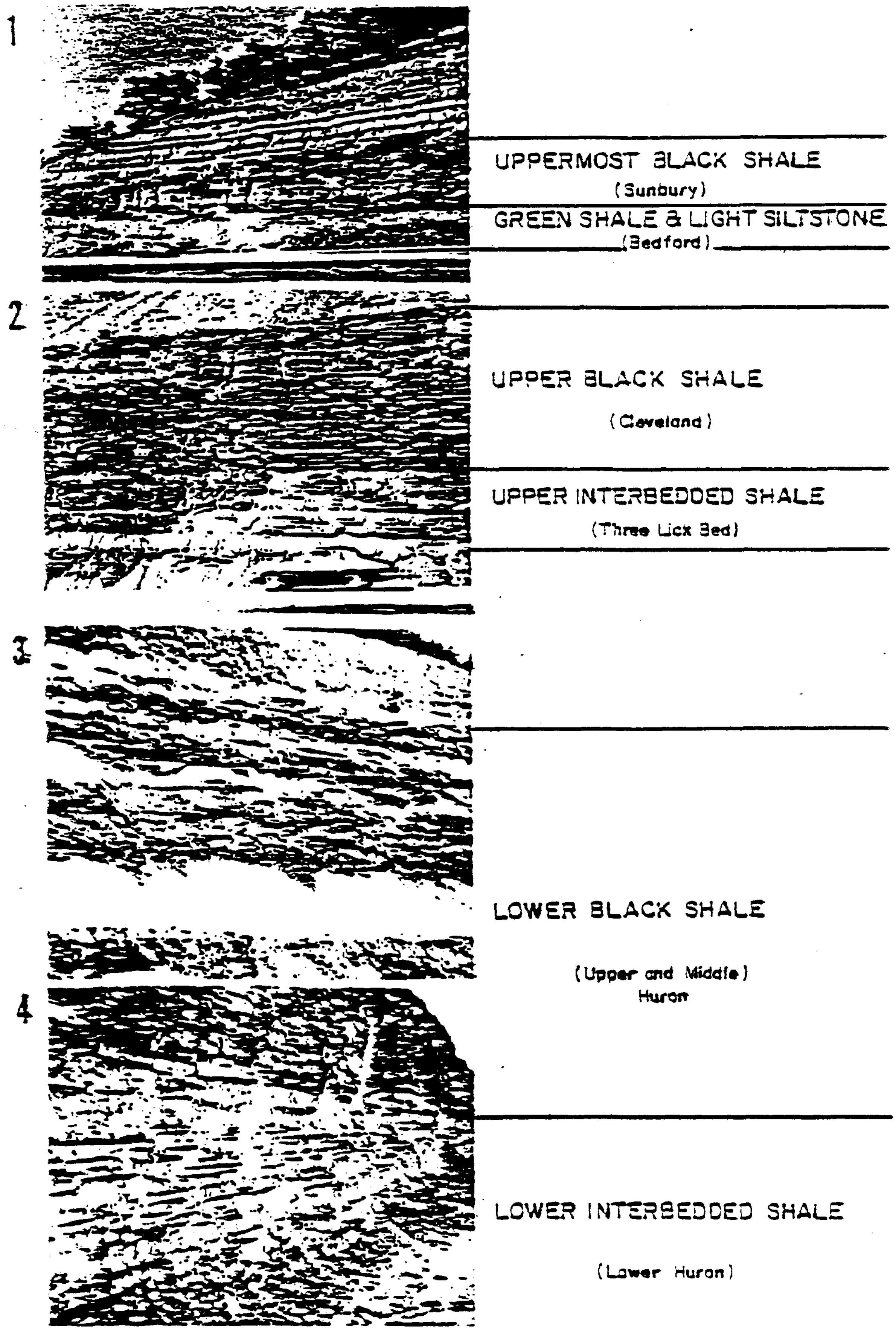
PLATE 2

Figure 1 Photograph of upper part of Morehead section (Appendix A, Section RW-1) showing Sunbury and Bedford Shales.

Figure 2 Photograph of Three Lick Bed (Provo and others, 1977) in the Morehead Section (Appendix A, Section RW-1) overlain by the upper black-shale, lithostratigraphic unit.

Figure 3 Photograph of middle part of Powell County section (Appendix A, Section PO-1) showing lower black-shale, lithostratigraphic unit.

Figure 4 Photograph of base of Morehead section (Appendix A, Section RW 1) showing the lower black-shale, and lower interbedded-shale lithostratigraphic units.


1
2
3
4
UPPERMOST BLACK SHALE
(Sunbury)
GREEN SHALE & LIGHT SILTSTONE
(Bedford)
UPPER BLACK SHALE
(Cleveland)
UPPER INTERBEDDED SHALE
(Three Lick Bed)
LOWER BLACK SHALE
(Upper and Middle)
Huron
LOWER INTERBEDDED SHALE
(Lower Huron)

Radioactive Units

Gamma-ray logs from well bores have been used extensively to correlate parts of the Upper Devonian-Lower Mississippian shale sequence in the subsurface. However, until the recent advent of radioactivity profiles from surface exposures, there was no real way to make detailed correlations from the surface to the subsurface. Radioactivity profiles are essentially synthetic gamma-ray logs made from surface exposures. These profiles are made by plotting scintillometer readings, recorded at uniform intervals on the outcrop, against formation thickness. Radioactivity profiles were made for each measured section (Appendices A-C). Once persistent radioactive units are defined, these profiles can then be used to correlate from the subsurface to the surface and from outcrop to outcrop. This method of correlation was suggested to the author by Dr. Linda Provo Fulton and is documented by Provo and others (1977) and Ettensohn and others (1978).

In Figure 6, the right column is a subsurface gamma-ray log with the seven radioactive units defined by Provo (1977). Five of these seven units correlate with the gamma-ray log of the well in the center column which is very near the outcrop belt just east of the Cincinnati Arch. Finally, the radioactive units from the gamma-ray logs on the right two columns are correlated with similar units from the radioactivity profile of the RW-1 outcrop section. Five of the units from the subsurface correlate directly with the five units from the radioactivity profile generated from the RW-1 section by plotting the scintillometer readings against outcrop thickness. This Figure demonstrates that radioactivity profiles from surface exposures can be used for correlation with black shale in the subsurface. Figures 5 and 7 show the correlation of radioactive profiles along the section

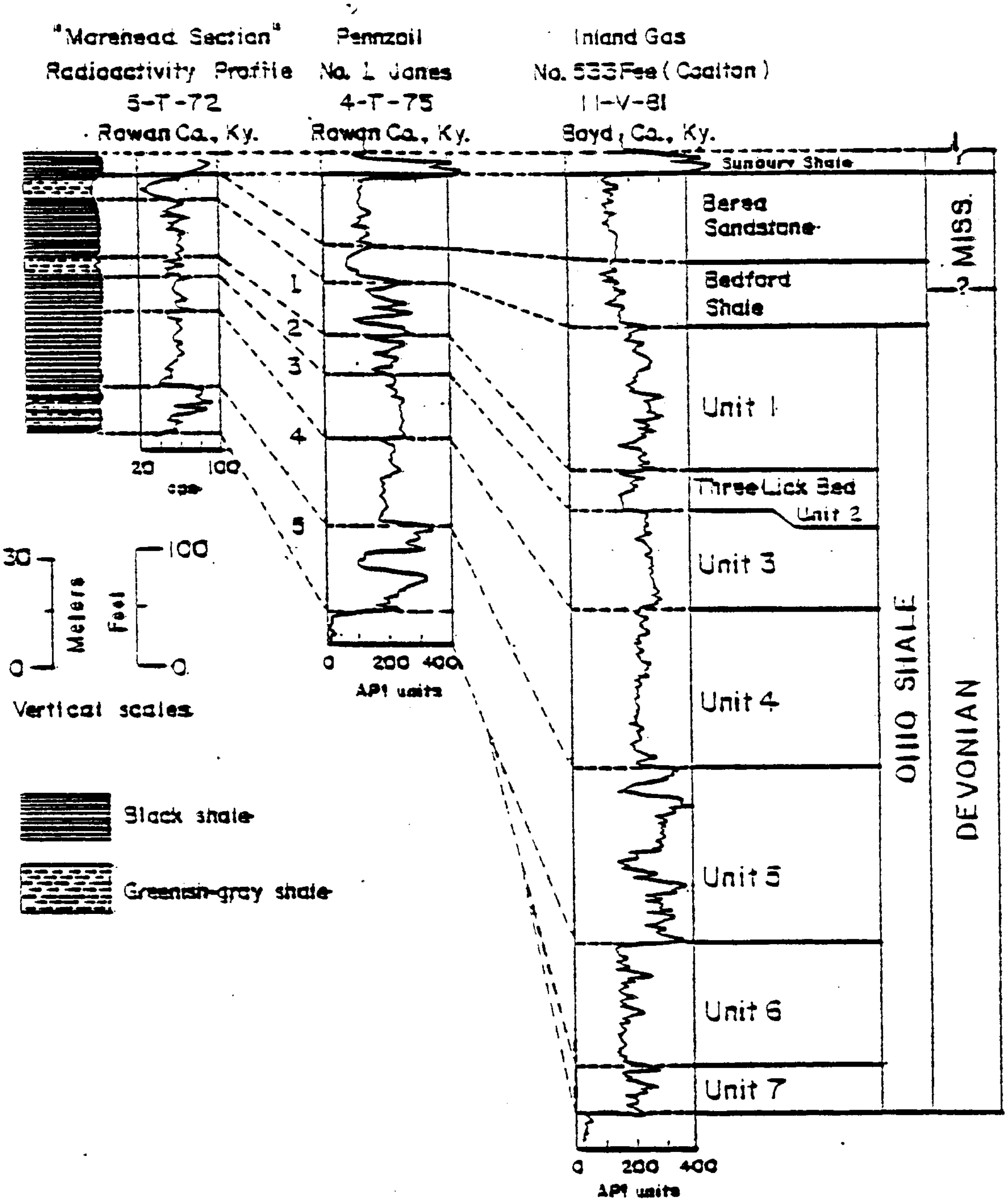


Figure 6. Gamma-ray logs for two subsurface well bores near the outcrop belt correlated with internal-radioactive-stratigraphic units of the Rowan County reference section (Ettensohn and others, 1978).

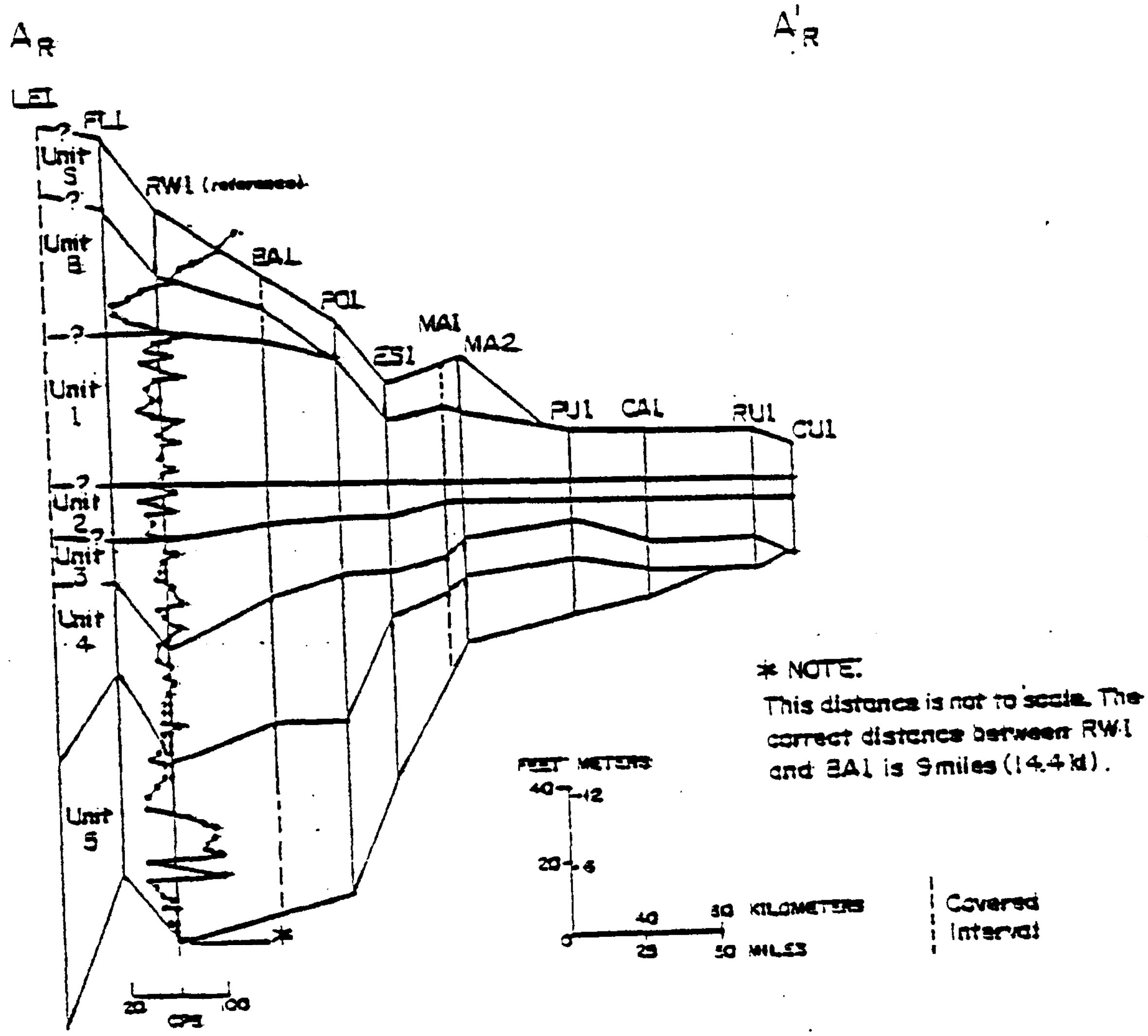


Figure 7. Schematic cross-section along the east-central Kentucky outcrop belt showing internal radioactive-stratigraphic units (the radioactive profile of the RW-1 reference section is included for clarity).

of outcrops in eastern Kentucky.

The radioactive units involved in these correlations are recognized by specific patterns and combinations of high-radioactive (positive) and low-radioactivity (negative) deflections to the right and left respectively. The following descriptions of the radioactive units are characteristic of the units along the outcrop belt. The radioactivity profile of the RW-1 reference section (Figure 8) shows these characteristic radioactive units.

The uppermost radioactive unit is the Sunbury Shale which shows a very strong high-radioactivity deflection; it is radioactive unit S in this study. The high-radioactive deflection from this unit is apparently related to a high concentration of uranium and thorium in this organic-rich black shale. Underlying the Sunbury is the Bedford-Berea sequence herein called radioactive unit B. This interval exhibits a very strong low-radioactivity deflection due to the presence of organic-deficient gray shales and siltstones. The next radioactive unit is called unit 1 and generally shows a high-radioactivity deflection which is somewhat less (Figure 8) than the deflection of radioactive unit S. Underlying unit 1 is radioactive unit 2 which shows three low-radioactivity deflections and two high-radioactivity deflections caused by three green shales interbedded with two black shales. The next radioactive unit is unit 3 which shows a high-radioactive deflection with less positive deviation than that seen in either radioactive units S or 1 (Figure 8). Unit 3 is underlain by radioactive unit 4 which shows a low-radioactive deflection with less negative deviation than that seen in radioactive unit 2 (Figure 8). The lowermost radioactive unit seen in outcrop, unit 5, exhibits a sequence of alternating high-radioactivity and low-radioactivity deflections, although the unit is more highly radioactive overall

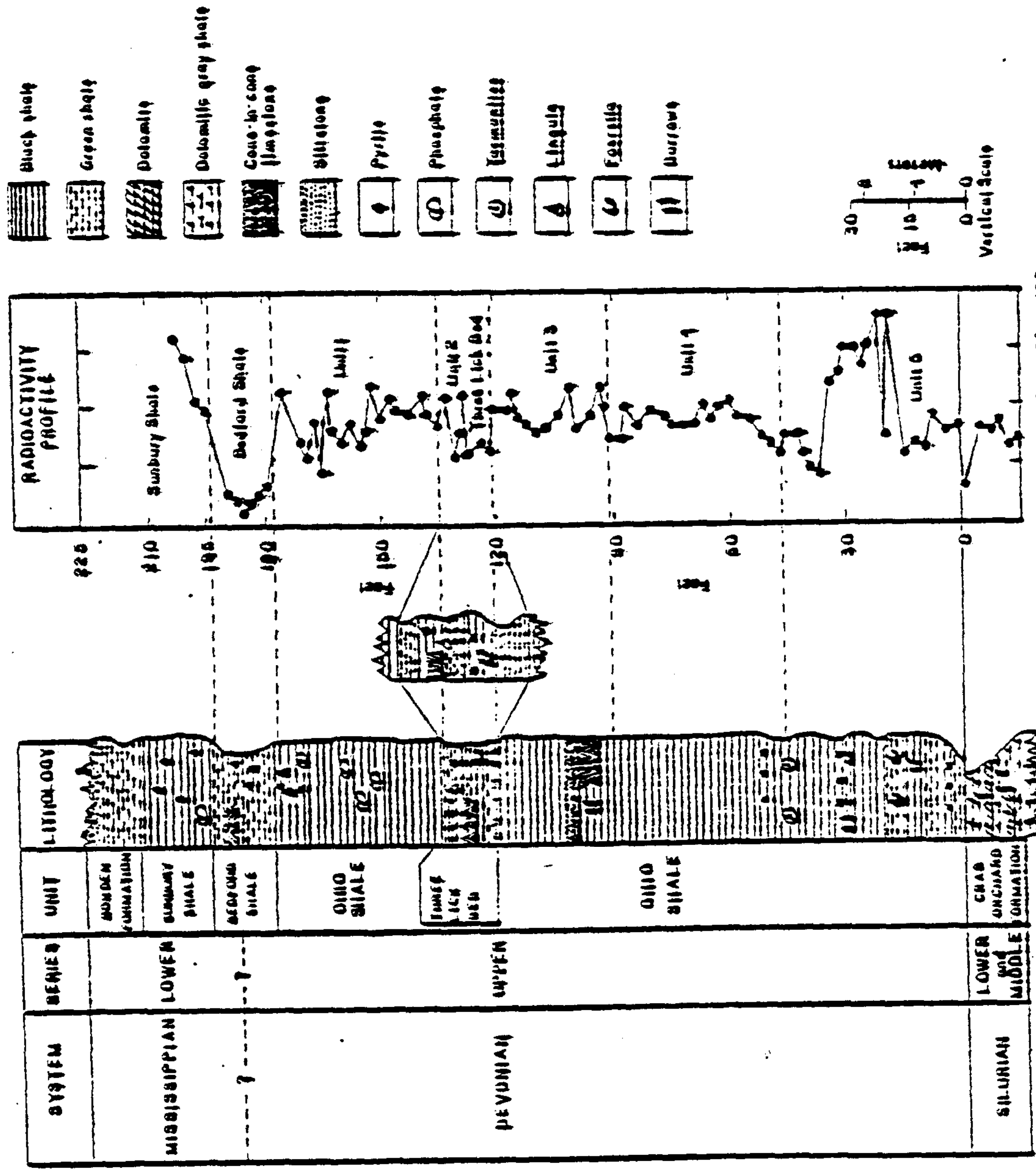


Figure 8. Radioactive profile and lithologic drawing of the Rowan County reference section.

(Figure 9). As illustrated in Figures 5 and 7, these units are present along both outcrop belts and are present throughout the subsurface of eastern Kentucky (Figure 6).

The radioactive units described above form useful stratigraphic divisions within continuous black shale sequences that are lithologically indistinguishable. Two specific examples of this are found in the east-central Kentucky outcrop sections (Appendix A). The first example is the differentiation of two radioactive units within the lower black-shale lithostratigraphic unit. Because the lithologies of radioactive units 3 and 4 are essentially the same, the contact between them is lithologically indistinguishable, but the radioactive profiles show a positive deviation in unit 3 and a negative deviation in unit 4; therefore, this continuous lower black-shale unit can be broken down into two distinct radioactive units. In addition, the differentiation of this continuous unit can be used to correlate the black-shale sequence of eastern Kentucky with stratigraphic terminology in other areas. This is shown in Figure 10 and discussed in detail in the section on correlations.

Another example of stratigraphic differentiation based on radioactive units occurs in the PO-1 section (Figure 9) of the New Albany Shale. Near the top of the black-shale sequence in this section, the radioactive profile shows a very strong high-radioactivity deflection. This deflection seems to be very similar to and in the proper position for the Sunbury Shale which can be seen in the LT-1, FL-1 and RW-1 sections (Appendices A and B). In these sections, the Bedford-Berea sequence lithologically separates the similar lithologies of the uppermost and upper black shale lithostratigraphic units. In the PO-1 section (Figure 9), however, the Bedford-Berea sequence has pinched out this

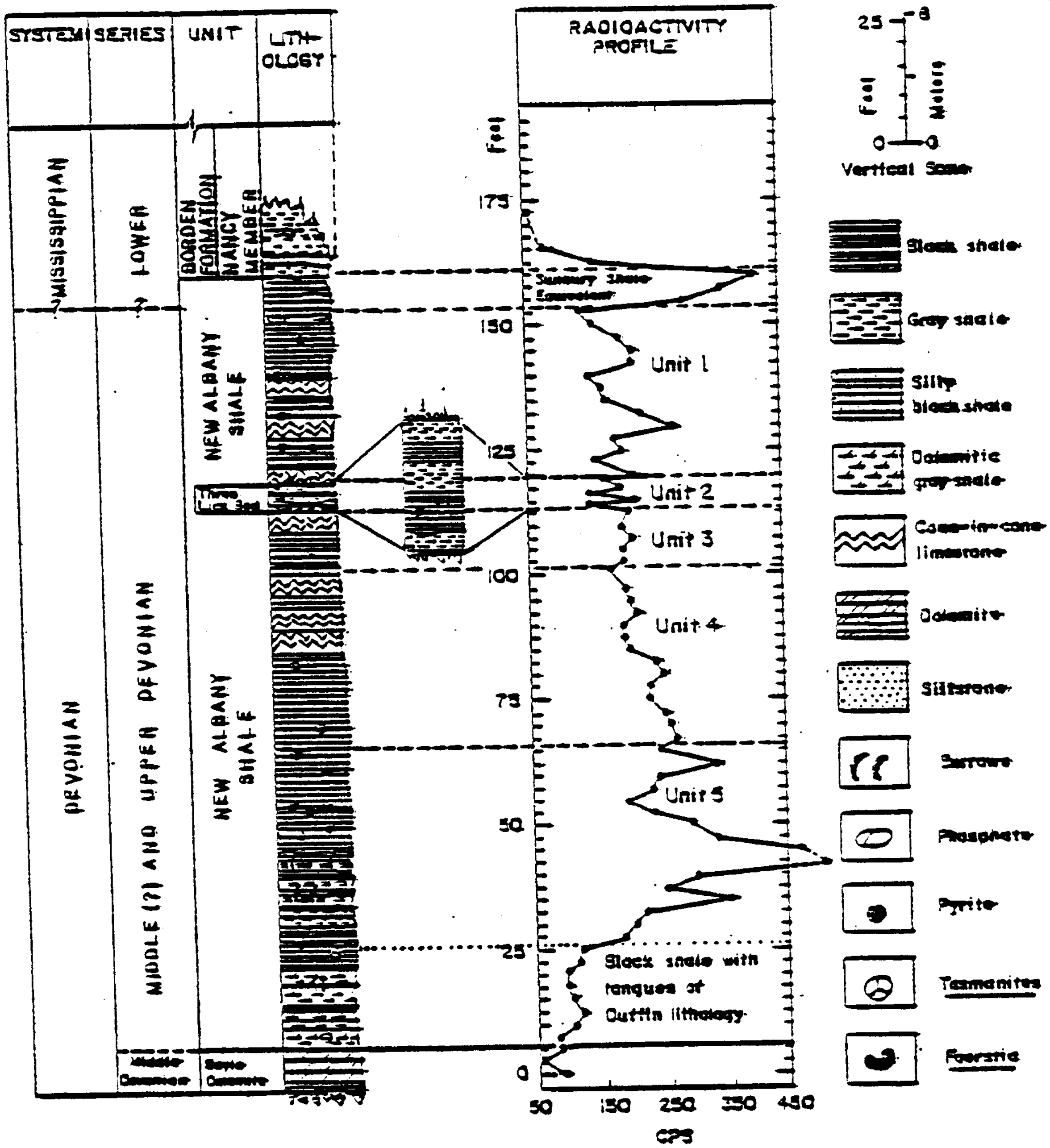


Figure 9. Radioactive profile and lithologic drawing of the Powell County section of the New Albany Shale.

far south (Peck, 1967 and Weir, 1976), and the contact between the Devonian upper black shale and the Mississippian uppermost black shale is lithologically indistinguishable. Many authors including Huddle (1933, 1934), Campbell (1946), Hass (1947), Hoskins and Cross (1951) and Weir (1976) have agreed that the upper part of the New Albany Shale is Mississippian in age, and this has been proven in eastern Kentucky by conodont studies (Weir, 1976). Hence, although conodont studies provide a way of separating Mississippian and Devonian parts of the New Albany Shale, such studies are much too laborious and time-consuming to be used in the field. Conodont studies have clearly shown that the very high radioactivity deflection atop the New Albany Shale in parts of eastern Kentucky (Figure 9) represent a Mississippian Sunbury equivalent. Hence, because the Mississippian black shale seems to be much more radioactive than underlying Devonian black shales, it is possible to use the positive deflection atop the New Albany to approximate the Mississippian-Devonian boundary in the field. A similar high-radioactivity deflection in the VA-1 and VA-2 sections (Appendix B) is tentatively interpreted to represent a Sunbury equivalent although there is no supportive paleontological evidence.

This brief description of these radioactive units serve as an explanation for introducing them as informal internal stratigraphic units. The use of these units for stratigraphic correlation is illustrated in Figure 10, and their actual correlation within the sections is shown in Figures 5 and 7.

Informal Biostratigraphic Zones

Fossils which are commonly found in the Upper Devonian-Lower Mississippian shale sequence include the small spore-like Tasmanites, the chitino-phosphatic tests of the inarticulate brachiopods Lingula and Orbiculoidae, thin films of coalified Callixylon logs, the pelagic alga Foerstia, various conodonts and fish plates. One unusual fossil was collected from the upper part of the New Albany Shale during field work for this study. This fossil was tentatively identified as a Lepidostrobilus, and collected by Miller (personal communication, 1978).

Two of the above fossils occur persistently in respective parts of the black-shale sequence and are termed informal biostratigraphic zones. These two informal units will be refered to as the Foerstia Zone and the Lingula zone. The conodonts have been studied and are good age indicators, but are not easily identified in the field. On the other hand, the Foerstia and Lingula zones are easily identified in hand samples with the naked eye.

The informal unit which is called the Lingula zone is restricted to those radioactive units above unit 3 (exclusive of unit 8) and to the lithostratigraphic units above the lower black-shale member (see Figure 10). Plate I contains two figures of Lingula. Figure 7 is Lingula and was found in the Sunbury Shale in the LT-1 section (Appendix B), and Figure 6 is Lingula and was found in the MA-1 section (Appendix A). Within radioactive unit 2 of the MA-1 section (Appendix A), Lingula were found in living position. They were oriented vertically atop small vertical burrows within greenish-gray shales. The greatest abundance of Lingula shells are found within the black-shale units overlying the Three Lick Bed where they are preserved as thin carbonized films parallel to bedding planes. Only in the PU-1 section (Appendix A) have Lingula been found below the Three Lick Bed. Although it is impossible to define a Lingula-bearing bed as either Mississippian or Devonian in age, the presence of Lingula generally indicates that the stratigraphic position of the bed is within or above the Three Lick Bed (radioactive unit 2). The common restriction of the chitino-phosphatic brachiopod Lingula to the upper part of the Mississippian-Devonian shale sequence, is the basis for defining an informal Lingula biostratigraphic zone.

The second informal biostratigraphic zone is called the Foestia Zone by Schopf and Schwietering (1970). Foerstia was originally named by White and Stadnichenko (1923) and was thought to be a source for some of the petroleum in black shales. Schwietering and Neal (1978) describe Foerstia as "being small carbonaceous compressions that are oval to bilobate in outline and have a cellular pitted surface. They occur as dark flattened fragments on bedding planes" (Plate 1, Figure 4 and 5). Hass (1956) describes the stratigraphic position of Foerstia as being correlative with the Late Devonian conodont assemblages within the lower Gassaway Member of the Chattanooga Shale. The radioactivity profile of the Gassaway reference section (DE-1, Appendix C) suggests that the lower Gassaway Member is equivalent to radioactive unit 3 or correlative with the upper part of the Huron Member in the Ohio Shale (Figure 10). The Foerstia Zone described in the sections measured in east-central Kentucky (Appendix A) was found in radioactive units 4 and 5. Radioactive units 4 and 5 are equivalent to the lower and middle members of the Huron Shale in eastern Kentucky (Figure 10). Schweitering and Neal (1978) place their Foerstia Zone in the West Virginia correlative of the Huron Member. Schopf and Schweitering (1970) place the Foerstia Zone in the Huron Members also. The Foerstia Zone is a good stratigraphic indicator because it is easily identified and occurs in the same relative stratigraphic position throughout eastern Kentucky. Although the maximum range of Foerstia appears to be throughout the Huron Member and its equivalents in the Appalachian Basin, in eastern Kentucky, the Foerstia Zone appears to be more narrowly restricted to the lower parts of radioactive unit 4 and the upper parts of radioactive unit 5 (Figure 10).

Summary

Within this section of this study, three types of internal stratigraphic units are discussed. Each type of unit is useful in the interpretation of stratigraphic relationships and correlation of units within the Upper Devonian-Lower Mississippian shale sequence. The relationships and correlations suggested in this paper (Figure 10) are based on a synthesis of all three, and are discussed in the following section.

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

CORRELATIONS

Introduction

Definition of internal radioactive units has greatly enhanced correlation within the black-shale sequence. Figures 5 and 7 show the results of correlation along the outcrop belts. The pinching out of some units and the thinning of others are concepts which would have been very difficult to demonstrate in uniform black-shale sequences without the use of radioactive stratigraphy. These radioactive units, however, are only part of the total stratigraphic framework. The relationships and correlations between these radioactive units, the biostratigraphic units, the lithostratigraphic units and units from adjacent areas must also be considered. These correlations are shown in Figure 10 and discussed in the following sections.

Sunbury Shale (Radioactive Unit S)

The Sunbury Shale is recognized in the northeastern portions of both outcrop belts in eastern Kentucky (Figure 1). In these areas, the underlying Bedford-Berea sequence serves as a basal lithologic boundary. The uppermost black-shale lithostratigraphic unit (Figure 10) is correlative with the Sunbury (radioactive unit S). The Sunbury is equivalent to the upper part of the Clegg Creek Member of the New Albany Shale in west-central Kentucky (Lineback, 1970), and more specifically a correlative of the Jacob's Chapel and Henryville Beds of the Clegg Creek Member (Figure 10). The Sunbury Shale is not correlative with any part of the Chattanooga Shale in south-central Kentucky (Hass, 1956), but is correlative with the upper part of the Big Stone Gap Member of the Chattanooga Shale in the southern Pine Mountain outcrop belt (Appendix 3, Sections VA-1 and

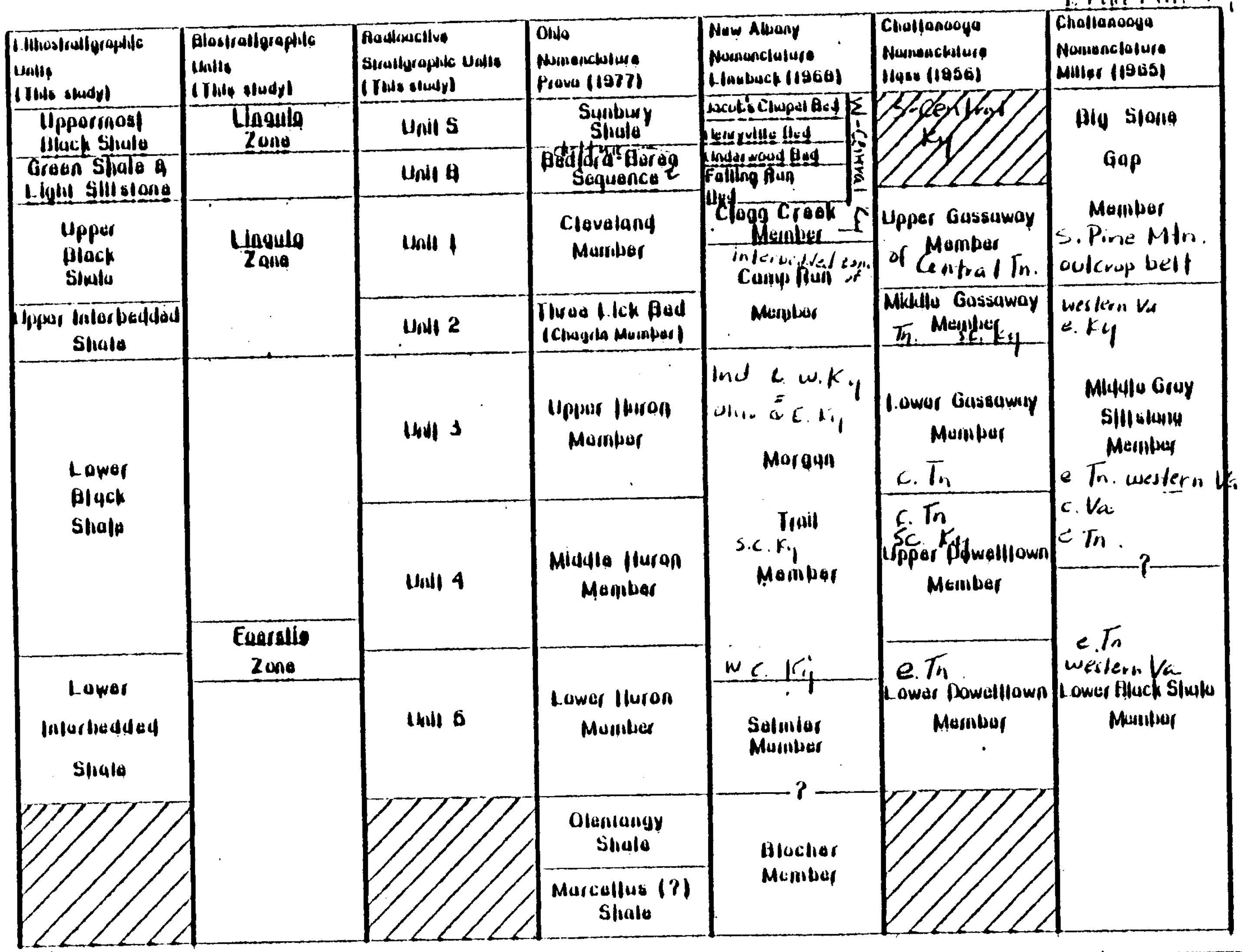


Figure 10. Three types of internal stratigraphic units of this study correlated with four individual stratigraphic nomenclatures of the shale sequence in nearby regions.

VA-2). The uppermost parts of the Lingula zone include the Sunbury Shale (Figure 10).

Bedford-Berea Sequence (Radioactive Unit 3)

The Bedford shales and siltstones are probably both Mississippian and Devonian in age whereas the Berea sandstones are wholly Mississippian in age (de Witt, 1951). This sequence is recognized in Ohio as a deltaic sequence (Hoover, 1960). The Bedford Shale is present in the northeastern part of both outcrop belts in eastern Kentucky, and serves to separate the similar lithologies of the Sunbury and uppermost parts of the Ohio Shale. In west-central portions of Kentucky, the Bedford is correlative to portions of the Clegg Creek Member of the New Albany Shale (Lineback, 1970). Cooper (1948) states that the Bedford is equivalent to the Underwood Bed of the New Albany Shale based on brachiopods. No part of the Chattanooga in south-central Kentucky is correlative to the Bedford (Figure 10), but the Big Stone Gap member of the Chattanooga in the southern Pine Mountain outcrop belt does probably contain correlatives (Appendix B, sections VA-1 and VA-2). The Bedford-Berea sequence is wholly correlative with the green shale and light siltstone lithostratigraphic unit of this study.

Radioactive Unit 1

Radioactive unit 1 is wholly correlative with the upper black shale lithostratigraphic unit of this study, and is contained within the Lingula zone (Figure 10). Unit I is correlative to the Cleveland Member of the Ohio Shale (Provo, 1977) and to portions of the Clegg Creek Member of the New Albany Shale of west-central Kentucky (Lineback, 1970). Furthermore, Cooper (1948), states that concretions in the Falling Run Bed of the New

Albany Shale in west-central Kentucky contain fauna correlative with the Cleveland Shale of Ohio. Unit 1 is equivalent to the upper Gassaway Member of the Chattanooga Shale (Appendix C, section DE-1) in central Tennessee based on similar radioactivity profiles. In the southern part of the Pine Mountain outcrop belt, radioactive unit 1 is included as part of the Big Stone Gap member of the Chattanooga Shale (Appendix B, section VA-1 and VA-2).

Radioactive Unit 2

The Three Lick Bed (Provo and others, 1977) is equivalent to parts of the Chagrin Member of the Ohio Shale and to internal radioactive unit 2. The Chagrin is essentially correlative with the interbedded zone of the Camp Run Member of the New Albany Shale (Lineback, 1970). Unit 2 is also correlative with the middle part of the Gassaway Member of the Chattanooga Shale in Tennessee and south-central Kentucky (Provo, 1977, and Appendix C, section DE-1). Parts of the middle gray siltstone member of the Chattanooga Shale in western Virginia and eastern Tennessee are probably correlative to radioactive unit 2 (Miller, 1965). Radioactive unit 2 is the same as the upper interbedded lithostratigraphic unit of this study and is included in the lowermost part of the Lingula zone (Figure 10).

Radioactive Unit 3

Radioactive unit 3 is included in the upper part of the lower black-shale lithostratigraphic unit of this study (Figure 10). Unit 3 is defined as the upper part of the Huron Member by Provo (1977). Lineback (1970) states that the Morgan Trail Member of the New Albany Shale in Indiana and western Kentucky is probably equivalent to the Huron Member (radioactive units 3-5) of the Ohio Shale in Ohio and eastern Kentucky. Unit 3 is correlative with the lower Gassaway Member of the Chattanooga Shale in central Tennessee based on radioactivity profiles (Appendix C, section DE-1), and possibly to parts of the middle gray siltstone and lower black-shale members of the Chattanooga Shale in eastern Tennessee and western Virginia (Miller, 1965). See Figure 10 for the relationships described above.

Radioactive Unit 4

Unit 4 is equivalent to the lower part of the lower black-shale lithostratigraphic unit of this study, and to the middle Huron Member of the Ohio Shale (Provo, 1977, and Figure 10). This unit is also equivalent to parts of the Morgan Trail Member of the New Albany Shale in south-central Kentucky, and to the Upper Dowellton Member of the Chattanooga Shale (Figure 10, and Appendix C, section DE-1) in central Tennessee and south-central Kentucky based on radioactivity profiles and sequences. Part of the lower black-shale member of the Chattanooga Shale (Miller, 1965) in central Virginia and eastern Tennessee are probably correlative to radioactive unit 4. Lower parts of unit 4 are also included in the Foerstia Zone.

Radioactive Unit 5

Radioactive unit 5 is the lower interbedded lithostratigraphic unit of this study. It is correlative with the lower part of the Huron Member of the Ohio Shale (Provo, 1977). Unit 5 is also probably equivalent to parts of both the Morgan Trail and the Selmier Members of the New Albany Shale in west-central Kentucky (Figure 10). Unit 5 is correlated with the Lower Dowelltown Member of the Chattanooga Shale in eastern

Tennessee (Provo, 1977, and Appendix C, section DE-1). It is probably equivalent to parts of the lower black shale member of Miller (1965) of the Chattanooga Shale in western Virginia and eastern Tennessee. Upper parts of this radioactive unit are also included in the Foerstia Zone.

Summary

The schematic cross-sections in Figures 4, 5 and 7 show the correlation of internal stratigraphic units of the black-shale sequence along both outcrop belts in eastern Kentucky. In some measured sections (Appendices A and B) some of the units are not exposed due to cover, but where good exposures are found, recognition of the internal stratigraphic sequence is not difficult. Recognition of these internal units has made correlation possible and reveals that these units are laterally continuous throughout most of eastern Kentucky (Figures 4, 5 and 7). As the shale sequence onlaps the Cincinnati Arch in Russell and Cumberland counties, Kentucky (Figure 7), the lower portions of the shale sequence (radioactive units 4 and 5) are not recognized because of thinning and eventual pinch outs on the Cincinnati Arch. This seems to indicate that either the subsidence of the Appalachian Basin was slower near the Cincinnati Arch or the rate of sedimentation was less in this area. The correlations suggested in this section (Figure 10) are based on observed continuity of lithostratigraphic and radioactive-stratigraphic internal units in eastern Kentucky outcrops as well as literature cited.

PALEOENVIRONMENTAL REVIEW

The depth of the Appalachian Basin during deposition of the shale sequence has been a controversial topic in the literature. Many theories of deposition have been introduced. Deep-water origins have been suggested by Rich (1951) and Lewis and Schwietering (1971). Shallow-water origins are supported by Stockdale (1939), Conant (1956), Swanson (1956), Conant and Swanson (1961), Breger and Brown (1963), Lineback (1968) and Provo (1977).

It has been suggested by both Lineback (1968) and Provo (1977) that the depth of the basin is not the essential controlling factor for deposition of black-shale sequences, because modern black muds are being deposited in a wide range of depths (Twenhofel, 1939 and Strom, 1939). A more critical factor in the deposition of black muds is merely an environment suitable for the formation and preservation of abundant organics. Two sources of organics in the shale are indicated. Organic carbon was derived from terrestrial floras, and carried into the basin by streams. Other organics, such as the pelagic alga Foerstia and abundant plankton were marine in origin.

Most authors support the theory that the shale sequence was deposited during anoxic bottom conditions, but suggest different methods for producing such conditions. The deep-water origin of Rich (1951), the shallow-water origin of Conant and Swanson (1961), the algal floatant of Lineback (1968, 1970) and the barred-basin origin of Whitehead (1978) all can account for the anoxic conditions, as can the stratified-water-column origins of Byers (1977) and Heckel (1977). These two authors suggest models of deposition for Pennsylvanian black shales, but the pycnocline theory of Byers (1977) and the thermocline (quasi-estuarine circulation) theory of Heckel (1977) could be modified to fit paleoenvironmental conditions for the Devonian-Mississippian shale sequence. Both of these models suggest an oceanographic mechanism in which quasi-estuarine circulation accounts for abundant organic production in uppermost, oxygenated parts of the water column and organic preservation in the lowermost, anoxic parts of the column. A number of modifications, however, need to be made in these models before they could be applied successfully to the Late Devonian situation, and this is beyond the scope of this current study. Furthermore, detailed paleocurrent, paleoclimate and paleoecological examinations of black-shale facies in the Appalachian Basin are needed before more specific paleoenvironmental interpretations and models can be defined for the Mississippian-Devonian shale sequence.

Dennis Ray Swager
Univ. of Kentucky, 1978

CONCLUSIONS

Based on the description of 18 measured sections in eastern Kentucky, north-central Tennessee and west-central Kentucky, and a review of the literature, the following conclusions are drawn:

1. This study of the Devonian-Mississippian black-shale sequence in eastern Kentucky shows that this lithologically uniform sequence can be internally subdivided and correlated.
2. Three types of stratigraphic subdivisions were defined: lithostratigraphic, biostratigraphic and radioactive units.
3. Six lithostratigraphic units were defined and traced along the outcrop belt. These are the Sunbury (uppermost black shale) of Mississippian age, Bedford-Berea sequence (green shale and light siltstones) of Mississippian and Devonian age and four lithostratigraphic units within the Devonian black shale (the upper black shale, the upper interbedded shale, the lower black-shale and the lower interbedded-shale units).
4. Based on the correlation of these lithostratigraphic units along the outcrop belt, all the units thin to the southwest as they onlap the Cincinnati Arch, and parts of the two lowermost units were not deposited on the arch. The Bedford-Berea sequence also is absent south of the BA-1 section.
5. Two persistent informal biostratigraphic zones were defined in the Devonian-Mississippian black-shale sequence of eastern Kentucky. The upper zone is herein called the Lingula zone and contains the four upper lithostratigpahic units. The lower Forestia zone contains parts of the two lower lithostratigraphic units.

6. Of the seven radioactive-stratigraphic units defined by Provo (1977) in the subsurface, the uppermost five units have been consistently recognized in eastern Kentucky outcrop.

7. Based on the correlation of these radioactive units along the outcrop belts, all the units thin to the southwest as they onlap the Cincinnati Arch, and the two lowermost units (units 4 and 5) are absent near the apex of the arch.

8. The onlapping relationships of the lower internal units of the shale sequence show the Devonian-Mississippian sea was transgressive and the proto-Cincinnati Arch was a positive feature at this time.

9. The Devonian-Mississippian boundary was defined by radioactive-stratigraphic units in the New Albany Shale of east-central Kentucky and in the Chattanooga Shale of southern Pine Mountain. Conodont evidence (Weir, 1976) supports this boundary approximation of the New Albany Shale.

10. The black-shale sequence was most likely formed at the base of a vertically stratified water column, wherein abundant organics could be produced in the upper oxygenated parts of the column and could be preserved by anoxic conditions near the base.

UGS File #25
Dennis Ray Swager
Univ. of Kentucky, 1978

APPENDIX A - DESCRIPTION OF OUTCROP SECTIONS IN THE EAST-CENTRAL KENTUCKY OUTCROP BELT

LEWIS COUNTY SECTION (LE #1)

This section contains an incomplete sequence of the Ohio Shale unconformably overlying the Bisher Limestone. The base of the section is located along Highway 10, 3.7 kilometers (2.3 miles) west of Vanceburg in Lewis County, Kentucky (Section 21-Z-74, 200' FNL x 400' FWL). The contact with the Bisher occurs in a creek valley just south of the highway. The elevation of that contact is 160.0 meters (525 feet) above sea level. The upper part of the section is 0.5 kilometers (0.3 miles) north west of Vanceburg along Highway 8. The entire section is located on the Vanceburg Quadrangle. The section was measured using Jacob's staff, Abney level, tape and scintillometer by Dennis Swager, Frank Ettensohn, Mike Miller and Don Chesnut on August 26, 1977.

Ohio Shale (incomplete):	Thickness Meters	(Feet)
(1) Shale, brownish-black (5 YR 2/1), silty, fissile laminated; contains pyrite nodules, coalified logs, plant debris; contains cone-in-cone limestones 0.06 m (0.2') thick located 36.7 m (120.5'), 40 m (131.3') and 41.1 m (134.8') from the base of section; forms a blocky, jointed cliff with "couplet weathering."	13.3	(43.5)
(Note: Due to developing soil horizon and vegitation cover, the upper part of the section was unmeasurable, and the top of the formation indistinguishable. The term "couplet weathering" refers to equidistantly spaced alternating resistant and reentrant beds which occur in weathered vertical sections.		
(2) Shale, brownish-black (5 YR 2/1) same as unit 1 (without cone-in-cone limestones).	10.4	(34.0)

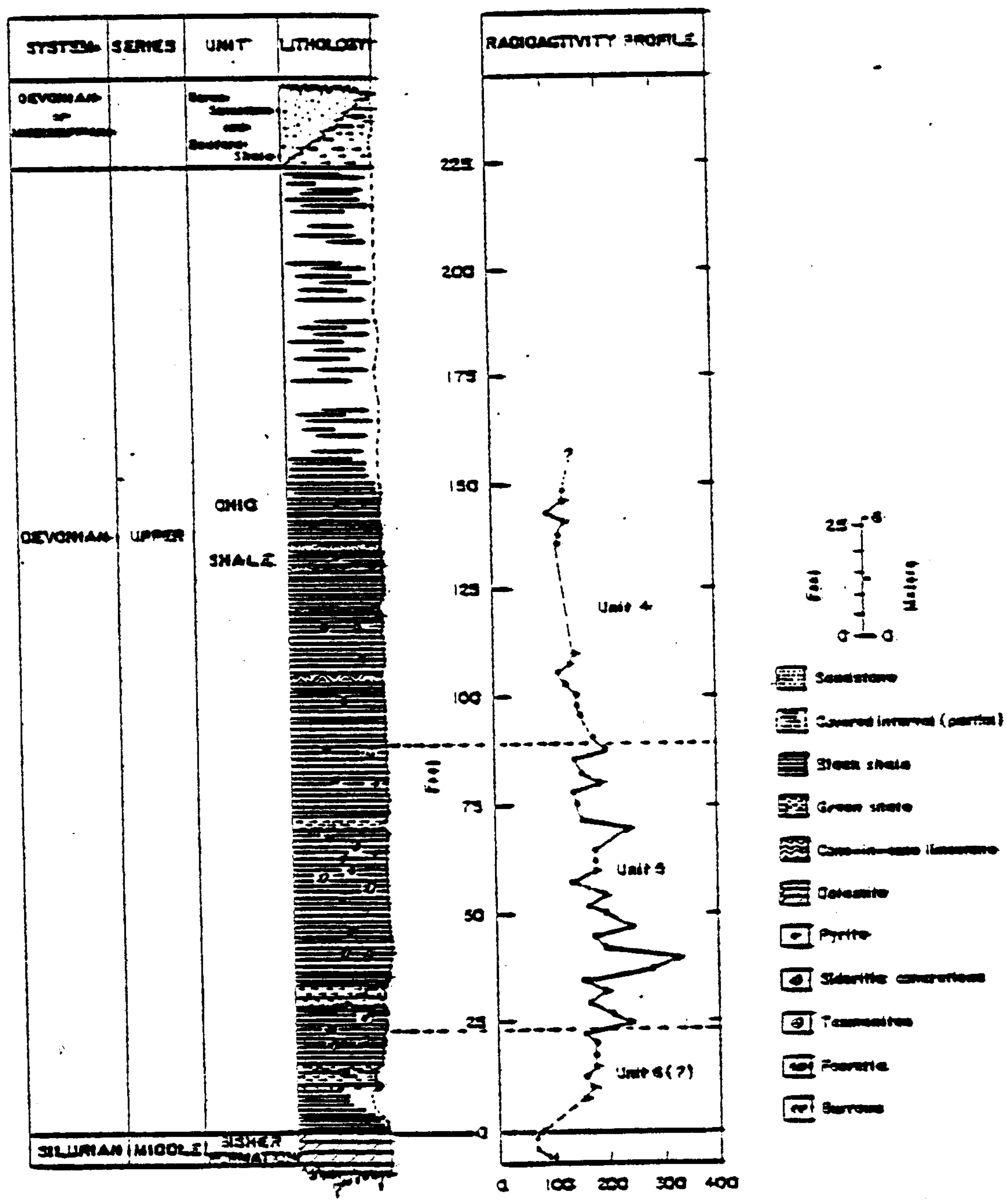
		Thickness Meters	(Feet)
(3)	Claystone, greenish-gray (5 GY 4/1) interbedded with shale, brownish-black (5 YR 2/1); shale is in 2 small beds in basal 0.1 m (0.3') of unit; claystone is iron-stained; forms reentrant	0.1	(0.5)
(4)	Shale, brownish-black (5 YR 2/1), laminated, very fissile; contains a large carbonate concretion. 19.1 m (65.5') from base of section; contains large, laterally-linked Foerstia in zone 20.9 m (68.5') to 21.5 m (70.6') from base; contains abundant Tasmanites, carbonized plant fragments; forms reentrant with "couplet weathering."	10.7	(35.2)
(5)	Shale, brownish-black (5 YR 2/1), very fissile; contains carbonate nodules up to 1.5 m (5') x 1.9 m (6.2') in dimension; shale draped over nodules; Tasmanites common; some interbedded claystone, greenish gray (5 GY 6/1); interbeds up to 0.2 m (0.6') thick.	1.7	(5.7)
(6)	Shale, brownish-black (5 YR 2/1), very fissile; contains carbonate nodules (semi-elliptical in shape) up to 0.9 m (3') x 2.1 m (7') in dimension; contains Tasmanites; weathered surface is iron-stained; forms blocky, jointed ledge.	4.0	(13.2)
(7)	Shale, greenish-gray (5 GY 6/1) interbedded with shale, brownish-black (5 YR 2/1); green shales are up to 0.7 m (2.3') thick; black shales are up to 0.2 m (0.5') thick, forms blocky, jointed cliff.	2.1	(6.8)
(8)	Covered interval within Ohio Shale	2.6	(8.5)
(9)	Claystone, light greenish-gray (5 GY 8/1); contains some brownish-black (5 YR 2/1) fragments; unit is highly weathered; forms reentrant above basal contact.	0.4	(1.2)

Disconformity

	Thickness of Ohio Shale in section	45.3	(148.4)

Bisher Limestone (incomplete):	Thickness Meters	(Feet)
(10) Claystone, moderate reddish brown (10 R 4/6); resembles Bisher; forms punky residium.	0.2	(0.7)
Total Thickness of Section	45.5	(149.1)

(Note: The contact is questionable.)


SYSTEM
SERIES
UNIT
LITHOLOGY
RADIOACTIVITY PROFILE
DEVONIAN
UPPER
OHIO
SHALE
SILURIAN
MIDDLE
225
200
175
150
125
100
75
50
25
0
Feet
Unit 4
Unit 5
Unit 6 (?)
0
100
200
300
400
cpm
25
0
0
Feet
Meters
Sandstone
Covered interval (partial)
Black shale
Green shale
Cone-in-cone limestone
Dolomite
Pyrite
Siderite concretions
Tasmanites
Fossils
Burrows

LE #1 Section

FLEMING COUNTY SECTION (FL #1)

This section contains the complete Bedford Shale and partial sections of the Ohio and Sunbury Shales. The section is exposed in a series of road-cuts on the east side of Kentucky Highway 559, 2.6 kilometers (1.6 miles) northeast of Wallingford in Fleming County, Kentucky. It is located on the Burtonville Quadrangle (Section 1-W-71, 3000' FNL x 1250' FEL), and the top of the Ohio Shale is 317.2 meters (1040 feet) above sea level. The section was measured using hand level and tape; samples and scintillometer readings were gathered on July 26, 1977 by Dennis Swager and John Goble.

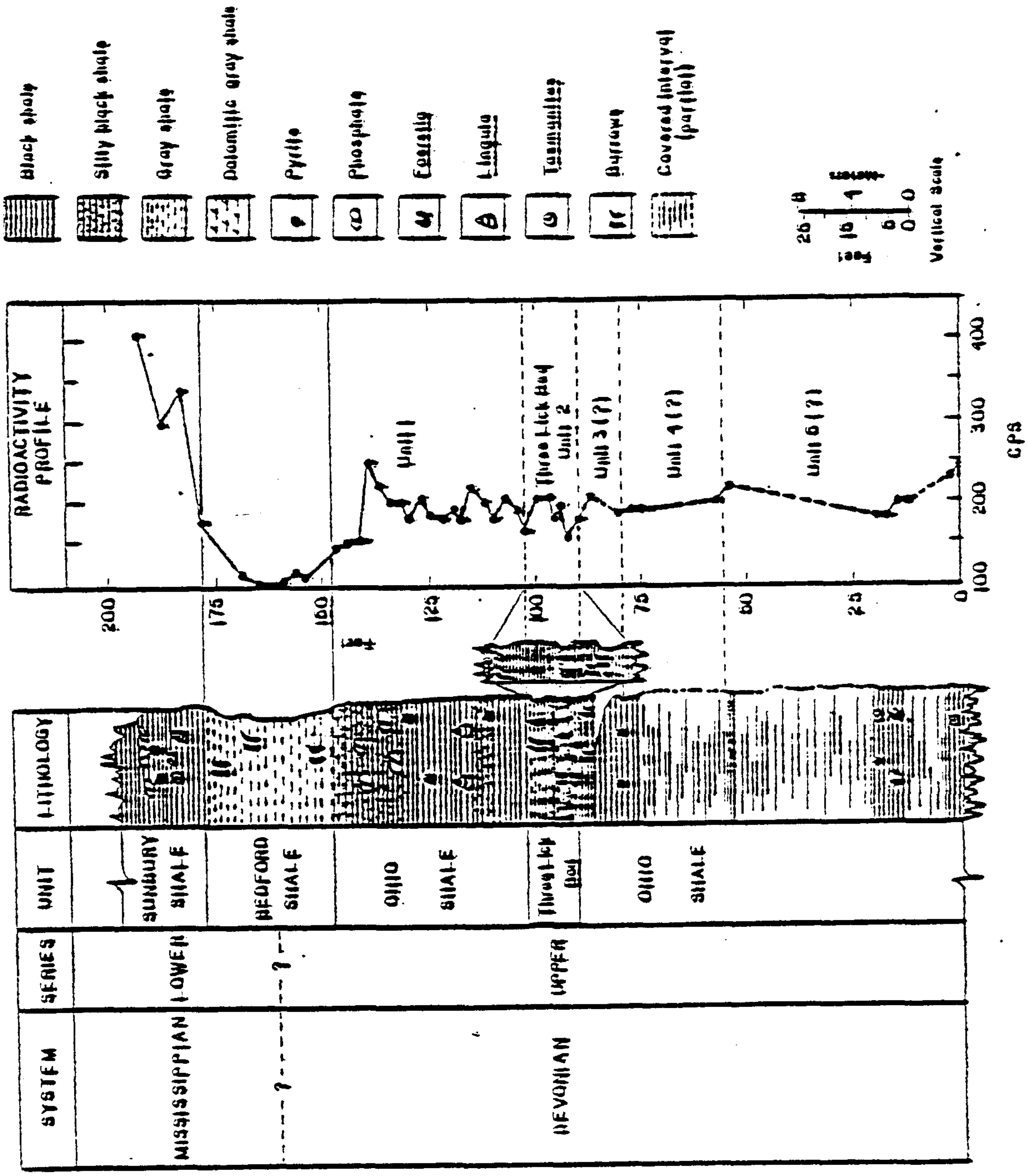
	Thickness Meters	(Feet)
Sunbury Shale (incomplete):		
(1) Shale, brownish-black (5 YR 2/1) to black (N2), fissile, laminated with silty layers, subconchoidal fracture; contains abundant Lingula and Tasmanites; has a strong petroliferous odor; forms jointed ledges with "couplet weathering."	4.4	(14.3)
Bedford Shale:		
(2) Shale, olive-gray (5 YR 4/1) to greenish-gray (5 YR 2/1), clayey, irregular bedding; forms talus covered slope and had to be trenched; contains horizontal burrows.	9.5	(31.2)
Ohio Shale (incomplete):		
(3) Shale, medium gray (N5) to light greenish-gray (5 YR 8/1), clayey, dolomitic; forms a reentrant	0.8	(2.5)
(4) Shale, brownish-black (5 YR 2/1), very fissile, laminated with silty layers; contains pyrite and phosphate nodules; contains bedded pyrite; contains abundant Lingula; has strong petroliferous odor; forms jointed cliffs with distinct "couplet weathering."	12.7	(41.8)

Three Lick Bed:

		Thickness Meters	(Feet)
(5)	Mudstone, greenish-gray (5 GY 4/1); contains traces of pyrite; contains burrowed zone 4-7 cm thick at the base; unit is iron-stained and forms reentrant.	0.4	(1.4)
(6)	Shale, brownish-black (5 YR 2/1), clayey, fissile; contains weathered pyrite nodules; contains rare *Tasmanites*; unit is iron-stained and forms a jointed ledge.	1.5	(4.8)
(7)	Mudstone, greenish-gray (5 GY 4/1); same as unit 5, but one *Lingula* found.	0.4	(1.2)
(8)	Shale, brownish-black (5 YR 2/1); same as unit 6.	0.8	(2.6)
(9)	Mudstone, greenish-gray (5 GY 4/1); same as unit 5.	0.9	(2.9)
	Total Three Lick Bed	3.9	(12.9)
(10)	Shale, brownish-black (5 YR 2/1), clayey, fissile; contains pyrite nodules; contains horizontal burrows; unit is iron-stained and covered with talus; contains possible syneresis cracks.	1.2	(3.8)
(11)	Covered interval within the Ohio Shale	1.4	(4.5)
(12)	Shale, brownish-black (5 YR 2/1); same as unit 10.	2.1	(7.0)
(13)	Covered interval within the Ohio Shale	5.3	(17.5)
(14)	Shale, brownish-black (5 YR 2/1), silty, very fissile; contains syneresis cracks; contains common *Tasmanites*; contains burrows in the lower part of unit; forms jointed ledge with petroliferous odor.	1.1	(3.5)
	(Note: Unit 5 outcrops in a small creek just east of the highway.)		
(15)	Covered interval within the Ohio Shale	10.0	(32.9)

	Thickness Meters	(Feet)
(16) Shale, brownish-black (5 YR 2/1), silty, very fissile; contains pyrite nodules; contains *Tasmanites*, fish plates and a zone of *Foerstia* 0.8 m (2.7') above base of unit; forms jointed iron-stained ledge.	2.6	(8.5)
(17) Covered interval within the Ohio Shale	3.1	(10.2)
(18) Shale, brownish-black (5 YR 2/1), fissile, laminated with silty layers; contains *Tasmanites*; weathers to a light brown (5 YR 5/6); forms a blocky, jointed ledge	0.7	(2.3)
Thickness of Ohio Shale in section	45.0	(147.5)
Total thickness of section	58.9	(193.0)

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978



Pl. #1 Section

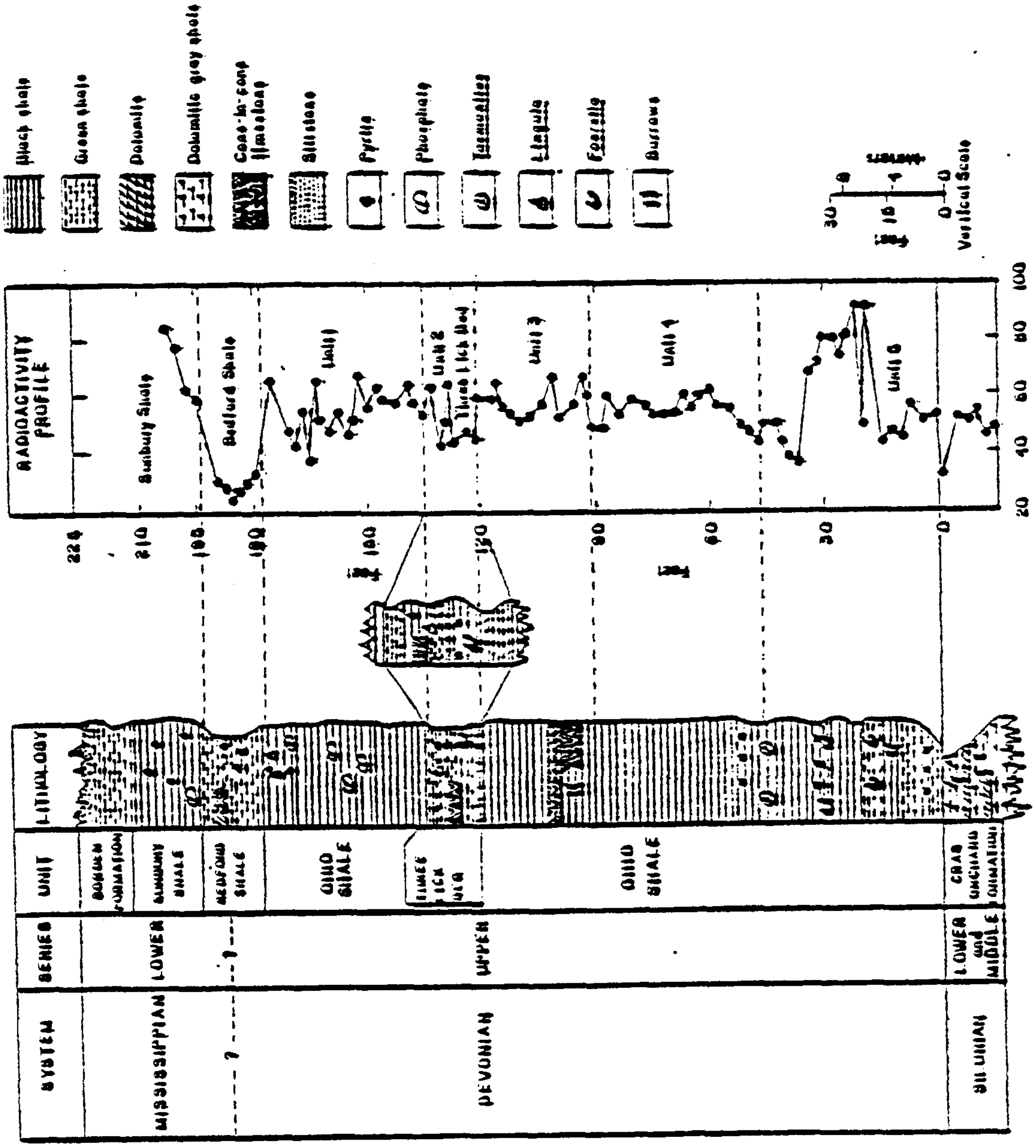
ROWAN COUNTY REFERENCE SECTION (RW #1)

This section contains the complete Ohio Shale, Bedford Shale and Sunbury Shale. The base of the section is on the south side of Interstate 75, 2.3 kilometers (1.4 miles) east of the Bath-Rowan County line (section 1-T-71, 900' FNL x 1100' FWL). The upper section is on the north side of Interstate 75, 5.0 kilometers (3.1 miles) from the Bath-Rowan County line (section 25-U-72, 1100' FNL x 600' FEL). The section is on the Farmers Quadrange, and the elevation of the base of the Ohio Shale is 216.5 meters (710' feet). The section was measured using hand level, Jacob's staff, tape and scintillometer on October 17, 1976 by Dennis Swager, Frank Ettensohn, Paul Potter, Roy Kepferle and John Goble.

	Thickness Meters	(Feet)
Borden Formation (incomplete): Henley Bed of the Farmers Member:		
(1) Mudstone, greenish-gray (5 GY 6/1); contains small interbeds of siltstone; contains glauconite filled burrows; contact with Sunbury sharp; forms reentrant.	1.7	(5.6)
(2) Shale, brownish-black (5 YR 2/1) to (N1); contains abundant pyrite nodules; contains common *Lingula*; weathers yellowish-orange (5 Y 8/1); forms cliff; contains basal lag zone with conodonts, fish plates and woody fragments.	5.9	(19.4)
Bedford Shale:		
(3) Shale, olive-gray (5 Y 4/1)-(5 Y 6/1), silty, slightly calcareous; contains siltstone lenses and cone-in-cone limestones; contact sharp with Ohio Shale; heavily stained with limonite; forms reentrant.	6.6	(21.5)

	Thickness Meters	(Feet)
Ohio Shale:		
(4) Shale, brownish-black (5 YR 2/1), fissile, laminated, semi-conchoidal fractures; contains abundant pyrite nodules, phosphate nodules and woody fragments; contains abundant Lingula (increasing near top); forms blocky, jointed cliff.	14.8	(48.5)
(5) Shale, greenish-gray (5 GY 4/1), clayey, thin bedded; contains some pyrite nodules; contains rare Lingula; forms reentrant	0.3	(1.1)
(6) Shale, brownish-black (5 YR 2/1), very fissile, thinly laminated; contains a discontinuous cone-in-cone limestone; contains pyrite and marcasite nodules; forms resistant outcrop	1.3	(4.1)
(7) Shale, greenish-gray (5 GY 4/1); same as unit 5 (without Lingula).	0.3	(1.1)
(8) Shale, brownish-black (5 YR 2/1); same as unit 6 (without cone-in-cone limestone)	0.7	(2.4)
(9) Shale greenish-gray (5 GY 4/1); same as unit 7.	0.7	(2.2)
Total Three Lick Bed	3.33	(10.9)
(10) Shale, brownish-black (5 YR 2/1), fissile, laminated with silty layers; contains 3 discontinuous cone-in-cone limestones, dark yellowish-orange (10 YR 6/6); contains abundant Tasmanites, coalified logs; contains dendritic burrows; forms resistant ledge	12.0	(39.3)
(11) Shale, brownish-black (5 YR 2/1); same as unit 10 (without the cone-in-cone limestones).	17.6	(57.7)
(12) Shale, dark greenish-gray (5 GY 4/1), interbeds of shale, brownish-black (5 YR 2/1) present; black shale contains abundant Foerstia; forms slight reentrant with "couplet-type" weathering.	0.9	(2.8)

	Thickness Meters	(Feet)
(13) Shale, brownish-black (5 YR 2/1), silty, fissile, laminated; contains irregular shaped pyrite nodules and bedded pyrite; contains coalified logs; weathers light brown (5 YR 5/6); forms a jointed ledge	6.6	(21.6)
(14) Shale, brownish-black (5 YR 2/1) interbedded with greenish-gray (6/1) shale; Beds are 5 to 7 centimeters thick; black shale contains *Foerstia*; green shale contains burrows; forms a reentrant	2.6	(8.5)
(15) Shale, brownish-black (5 YR 2/1), fissile, laminated; contains pyrite nodules and burrows; forms blocky, jointed, resistant ledge.	1.5	(4.9)
(16) Shale, brownish-black (5 YR 2/1), fissile, thinly laminated; contains a 6 cm basal lag zone with woody fragments and quartz pebbles	0.7	(2.4)
Total Ohio Shale	60.0	(196.6)
Disconformity		
Crab Orchard Formation (incomplete):		
(17) Shale, dark greenish-gray (5 Y 5/1); interbedded with dolomite, light brown (5 YR 5/6); dolomite is in stringers from 0.1 m (4") to 0.2 m (8") thick; shale weathers to light brown (5 YR 5/6); unit forms reentrant.	2.4+	(8+)
Total thickness of Section approximately	76.6	(251)


Black shale
Green shale
Dolomite
Dolomitic gray shale
Cone-in-cone limestone
Siltstone
Pyrite
Phosphate
Tasmanites
Lingula
Fossils
Burrows
Vertical Scale
RADIOACTIVITY PROFILE
Sunbury Shale
Bedford Shale
Unit 1
Unit 2
Three Lick Bed
Unit 3
Unit 4
Unit 5
cps
SYSTEM
SERIES
UNIT
LITHOLOGY
MISSISSIPPIAN
DEVONIAN
LOWER
UPPER
OHIO SHALE

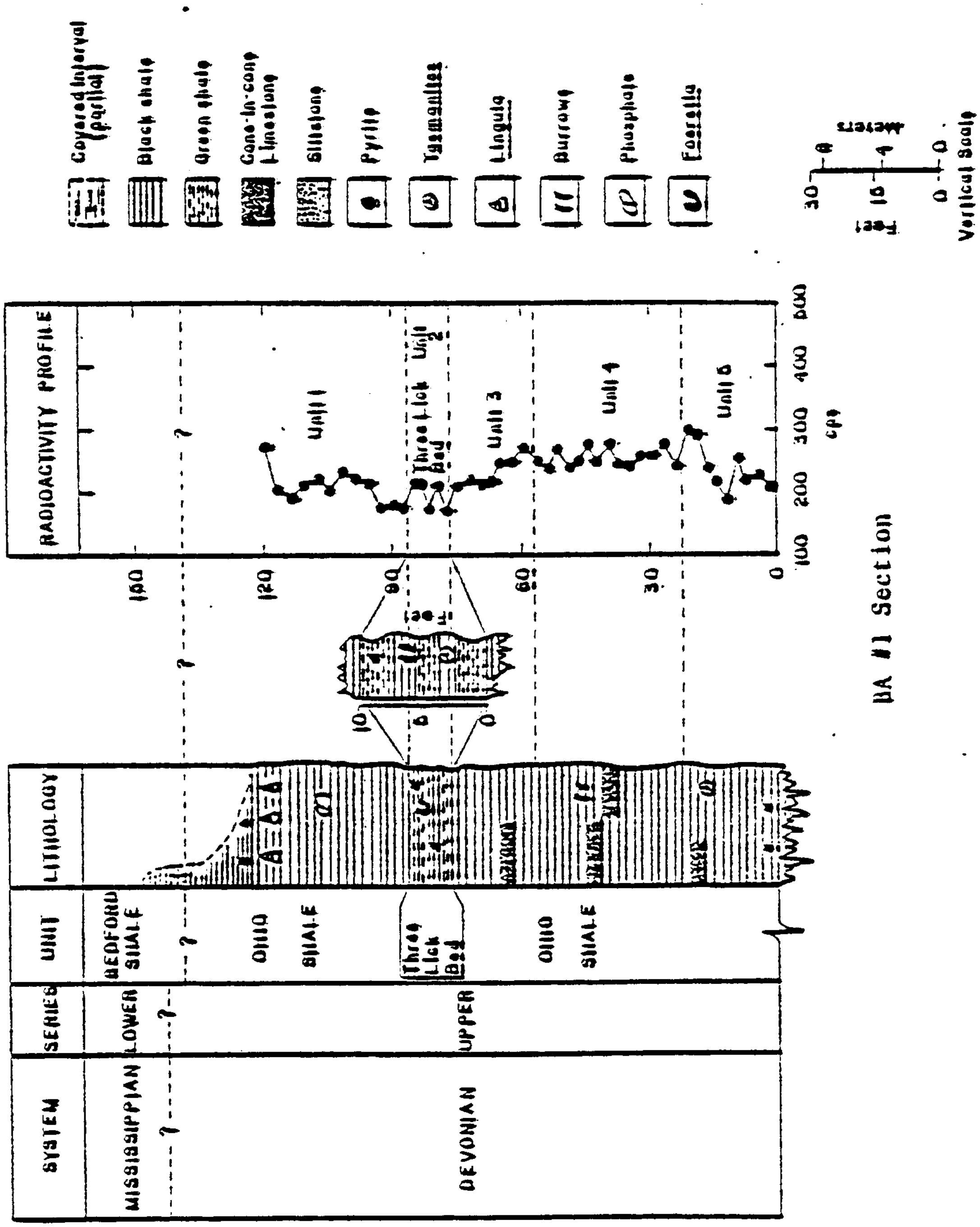
RW #1 Section

BATH COUNTY SECTION (BA #1)

This is a partial section of the Ohio Shale exclusive of either bottom or top, but does expose the Three Lick Bed very well on the first ledge of the quarry. The quarry is located approximately 0.3 kilometers (300 yards) west of Kentucky Highway 211, 2.7 kilometers (1.7 miles) south of Salt Lick in Bath County, Kentucky. The quarry is on the Salt Lick Quadrangle (section 23-T-71, 2000' FEL x 1300' FNL), and the base of the Three Lick Bed is 256.8 meters (842 feet) above sea level. The section was measured and described using hand level and tape on November 7, 1976 by Dennis Swager, John Goble and Mike Miller. The radioactive profile was measured with a scintillometer on May 12, 1977 by Dennis Swager and John Goble.

Ohio Shale (incomplete):	Thickness Meters	(Feet)
(1) Shale, brownish-black (5 YR 2/1) to black (N2), fissile, silty, laminated with silty layers; has subconchoidal fracture; contains abundant Lingula; forms a jointed cliff with "couplet weathering."	12.9	(42.2)
(Note: The exact top is indistinguishable, but the last black shale was found at the top of unit 1.)		
(2) Shale, brownish-black (5 YR 2/1), clayey, laminated, fissile; contains pyrite nodules; basal contact sharp; forms jointed, iron-stained ledges.	4.5	(14.3)
Three Lick Bed:		
(3) Mudstone, greenish-gray (5 GY 8/1), clayey; pyrite nodules common; contains numerous burrows; forms an iron-stained reentrant; sharp basal contact.	0.6	(2.0)

		Thickness Meters	(Feet)
(4)	Shale, brownish-black (5 YR 2/1), laminated, fissile; contains pyrite nodules; weathers to a light brown (5 YR 5/6); forms a slight ledge.	0.7	(2.2)
(5)	Mudstone, greenish-gray (5 GY 8/1): same as unit 3; weathers to a dark reddish-brown (10 R 3/4)	0.3	(1.0)
(6)	Shale, brownish-black (5 YR 2/1); same as unit 4.	0.7	(2.3)
(7)	Mudstone, greenish-gray (5 GY 8/1) same as unit 5.	0.5	(1.7)
(8)	Shale, brownish-black (5 YR 2/1), silty, laminated, fissile; contains abundant pyrite nodules and bedded pyrite; contains discontinuous cone-in-cone limestones, medium-gray (N3); limestones vary up to 0.2 m (0.7') in thickness; contains abundant Tasmanites; forms jointed blocky ledges with "couplet weathering."	23.5	(76.9)
	Total thickness of Ohio Shale in section	43.6	(143.1)


SYSTEM
SERIES
UNIT
LITHOLOGY
RADIOACTIVITY PROFILE
MISSISSIPPIAN
DEVONIAN
LOWER
UPPER
BEDFORD SHALE
OHIO SHALE
Three Lick Bed
OHIO SHALE
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Three Lick Bed
cps
Feet
Covered Interval (partial)
Black shale
Green shale
Cone-in-cone Limestone
Siltstone
Pyrite
Tasmanites
Lingula
Burrows
Phosphate
Fossils
Feet
Meters
Vertical Scale

BA #1 Section

POWELL COUNTY SECTION (PO #1)

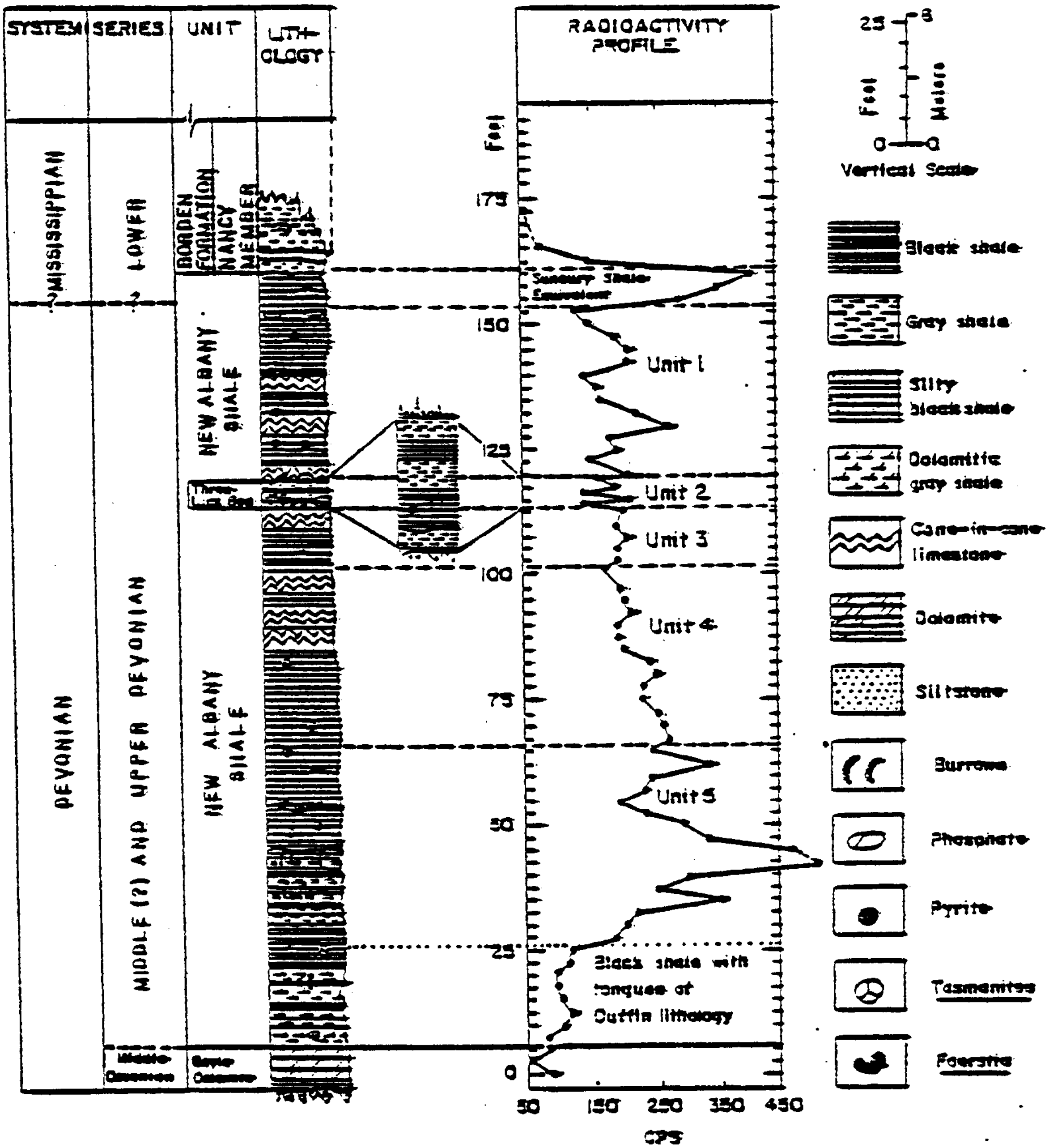
This section contains the complete New Albany Shale and partial sections of the Boyle Dolomite and New Providence Shale. The section is exposed and was measured on the north side of the Mountain Parkway, 0.4 kilometers (0.25 miles) west of the Clay City Interchange in Powell County, Kentucky on the Clay City Quadrangle (section 12-Q-67, 100' FSL x 1000' FWL). The upper part of the section was measured and described in a quarry, 0.5 kilometers (0.3 miles) north of Highway 11 along the east side of Highway 1057 in Powell County, Kentucky on the Levee Quadrangle (section 3-Q-67, 0' FSL x 750' FWL). The section was measured and described by Dennis Swager and Roy C. Kepferle with Jacob's staff, Abney level and tape. Scintillometer readings were taken by Frank R. Ettensohn, John Goble and Les Booth. Sampling was completed by Mike Miller and Les Booth on May 19, 1977. The base of the New Albany Shale is 197.3 meters (647 feet) above sea level.

Borden Formation (incomplete):	Thickness Meters	(Feet)
New Providence Shale Member (incomplete):		
(1) Mudstone, greenish-gray (5 GY 6/1); contains small interbedded siltstone layers; contains clayey phosphate nodules; contains Tanaurous burrows; weathers to a yellowish-gray (5 Y 8/1); mudstones form reentrants and siltstone form resistant layers.	2.4	(8.0)

	Thickness Meters	(Feet)
Disconformity		
New Albany Shale		
(2) Shale, brownish-black (5 YR 2/1), very fissile, thin laminae, silty; contains pyrite and phosphate nodules; contains discontinuous cone-in-cone limestones, medium gray (N3) up to 0.2 m (0.6') thick, limestones occur at 0.5 m (1.6'), 2.9 m (9.6'), 3.2 m (10.6') and 6.3m(20.8') from the base of unit; phosphate nodules occur 6.7 m (22.1') from the base of unit and are oriented 280° -320° in strike; contains _Tasmanites_ and burrows; unit forms jointed, blocky cliff and has "couplet weathering."	14.0	(46.0)
Three Lick Bed:		
(3) Mudstone, light gray (N6), crumbly texture, silty, poorly laminated, cohesive; iron-stained surface; forms reentrant with sharp basal contact.	0.3	(0.9)
(4) Shale, brownish-black (5 YR 2/1), very fissile, laminated; contains pyrite nodules; contains rare _Tasmanites_; burrowed at basal contact.	0.5	(1.6)
(5) Mudstone, light gray (N6); same as unit 3.	0.1	(0.3)
(6) Shale, brownish-black (5 YR 2/1); same as unit 4.	0.5	(1.6)
(7) Mudstone, Light gray (N6); same as unit 3.	0.4	(1.4)
Total Three Lick Bed	1.8	(6.0)
(8) Shale, brownish-black (5 YR 2/1), laminated with silty layers, fissile; contains pyrite nodules; contains continuous cone-in-cone limestones, medium gray (N3), less than 0.9 m (0.3') thick occurring in six distinct		

	Thickness Meters	(Feet)
horizons: 1.5 m (5'), 1.9 m (6.2'), 3.7 m (12.0'), 43 m (14.0'), 5.3 m (17.3') above the base of unit, and at the base of unit; contains coalified plant fragments; contains abundant Tasmanites; forms resistant outcrop with "couplet weathering."	8.8	(28.8)
(9) Shale, brownish-black (5 YR 2/1); same as unit 8 without the cone-in-cone limestones; contains abundant Foerstia in a zone 7.9 m (26') thick beginning 4.3 m (14') from base of unit; unit had to be trenched in areas where talus covered.	14.0	(46.0)
(10) Mudstone, dark greenish-gray (5 GY 4/1) to grayish-brown (5 YR 3/2) interbedded with shale, black (N1); black shale beds up to 0.3 m (1.0') thick at base; contains pyrite nodules; contains abundant Tasmanites; contains Condrities and Tanaurous burrows; contains large continuous burrowed bed 11.1 m (36.5') from base of formation; unit forms slight reentrant with "couplet weathering" (the base of each "couplet" is burrowed.)	3.3	(10.7)
(11) Shale, brownish-black (5 YR 2/1) to grayish-black (N2); contains pyrite nodules along bedding planes; contains abundant Tasmanites; unit weathers to light gray (N7); forms a ledge with massive blocks and "couplet weathering" in upper 2.1 m (6.8').	2.5	(8.3)
(12) Shale, brownish-black (5 YR 2/1) interbedded with brownish-gray (5 YR 6/1) dolomitic mudstone; black shale is fissile with platy laminae; beds are from 0.6 m (0.2') thick to 0.2 m (0.6') thick; contains a zone of lenticular burrows in upper 0.3 m (0.9') of unit; unit is heavily iron-stained.	2.8	(9.2)

	Thickness Meters	(Feet)
(13) Mudstone, olive-gray (5 Y 4/1), silty, dolomitic, very fissile; contains a discontinuous dolomite stringer 0.2 m (0.6') thick; contains rare Tasmanites; unit is jointed, iron-stained, and forms reentrant.	1.8	(5.8)
Total New Albany Shale	49.0	(160.8)
Boyle Dolomite (incomplete):		
(14) Dolomite, medium gray (5 Y 6/1), sucrosic; contains large vugs filled with dead oil, calcite and dolomite crystals; contains nodularly bedded chert up to 0.2m(0.7') thick; contains silicified corals, bryozoans and crinoids; unit weathers to grayish-orange (10 YR 7/4).	1.3	(4.2)
(15) Dolomite, medium gray (5 Y 6/1), sucrosic; contains large joints filled with brown shale, green and gray clays, siltstones and quartz pebbles.	0.8	(2.6)
Total Boyle Dolomite	2.1	(6.8)
Total Thickness of Section	53.5	(195.4)


SYSTEM
SERIES
UNIT
LITH-OLOGY
RADIOACTIVITY PROFILE
MISSISSIPPIAN
LOWER
BORDEN FORMATION NANCY MEMBER
DEVONIAN
MIDDLE (?) AND UPPER DEVONIAN
NEW ALBANY SHALE
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
Feet
175
150
125
100
75
50
25
0
50
150
250
350
450
CPS
Vertical Scale
Feet
Meters
Black shale
Gray shale
Silty black shale
Dolomitic gray shale
Cone-in-cone limestone
Dolomite
Siltstone
Burrows
Phosphate
Pyrite
Tasmanites
Foerstia

PO #1 Section

ESTILL COUNTY SECTION (ES #1)

This section contains the complete New Albany Shale, a partial section of the Boyle Dolomite and possibly part of the Irvine Formation. The section was described in a series of road cuts on the north side of Kentucky Highway 52, west of Irvine in Estill County, Kentucky. The section is located on the Panola Quadrangle (section 13-0-66, 1900' FSL x 100' FEL), and the base of the New Albany Shale is 226.6 meters (743 feet) above sea level. The section was measured and described by Dennis Swager, John Goble, and Mike Miller on May 24, 1977 using hand level, Jacob's staff and tape. The section was sampled and a radioactive profile compiled on the same date.

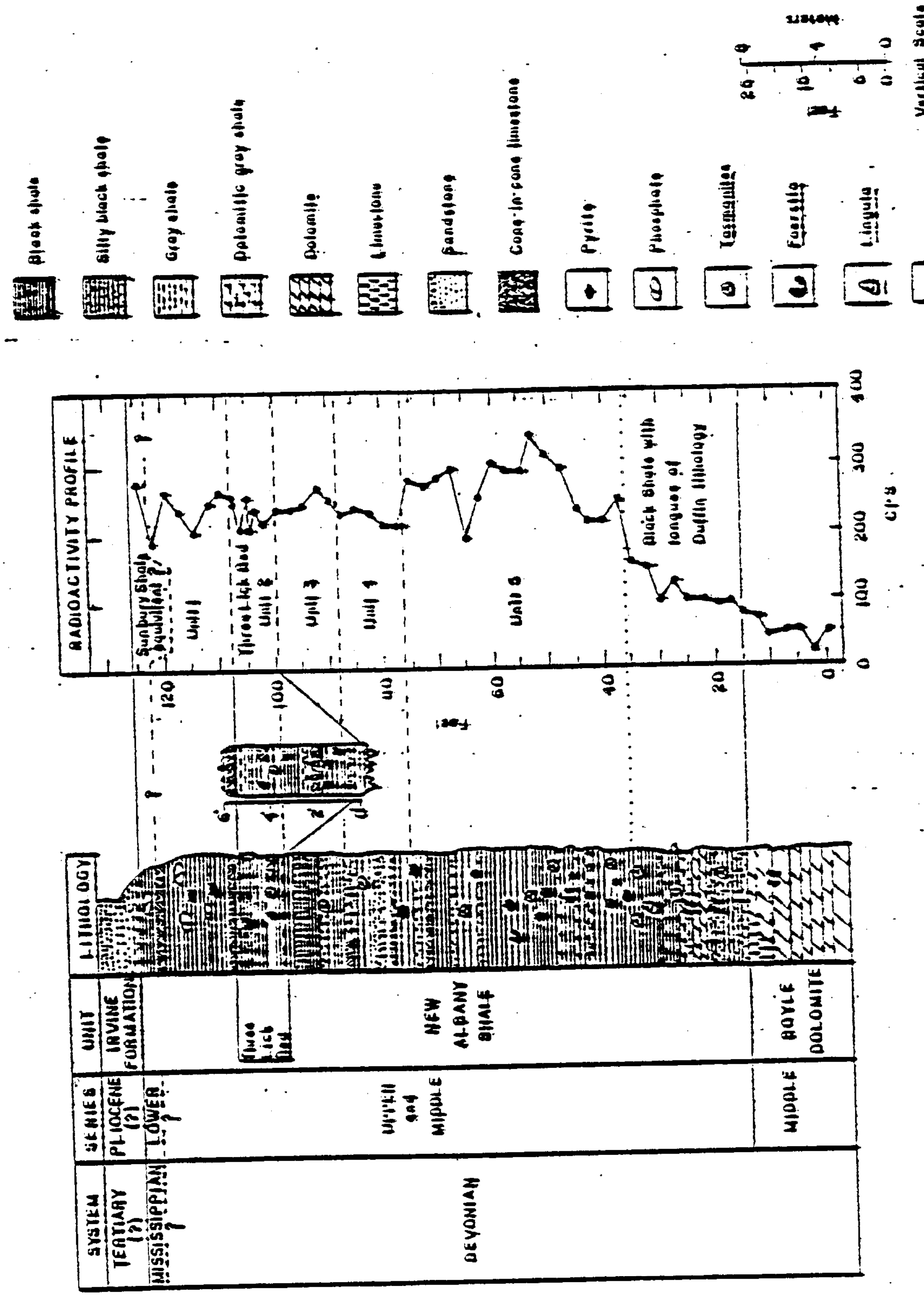
	Thickness Meters	(Feet)
Irvine Formation (incomplete):		
(1) Shale, light greenish-gray (5 GY 8/1), argillaceous and clay, grayish-orange (10 YR 7/4); this was found at the top of the road cut and no thickness was estimated.	?	(?)
(Note: According to the geologic quadrangle, there should be Irvine on the top of this outcrop. The few chips of shale are the only evidence that it exists there.)		
Disconformity		
New Albany Shale:		
(2) Shale, brownish-black (5 YR 2/1), fissile, silty; contains pyrite nodules and phosphate nodules; contains Tasmanites; forms a massive ledge with "couplet weathering" (Not sure of top due to developing soil horizon.)	7.0	(22.9)

	Thickness Meters	(Feet)
Three Lick Bed:		
(3) Mudstone, greenish-gray (5 GY 4/1) to light gray (N3); burrowed at the base; heavily iron-stained; forms reentrant.	0.1	(0.4)
(4) Shale, brownish-black (5 YR 2/1), very fissile, laminated; contains pyrite nodules; contains a discontinuous cone-in-cone limestone; contains _Tasmanites_; forms an iron-stained ledge.	0.7	(2.3)
(5) Mudstone, greenish-gray (5 GY 4/1); same as unit 3.	0.1	(0.4)
(6) Shale, brownish-black (5 YR 2/1); same as unit 4 without the cone-in-cone limestone.	0.5	(1.7)
(7) Mudstone, greenish-gray (5 GY 4/1); same as unit 3.	0.2	(0.6)
Total Three Lick Bed	1.6	(5.4)
(8) Shale, brownish-black (5 YR 2/1), laminated, fissile; contains pyrite nodules and bedded pyrite; contains cone-in-cone limestones at 23.2 m (76'), 25.3 m (83') and 25.9 m (85') from base of unit; contains _Tasmanites_ and coalified plant fragments; contains a zone of abundant _Foerstia_ between 17.4 m (56.9') and 18.3 m (60.0') from the base of formation; forms a jointed ledge with "couplet weathering."	13.9	(45.4)
(9) Shale, brownish-black (5 YR 2/1), fissile, laminated with silty layers; contains few pyrite nodules and bedded pyrite; contains abundant _Tasmanites_ and plant fragments; forms iron-stained, jointed cliff.	2.3	(7.7)

		Thickness Meters	(Feet)
(10)	Shale, brownish-black (5 YR 2/1) interbedded with gray (N8) dolomitic claystone; black shales contain pyrite nodules, burrows, plant fragments and *Tasmanites*; gray claystones contain pyrite nodules; gray beds are from 0.2 m (0.7') to 0.3 m (1.0') thick; forms reentrants.	1.8	(6.0)
(11)	Shale, brownish-black (5 YR 2/1); contains little or no silt; contains pyrite nodules; contains *Lingula* fragments and *Tasmanites*; forms a jointed, massive ledge.	3.7	(12.2)
(12)	Shale, gray (N6), dolomitic; interbedded with brownish-black (5 YR 2/1) silty shale; gray shales are in five beds about 0.1 m (0.4') thick which form reentrants.	1.0	(3.2)
(13)	Shale, brownish-black (5 YR 2/1), laminated, fissile; contains abundant *Tasmanites*; forms a small continuous ledge.	0.2	(0.6)
(14)	Dolomite, medium gray (N3) to light gray (N6), silty; contains numerous burrows near the base of unit; forms a highly jointed reentrant which weathers to a mass of chips.	0.7	(2.2)
(15)	Dolomite, medium gray (N3), sucrosic; contains silicified coralline fragments; contains a high amount of vugular porosity; weathers to a slight reentrant.	0.8	(2.7)

(Note: The two dolomite units 14 and 15 are in a portion of the outcrop which seems to be slumped. They contain flow rolls surrounded by bands of black shale in this slumped section. Unit 14 is not continuous across the outcrop, but it pinches out at the slumped area.)

		Thickness Meters	(Feet)
(16)	Shale, brownish-black (5 YR 2/1), laminated with silty layers; contains abundant *Tasmanites* and burrows near the top; forms an iron-stained ledge with "couplet weathering."	2.2	(7.3)
	Total New Albany Shale	35.2	(115.6)
	Disconformity		
	Boyle Dolomite:		
(17)	Dolomite, medium light gray (N6), silty; interbedded with medium gray (N5) limestone; dolomite contains quartz pebbles, shale clasts, silicified brachiopod, crinoid and coralline fragments; limestone contains 3 small brownish-black (5 YR 2/1) shale interbeds up to 0.1 m (0.3') thick; unit contains vugular porosity, stylolites along bedding planes, and a strong petroliferous odor.	4.2	(13.6)
(18)	Dolomite, medium light gray (N6); same as the dolomite of unit 17; contains rare burrows.	0.3	(1.1)
(19)	Coquina, clay sized matrix cementing abundant silicified brachiopod shells.	0.1	(0.3)
	Total Boyle Dolomite	4.6	(15.0)
	Total thickness of section	39.8	(130.6)


SYSTEM
TERTIARY (?)
MISSISSIPPIAN ?
DEVONIAN
SERIES
PLIOCENE (?)
LOWER ?
UPPER and MIDDLE
MIDDLE
UNIT
IRVINE FORMATION
Three Lick Bed
NEW ALBANY SHALE
BOYLE DOLOMITE
LITHOLOGY
RADIOACTIVITY PROFILE
Sunbury Shale equivalent ?
Unit 1
Three Lick Bed Unit 2
Unit 3
Unit 4
Unit 5
Black Shale with tongues of Duffin lithology
Feet
CPS
Black shale
Silty black shale
Gray shale
Dolomitic gray shale
Dolomite
Limestone
Sandstone
Cone-in-cone limestone
Pyrite
Phosphate
Tasmanites
Foerstia
Lingula
Burrows
Vertical Scale

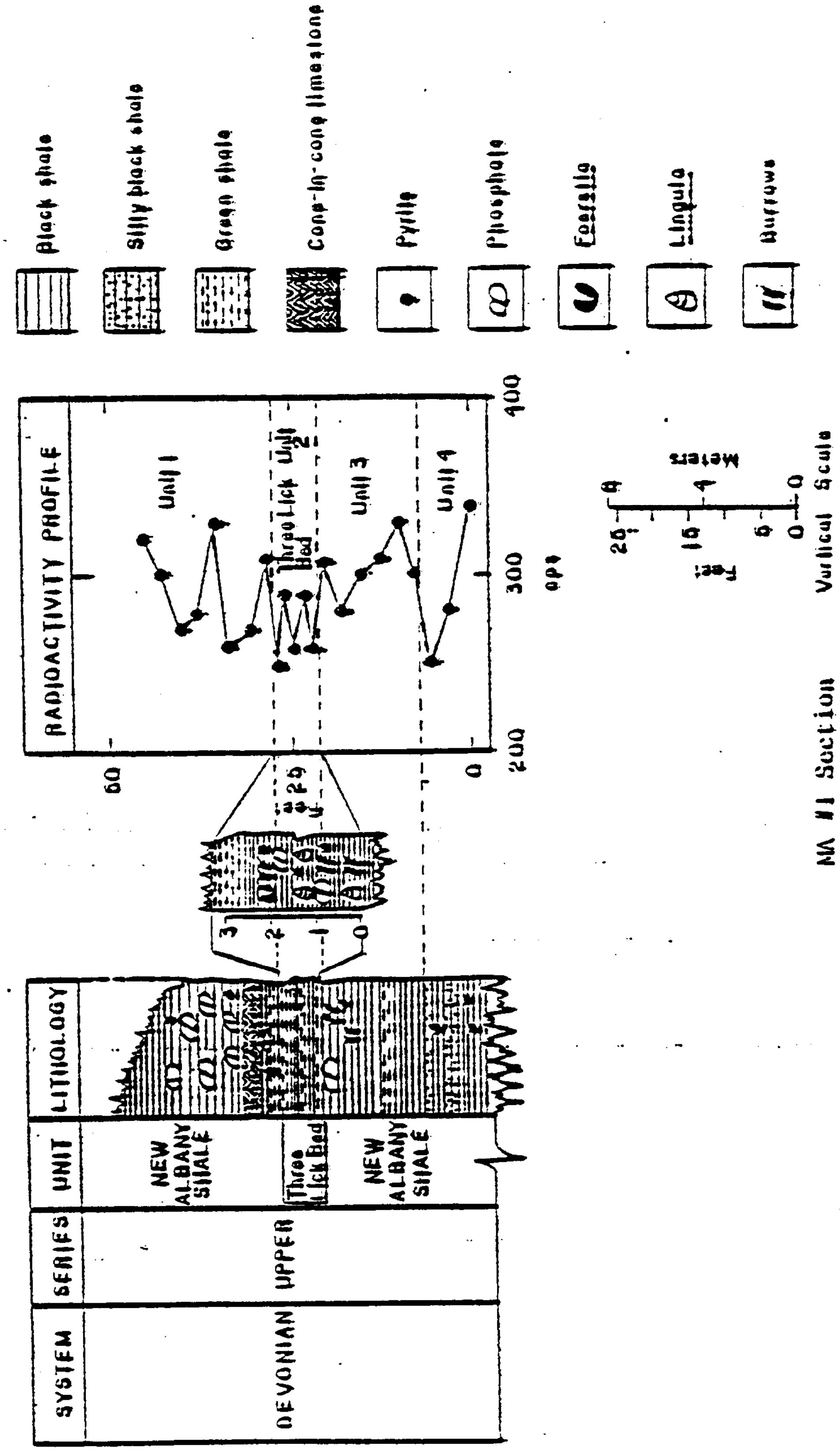
RS #1 Section

MADISON COUNTY SECTION (MA #1)

This section contains an incomplete sequence of the New Albany Shale. The top of the section is approximately the top of the formation, but due to the developed soil horizon at the top of the quarry the upper contact is indistinguishable. The entire Three Lick Bed is well exposed in the wall of this quarry or borrow pit. The section was measured 0.1 kilometers (100 yards) southwest of Kentucky Highway 21, 2.4 kilometers (1.5 miles) west of its intersection with Interstate 75 at the Berea exchange in Madison County, Kentucky. The section is located on the Berea Quadrangle (section 6-M-63 1600' FNL x 2150' FEL), and the base of the Three Lick Bed is 318.1 meters (1,043 feet) above sea level. Measuring, describing, sampling and radioactive profiling were conducted by Dennis Swager, John Goble and Mike Miller on April 16, 1977 with the use of hand level, tape and scintillometer.

New Albany Shale	Thickness Meters	(Feet)
(1) Shale, brownish-black (5 YR 2/1), fissile, laminated with silty layers; contains large phosphate nodules (up to 0.4 m (1.2') across); contains abundant _Tasmanites_ and plant fragments.	1.6	(5.2)
(Note: The developing soil horizon at the top of the borrow pit makes the upper contact of the New Albany Shale indistinguishable.)		
(2) Shale, brownish-black (5 YR 2/1); same as unit 1; contains abundant pyrite nodules and framboids; contains two small continuous cone-in-cone limestones at 1.6 m (5.3') and 4.2 m (13.8') from base of unit, forms blocky, jointed ledges.	4.8	(15.8)

	Thickness Meters	(Feet)
Three Lick Bed:		
(3) Claystone, greenish-gray (5 GY 4/1); contains pyrite nodules; contains abundant burrows; forms an iron-stained reentrant.	0.2	(0.8)
(4) Shale, brownish-black (5 YR 2/1), fissile; contains pyrite and phosphate nodules; contains Foerstia; highly burrowed; forms resistant bed.	0.3	(1.0)
(5) Mudstone, greenish-gray (5 GY 4/1); contains pyrite nodules; contains abundant large Lingula (up to 4 centimeters in length); contains prolific lenticular and vertical burrows; forms reentrant.	0.1	(0.3)
(6) Shale, brownish-black (5 YR 2/1); same as unit 4; contains rhombohedral fish plates.	0.3	(1.0)
(7) Mudstone, greenish-gray (5 GY 4/1); same as unit 5.	0.1	(0.3)
Total Three Lick Bed:	1.0	(3.4)
(8) Shale, brownish-black (5 YR 2/1), fissile laminated with silty layers; contains pyrite nodules, bedded pyrite and cubic pyrite crystals; contains small phosphate nodules in upper 1.5 m (5.0') of unit; contains plant fragments and burrow-mottling in upper 4.6 m (15.0'); forms massive, jointed outcrop with "couplet weathering."	6.6	(21.5)
Total thickness of New Albany Shale	14.0	(45.9)


Black shale
Silty black shale
Green shale
Cone-in-cone limestone
Pyrite
Phosphate
Fossils
Lingula
Burrows
RADIOACTIVITY PROFILE
Unit 1
Three Lick Unit 2 Bed
Unit 3
Unit 4
200
300
400
cps
60
0
Meters
Feet
Vertical Scale
SYSTEM
SERIES
UNIT
LITHOLOGY
DEVONIAN
UPPER
NEW ALBANY SHALE
Three Lick Bed
NEW ALBANY SHALE
NA #1 Section

MADISON COUNTY SECTION (MA #2)

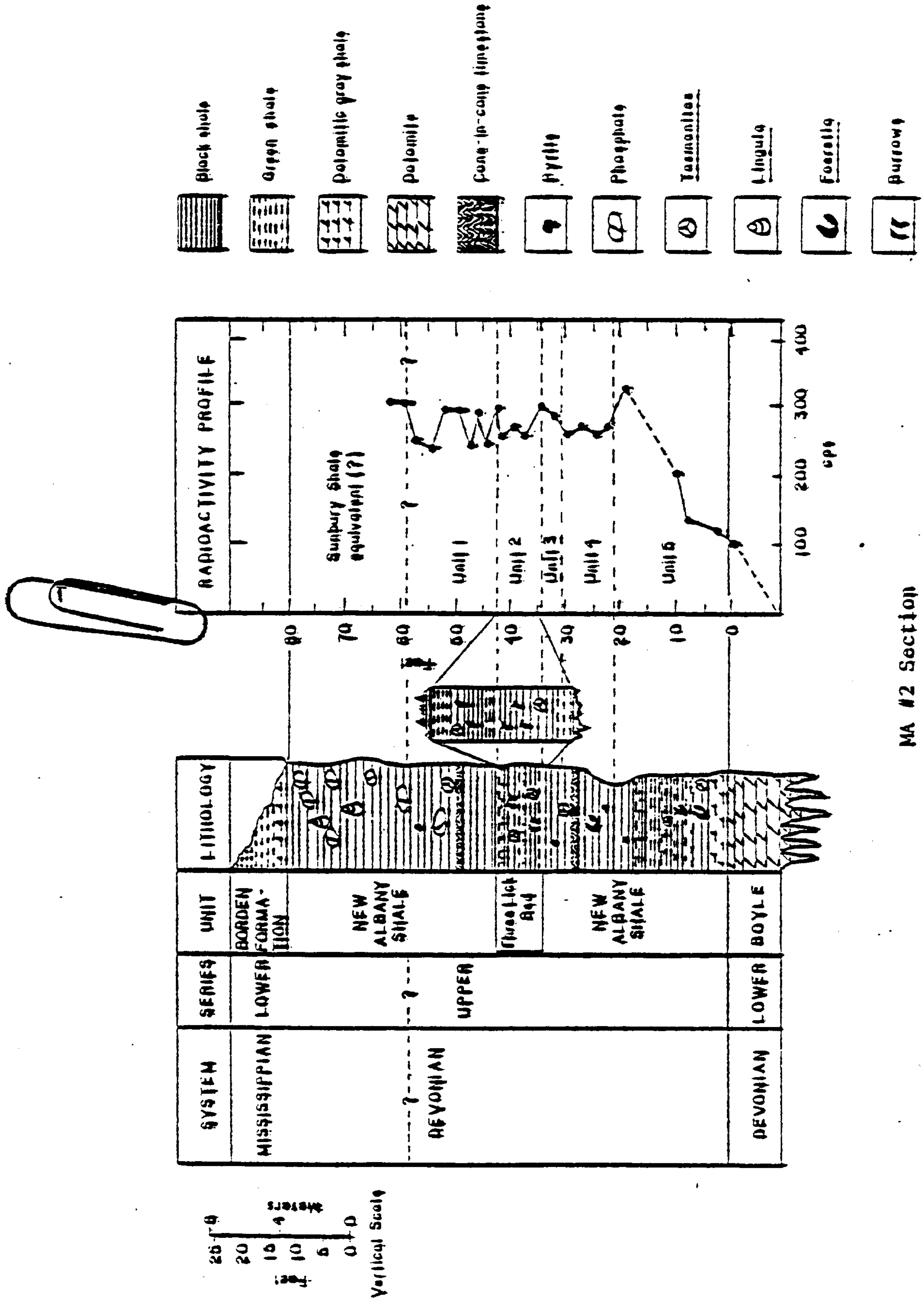
This section contains a nearly complete section of the New Albany Shale exposed in a series of road cuts along the north-bound lanes of Interstate 75 near the Berea exchange in Madison County, Kentucky. It is located on the Berea Quadrangle (section 7-M-63, 575' FNL x 600' FWL), and the base of the New Albany Shale is 295.9 meters (970 feet) above sea level. Nearly all the section had to be trenched in order to remove the large amount of regolith covering it, and in areas was completely covered. The section was originally measured by Dennis Swager and John Goble on June 1, 1977 using hand level, tape and scintillometer. It was remeasured with a Jacob's staff and Abney level on July 7, 1977 by Roy C. Kepferle, Dennis Swager and John Goble.

	Thickness Meters	(Feet)
New Albany Shale:		
(1) Unsure of lithology, but above outcrop of unit 2, the section is covered by a developing soil horizon containing chips of gray shale which look like the New Providence. Top is indistinguishable and elevation uncertain.	1.5+	(5.0+)
(2) Shale, brownish-black (5 YR 2/1), very fissile, laminated with silty layers; contains large elliptical phosphate nodules; contains a few discontinuous cone-in-cone limestone beds; contains abundant pyrite and marcasite nodules; contains abundant _Tasmanites_; has a previlent petroliferous odor; forms small talus covered outcrops with "couplet weathering."	8.3	(27.2)
Three Lick Bed:		
(3) Shale, greenish-gray (5 GY 6/1), fissile, burrowed; contains _Lingula_; forms iron-stained reentrant.	0.2	(0.8)

		Thickness Meters	(Feet)
(4)	Shale, brownish-black (5 YR 2/1), fissile; contains abundant <u>Tasmanites</u>; burrow mottled; forms reentrant.	0.3	(1.1)
(5)	Shale, greenish-gray (5 GY 6/1); same as unit 3.	0.2	(0.5)
(6)	Shale, brownish-black (5 YR 2/1); same as unit 4; contains small discontinuous cone-in-cone limestone near the top.	0.3	(1.1)
(7)	Shale, greenish-gray (5 GY 6/1); same as unit 3.	0.4	(1.3)
	Total Three Lick Bed	1.4	(4.8)
(8)	Shale, brownish-black (5 YR 2/1), fissile, laminated with paper-thin silty layers; contains pyrite nodules; contains small, discontinuous cone-in-cone limestone 0.8 m (2.5') from the top of unit; contains abundant <u>Tasmanites</u>.	8.0	(26.1)
(9)	Covered Interval within New Albany Shale	3.0	(9.9)
(10)	Shale, brownish-black (5 YR 2/1) interbedded with gray (N4) dolomitic shale; black shales contain pyrite nodules, bedded pyrite, <u>Lingula</u> and plant fragments; dolomitic beds are less than 0.3 m (1.0') thick; unit is mostly covered with a few resistant outcrops; outcrops are highly jointed.	3.1	(10.3)
	Total New Albany Shale	25.3	(83.3)
(11)	Limestone, moderate yellowish-brown (10 YR 5/4), dolomitic; contains nodularly bedded chert, shale clasts, vugs filled with quartz and dolomite crystals, stylolites along bedding planes, and silicified crinoid, bryozoan and coralline fragments; forms a resistant cliff.	4.6	(15.0)
	Total Thickness of Section	29.9	(98.3)

(Note: Some of the lower parts of the section were described from the walls of the quarry or borrow pit located about

50 meters east of the Interstate road cuts. The Three Lick Bed was well exposed in this pit.)


Black shale
Green shale
Dolomitic gray shale
Dolomite
Cone-in-cone limestone
Pyrite
Phosphate
Tasmanites
Lingula
Foerstia
Burrows
RADIOACTIVITY PROFILE
Sunbury Shale equivalent (?)
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
100
200
300
400
cps
80
70
60
50
40
30
20
10
0
LITHOLOGY
UNIT
SERIES
SYSTEM
BORDEN FORMATION
NEW ALBANY SHALE
Three Lick Bed
NEW ALBANY SHALE
BOYLE
LOWER
UPPER
LOWER
MISSISSIPPIAN
DEVONIAN
DEVONIAN
Feet
Meters
Vertical Scale
25
20
15
10
5
0
8
4
0

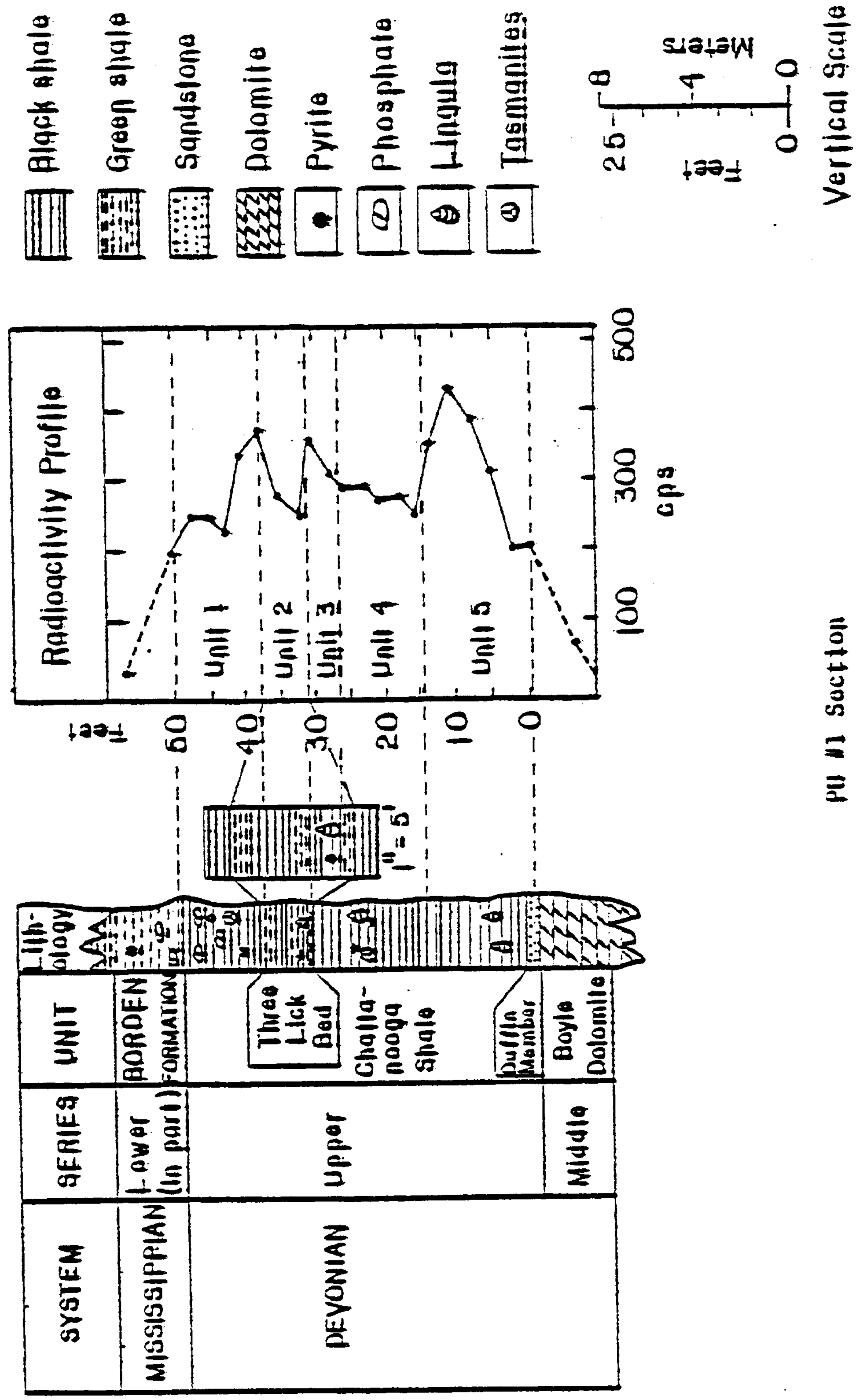
MA #2 Section

PULASKI COUNTY SECTION (PU #1)

This section contains the complete thickness of the Chatanooga shale and partial sections of both the Boyle Dolomite and the Borden Formation. The section is located 6.8 kilometers (4.2 miles) west of West Somerset along Ringgold Road in Pulaski County, Kentucky. The section is located on the Delmer Quadrangle (section 19-H-58, 2850' FSL X 2400' FEL), and the base of the Chattanooga Shale is 219.0 meters (718 feet) above sea level. The section was measured and described using Jacob's staff, Abney level and tape. Samples and radioactive readings were taken by Dennis Swager and John Goble on July 12, 1977.

	Thickness Meters	(Feet)
Borden Formation (incomplete):		
Nancy Shale Member (incomplete):		
(1) Shale, light greenish-gray (5 GY 6/1), silty; contains dissiminated pyrite and glauconite; contains reworked phosphate nodules near the base; contains geodes filled with quartz and hematite; contains abundent crinoidal debris; forms talus covered cliffs	5.5	(18.0)
Disconformity		
Chattanooga Shale:		
(2) Shale, brownish-black (5 YR 2/1), laminated with paper-thin silty layers; contains abundent pyrite nodules; contains phosphate nodules in upper 2.4 meters (8.0'); contains abundent <u>Tasmanites</u>; unit forms jointed ledges with "couplet weathering"; upper part of unit is covered and had to be trenched	4.2	(13.7)
Three Lick Bed:		
(3) Shale, brownish-black (5 YR 2/1) interbedded with 3 small greenish-gray mudstones; <u>Tasmanites</u> and abundent burrows at upper contacts; mudstones contain pyrite nodules and <u>Lingula</u> and are up to 0.1m (0.3')		

	Thickness Meters	(Feet)
thick; all contacts are sharp; unit forms a slight reentrant	0.8	(2.7)
(4) Shale, brownish-black (4 YR 2/1), laminated with silty layers at base (becomes less silty upward); contains pyrite nodules; contains abundant *Tasmanites* and rare *Lingula* fragments; forms cliffs with "couplet weathering"	9.7	(31.7)
Duffin Layer:		
(5) Sandstone, olive-black (5 Y 2/1), medium grained, well rounded; contains phosphate pebbles, pyrite nodules and chert pebbles; contains basal lag zone of fish plates and plant debris; forms reentrant	0.3	(1.0)
Total Chattanooga Shale	15.0	(49.1)
Disconformity		
Boyle Dolomite (incomplete):		
(6) Dolomite, olive-gray (5 Y 4/1); contains nodularly-bedded chert, and pyrite nodules; contains silicified brachiopod, bryozoan and crinoid debris; contains vugs filled with dolomite and calcite crystals; contains stylolites along bedding planes; forms sharp cliff	2.3	(7.6)
Thickness of Section	22.8	(74.7)


SYSTEM
SERIES
UNIT
Lith-ology
MISSISSIPPIAN
DEVONIAN
Lower (in part)
Upper
Middle
BORDEN FORMATION
Three Lick Bed
Chatta-nooga Shale
Duffin Member
Boyle Dolomite
1" = 5'
Feet
60
40
30
20
10
0
Radioactivity Profile
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
100
300
500
cps
Black shale
Green shale
Sandstone
Dolomite
Pyrite
Phosphate
Lingula
Tasmanites
25
Feet
0
8
4
0
Meters
Vertical Scale

PH #1 Section

CASEY COUNTY SECTION (CA #1)

This section contains the complete New Albany Shale and partial sections of both the Drakes Formation and the Borden Formation. The section is exposed on the west side of Kentucky Highway 127, 0.3 kilometers (0.2 miles) north of Liberty in Casey County, Kentucky. The section is on the Liberty Quadrangle (section 25-K-56, 500' FSL x 2250' FWL), and the base of the New Albany Shale is 259.6 meters (851 feet) above sea level. The section was measured using hand level and tape; radioactive profile taken with a scintillometer; and completely sampled on July 28, 1977 by Dennis Swager, John Goble, and Mike Miller.

	Thickness Meters	(Feet)
Borden Formation (incomplete):		
New Providence Shale Member (incomplete):		
(1) Shale, greenish-gray (5 GY 8/1), silty; laminated with glauconitic layers; covered with soil horizon; had to be trenched	1.5	(5+)
Disconformity		
New Albany Shale (complete):		
(2) Shale, brownish-black (5 YR 2/1), very fissile, laminated with silty layers; contains pyrite nodules; contains abundant, bored phosphate nodules; contains a quartz nodule (possibly a pseudomorph after anhydrite); forms a jointed cliff	2.8	(9.3)
(3) Shale, brownish-black (5 YR 2/1); same as unit 2; forms "couplet weathering"	0.8	(2.7)
Three Lick Bed:		
(4) Shale, brownish-black (5 YR 2/1); occurs in two beds interbedded with mudstone, olive gray (5 Y 4/1); occurs in three beds less than 0.03 m (0.1') thick;		

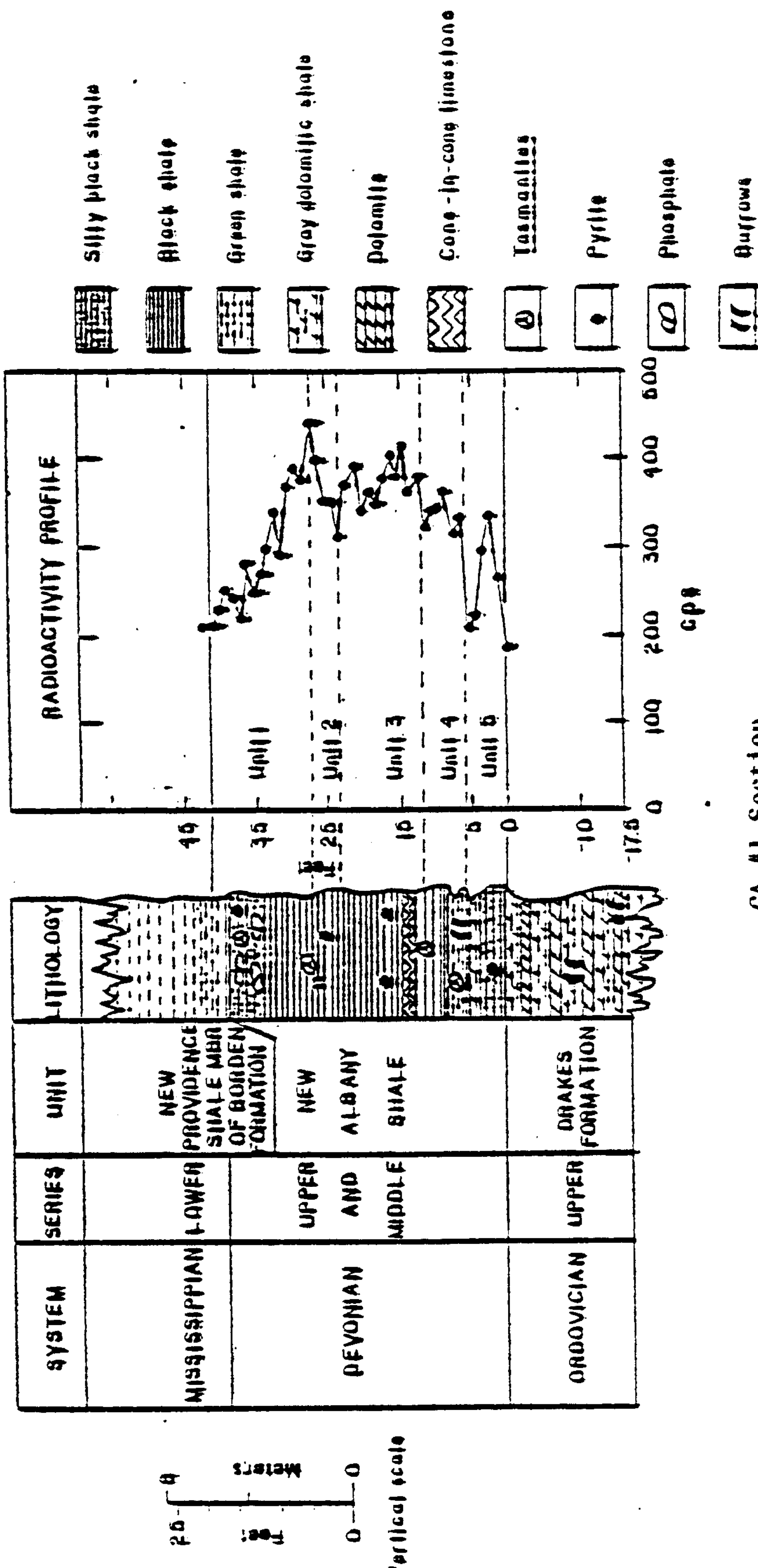
		Thickness Meters	(Feet)
	shale is burrowed at the upper contacts; mudstone is burrowed throughout; mottled in appearance; forms slight reentrant	0.8	(2.5)
(5)	Shale, brownish-black (5 YR 2/1); same as unit 3; contains one continuous cone-in-cone limestone bed 4 centimeters thick, 1.0 m (3.4') from base of unit	7.4	(24.4)
(6)	Mudstone, greenish-gray (5 GY 4/1); interbedded with shale, brownish-black (5 YR 2/1); Shale is fissile, silty contains abundant burrows and <u>Tasmanites</u>; beds are up to 15 cm thick; forms slight reentrant	0.4	(1.4)
(7)	Shale, medium gray (5 G 6/1), silty, dolomitic; contains pyrite nodules; contains fractures or veins filled with calcite . . .	0.2	(0.6)
(8)	Shale, brownish-black (5 YR 2/1), fissile, laminated with silty layers; contains basal lag zone of sandy, dolomitic, "punky," clayey material (possibly equivalent to the Kiddville layer) 0.1 m (0.3') thick; basal contact irregular; forms ledge	0.3	(1.1)
	Total New Albany Shale in section.	12.8	(42.0)

Unconformity

Drakes Formation (incomplete):

Preachersville Member (incomplete):

(9)	Shale, light greenish-gray (5 GY 8/1) interbedded with dolomite, olive-gray (N2); shale is dolomitic, irregularly bedded; dolomites are discontinuous stringers up to 0.2 m (0.8') thick, wavy bedded; forms jointed, steep, talus-covered cliff.	5.5	(18+)
	Total Thickness of section approximately . .	19.83	(65+)


RADIOACTIVITY PROFILE
cps
0
100
200
300
400
500
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
45
35
25
15
5
0
-10
-17.5
LITHOLOGY
UNIT
SERIES
SYSTEM
NEW PROVIDENCE SHALE MBR OF BORDEN FORMATION
NEW ALBANY SHALE
DRAKES FORMATION
LOWER
UPPER AND MIDDLE
UPPER
MISSISSIPPIAN
DEVONIAN
ORDOVICIAN
Silty black shale
Black shale
Green shale
Gray dolomitic shale
Dolomite
Cone-in-cone limestone
Tasmanites
Pyrite
Phosphate
Burrows
Vertical scale
Feet
Meters
25
8
0
0

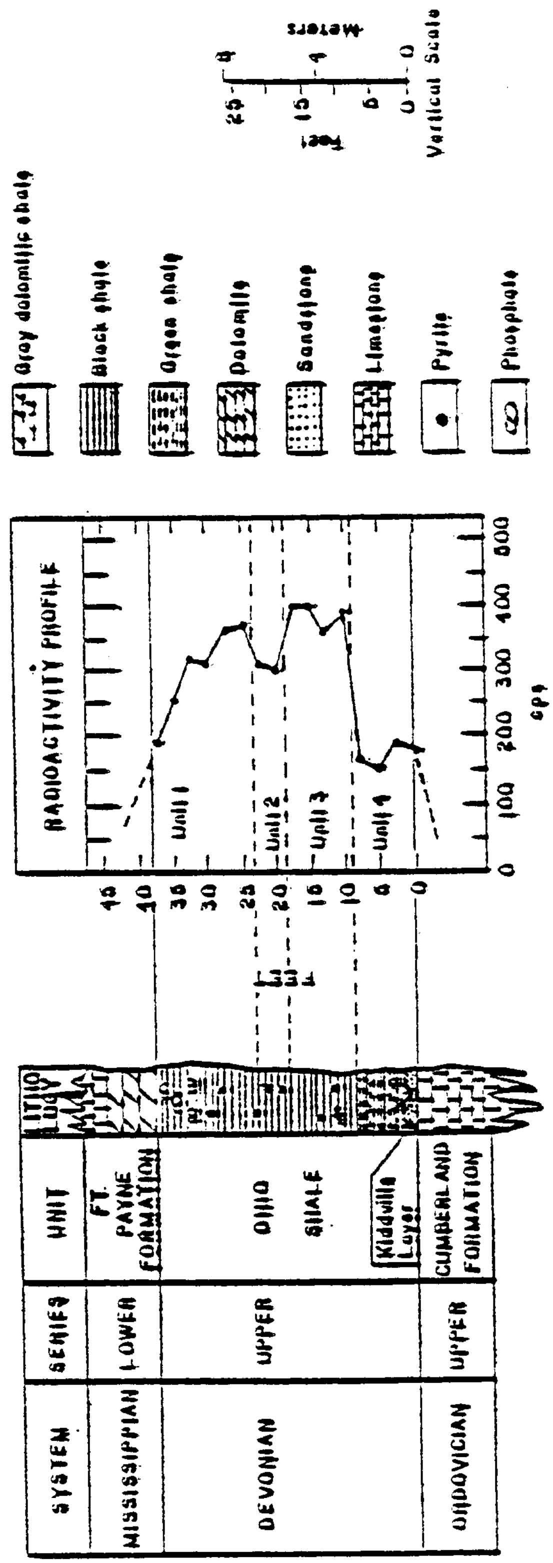
CA #1 Section

RUSSELL COUNTY SECTION (RU #1)

This section contains the complete Kiddville layer and Chattanooga Shale and partial sections of the Fort Payne Formation and Cumberland Formation. The section is exposed in a series of road cuts on the south side of Kentucky Highway 379, 3.4 kilometers (2.2 miles) west of Creelsboro in Russell County, Kentucky. The section is located on the Creelsboro Quadrangle (Section 15-E-52, 1900' FNL x 2225' FEL). The section was measured using hand levels and tape; radioactive profile taken with a scintillometer; and completely sampled by Dennis Swager and John Goble on July 5, 1977. The base of the Chattanooga Shale is 203.7 meters (668') above sea level.

	Thickness Meters	(Feet)
Fort Payne Formation (incomplete):		
(1) Shale, greenish-gray (5 YR 6/1), silty; contains silica filled geodes with doubly-terminated quartz crystals; contains phosphate nodules	1.5	(5)
Disconformity		
(note: Contact is clear, but green shale may be equivalent to the Maury Formation.)		
Chattanooga Shale (complete):		
(2) Shale, brownish-black (5 YR 2/1), fissile, laminated; contains pyrite nodules; contains large bored phosphate nodules; forms jointed, blocky ledges	2.6	(8.5)
Three Lick Bed:		
(3) Shale, brownish-black (5 YR 2/1) interbedded with shale, brownish-gray (5 YR 4/1); black shales are burrowed at the top and bottom; gray shales (equivalent to Three Lick Bed) are burrow mottled; forms a slight reentrant	0.4	(1.2)
(note: Only one of the Three Lick Beds was definitely identified.)		

(4)	Shale, brownish-black (5 YR 2/1); same as unit 2	0.7	(2.3)
(5)	Shale, brownish-black (5 YR 2/1); laminated with silty layers; contains bedded pyrite and pyrite nodules; contains a discontinuous detrital coal bed 0.03 meters (0.1') thick (3.1 meters (10') from the base of the section); forms blocky, jointed ledge	5.7	(18.7)
(6)	Shale, brownish-black (5 YR 2/1), silty, fissile; contains pyrite nodules; contains carbonized plant fragments; forms ledge	0.4	(1.3)
(7)	Mudstone, greenish-gray (5 GY 4/1); forms reentrant	0.1	(0.4)
(8)	Shale, brownish-black (5 YR 2/1); same as unit 6	0.1	(0.2)
(9)	Mudstone, greenish-gray (5 GY 4/1); same as unit 7; contains burrows and burrow mottling	0.1	(0.3)
(10)	Shale, brownish-black (5 YR 2/1); same as unit 6	0.3	(1.1)
(11)	Shale, grayish-orange (10 YR 7/4); forms a reentrant	0.1	(0.5)
(12)	Shale, brownish-black (5 YR 2/1); silty, fissile; contains pyrite nodules; contains coalified logs; contains a zone of pyritized burrows 0.8 m (2.5') above base of shale; forms jointed cliff	1.5	(5.0)
	Kiddville Layer:		
(13)	Sandstone, medium grained, well rounded; contains quartz pebble conglomerate near the base; contains phosphate nodules, glauconite pebbles and semibedded globular chert nodules; forms reentrant	0.3	(1.0)
	Total Chattanooga Shale	12.4	(40.5)
	Disconformity		
(14)	Dolomite, medium gray (N5), sandy; contains semibedded chert, quartz veins; weathers to a clayey residum; forms a ledge at very base of roadcut	1.22	(4.0)
	Approximate thickness of section	15.1	(49.5)


SYSTEM
SERIES
UNIT
LITHOLOGY
MISSISSIPPIAN
LOWER
FT. PAYNE FORMATION
DEVONIAN
UPPER
OHIO SHALE
Kiddville Layer
ORDOVICIAN
UPPER
CUMBERLAND FORMATION
FEET
45
40
35
30
25
20
15
10
5
0
RADIOACTIVITY PROFILE
Unit 1
Unit 2
Unit 3
Unit 4
0
100
200
300
400
500
cps
Gray dolomitic shale
Black shale
Green shale
Dolomite
Sandstone
Limestone
Pyrite
Phosphate
Burrows
Coal
Feet
25
15
5
0
Meters
8
4
0
Vertical Scale

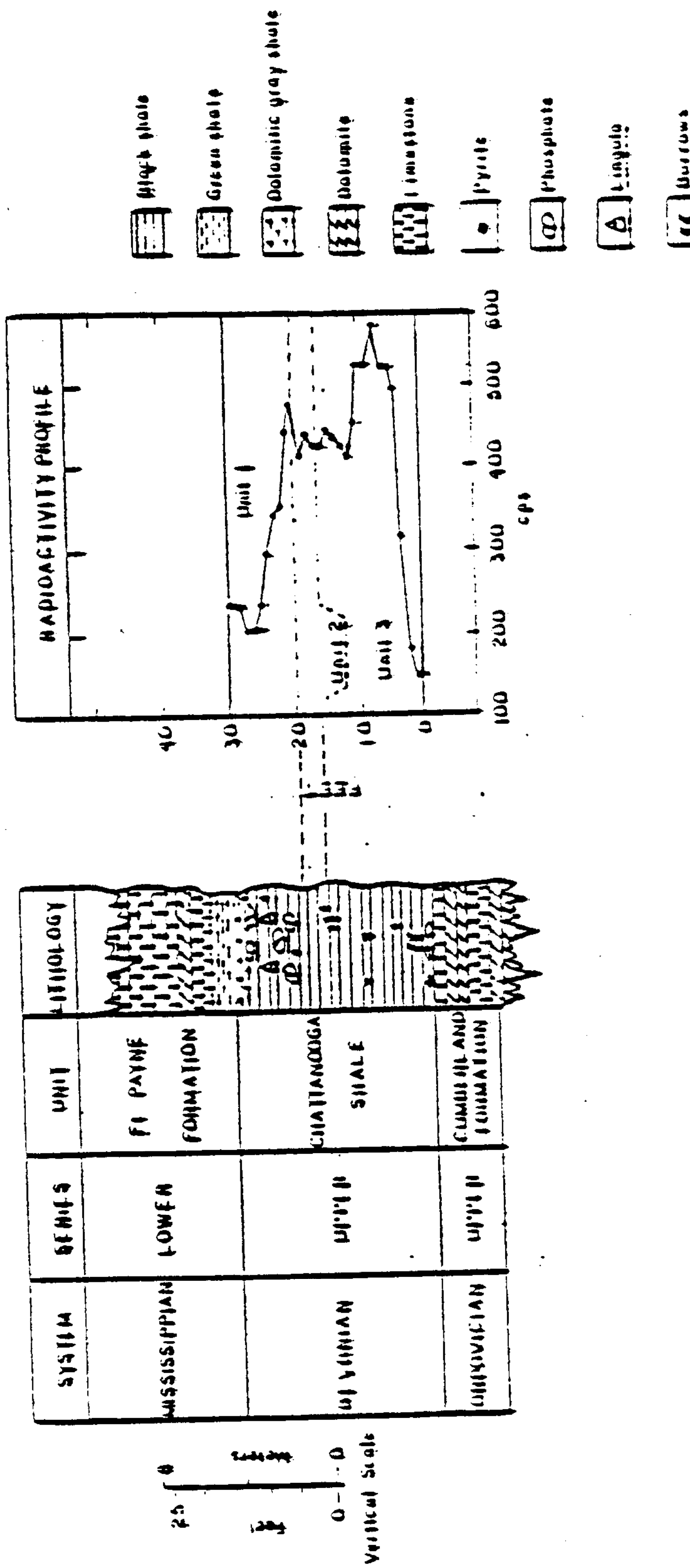
RU #1 Section

CUMBERLAND COUNTY SECTION (CU #1)

This section contains the complete Chattanooga Shale and partial sections of the Fort Payne Formation and the Cumberland Formation. The section is exposed on the north side of Kentucky Highway 90, 4.03 kilometers (2.5 miles) east of Burkesville in Cumberland County, Kentucky. The section is on the Burkesville Quadrangle (section 21-D-50, 1250' FNL x 1400' FWL), and the base of the Chattanooga Shale is 194.0 meters (636') above sea level. The section was described, measured and scintillometer readings gathered by Dennis Swager and John Goble on July 5, 1977.

Fort Payne Formation (incomplete):	Thickness Meters	(Feet)
(1) Shale, dark gray (N3), contains brachiopod and crinoid debris; by dolomite, medium gray (N5); contains quartz geodes; forms cliff at top of road cut	9.8	(32.3)
(2) Mudstone, greenish-gray (5 GY 4/1); contains possible reworked phosphate nodules; forms reentrant and had to be trenched	0.1	(0.2)
Disconformity		
Total Fort Payne in section.	9.9	32.5
(3) Shale, brownish-black (5 YR 2/1); contains pyrite nodules and phosphate nodules (0.1 - 0.2 m in length); contains abundant *Lingula* fragments; forms blocky, jointed cliff.	1.3	(4.3)
(4) Shale, brownish-black (5 YR 2/1); same as unit 3, but contains bedded pyrite; contains one of the Three Lick Beds: mudstone, olive gray (5 Y 4/1), burrow mottled; mudstone exists 5.5 m (17.9') above base of shale.	6.8	(22.2)
(5) Shale, brownish-black (5 YR 2/1); contains 40% pyritized burrows, coalified logs and woody fragments.	0.1	(0.1)

	Thickness Meters	(Feet)
(6) Shale, brownish-black (5 YR 2/1), fissile, silty; contains pyrite and marcasite nodules; contains a basal sandy lag zone 4-5 cm thick covered by 0.03 m (0.1') of mudstone; greenish-gray (5 GY 4/1).	0.6	(1.9)
Disconformity		
Total thickness of Chattanooga Shale . . .	8.7	(28.5)
(7) Dolomite and dolomitic limestone, very light gray (N7), fine grained, silty; contains dendritic weathering forms on bedding surfaces.	6.1+	(20+)
Total thickness of section	24.7	(81.0)


Green shale
Dolomitic gray shale
Dolomite
Pyrite
Phosphate
Burrows
RADIOACTIVITY PROFILE
Unit 1
Unit 2
Unit 3
100
200
300
400
500
600
cps
0
10
20
30
40
LITHOLOGY
UNIT
SERIES
SYSTEM
Ft PAYNE
FORMATION
CHATTANOOGA
SHALE
LOWER
MISSISSIPPIAN
Vertical Scale

CU #1 Section

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

APPENDIX B - DESCRIPTION OF OUTCROP SECTIONS ALONG THE PINE MOUNTAIN THRUST BELT OF EASTERN KENTUCKY

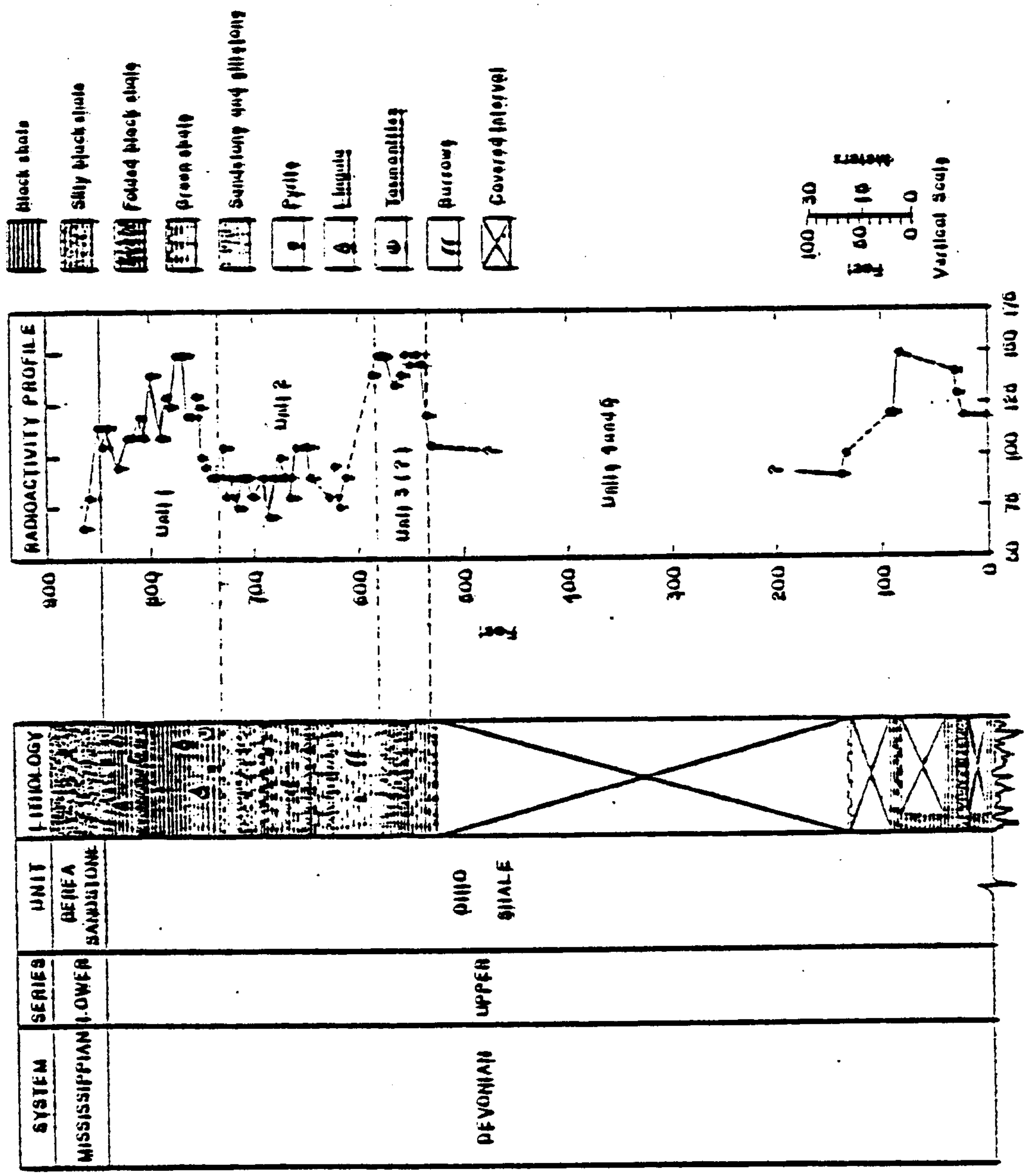
PIKE COUNTY SECTION (PK #1)

This section contains incomplete exposures of the Ohio Shale and Berea Sandstone along the access road to the Johnson Brothers Limestone Quarry. The quarry is located just off of Kentucky Highway 197, 8.5 kilometers (5.3 miles) south of Elkhorn City in Pike County, Kentucky. The section is located on the Hellier Quadrangle (section 25-T-86, 875' FNL x 1000' FEL). The section is exposed along the Pine Mountain Thrust Fault, and the base of the section is in contact with Pennsylvanian sandstones and shale. The section was measured using Abney level, Jacob's staff, tape and Brunton compass. Samples and scintillometer readings were taken at regular intervals by Dennis Swager, Mike Miller and Catherine Swager on December 18, 1977. Much of the lower section was covered by talus and recent slide material.

	Thickness Meters	(Feet)
Berea Sandstone (incomplete):		
(1) Siltstone, medium gray (N5), massive bedding (beds are up to 1.0 m (3.2') thick); contains some small green shale partings; shale is silty and makes up about 5% of total; unit weathers to a dark yellowish-orange (10 YR 6/6); forms a cliff made up of large blocks.	7.6	(25.0)
Disconformity		
Ohio Shale (incomplete):		
(2) Shale, brownish-black (5 YR 2/1) to grayish-black (N2), very fissile, laminated with silty layers; contains pyrite nodules; contains Lingula and Tasmanites; parts of unit are talus covered; forms iron-stained ledges.	10.7	(35.0)

		Thickness Meters	(Feet)
(3)	Shale, brownish-black (5 YR 2/1); same as unit 2; beds are folded, faulted and contorted.	2.1	(7.0)
(4)	Shale, brownish-black (5 YR 2/1), fissile, laminated with silty layers; contains pyrite nodules; contains Lingula in upper part of unit; Tasmanites present near base; contains some tectonically disturbed bedding; forms resistant ledges.	20.4	(67.0)
(5)	Shale, brownish-black (5 YR 2/1) interbedded with medium gray (N6) mudstone; shale is silty, fissile; contains pyrite nodules and horizontal burrows; mudstone is moldable, burrowed and contains pyrite nodules; unit forms slight talus-covered reentrant.	45.8	(150.0)
(6)	Shale, olive-black (5 Y 2/2), fissile, silty; contains plant fragments; beds are fractured; forms ledges.	9.8	(32.0)
(7)	Mudstone, greenish-gray (5 GY 6/1) interbedded with brownish-black (5 YR 2/1) shale; mudstone makes up 80% of unit, is fractured and jointed; shale beds are less than 0.3 m (1.0') thick; shale is fissile, silty; unit forms reentrant with black shales forming resistant beds.	6.9	(22.5)
(8)	Covered interval within Ohio Shale.	119.6	(392.0)
(9)	Mudstone, greenish-gray (5 GY 6/1); same as mudstone in unit 7.	2.1	(7.0)
(10)	Covered interval within Ohio Shale.	10.7	(35.0)
(11)	Mudstone, greenish-gray (5 GY 6/1) interbedded with black (N1) shale; mudstone makes up about 60% of total unit; black shale is fissile, fractured; contains Tasmanites; unit forms a reentrant.	3.7	(12.0)
(12)	Covered interval within the Ohio Shale.	13.7	(45.0)

		Thickness Meters	(Feet)
(13)	Shale, brownish-black (5 YR 2/1), fissile; rich in organics, highly fractured; has petroliferous odor; forms small ledge.	7.6	(25.0)
(14)	Covered interval within the Ohio Shale.	4.6	(15.0)
(15)	Shale, brownish-black (5 YR 2/1); same as unit 13; contains Tasmanites.	1.5	(5.0)
	Thickness of Ohio Shale	259.2	(849.5)
	Thickness of Section	266.8	(874.5)


Black shale
Silty black shale
Folded black shale
Green shale
Sandstone and siltstone
Pyrite
Lingula
Tasmanites
Burrows
Covered interval
Feet
Meters
Vertical Scale
RADIOACTIVITY PROFILE
Unit 1
Unit 2
Unit 3 (?)
Units 4 and 5
cps
Feet
LITHOLOGY
UNIT
SERIES
SYSTEM
BEREA SANDSTONE
OHIO SHALE
LOWER
UPPER
MISSISSIPPIAN
DEVONIAN

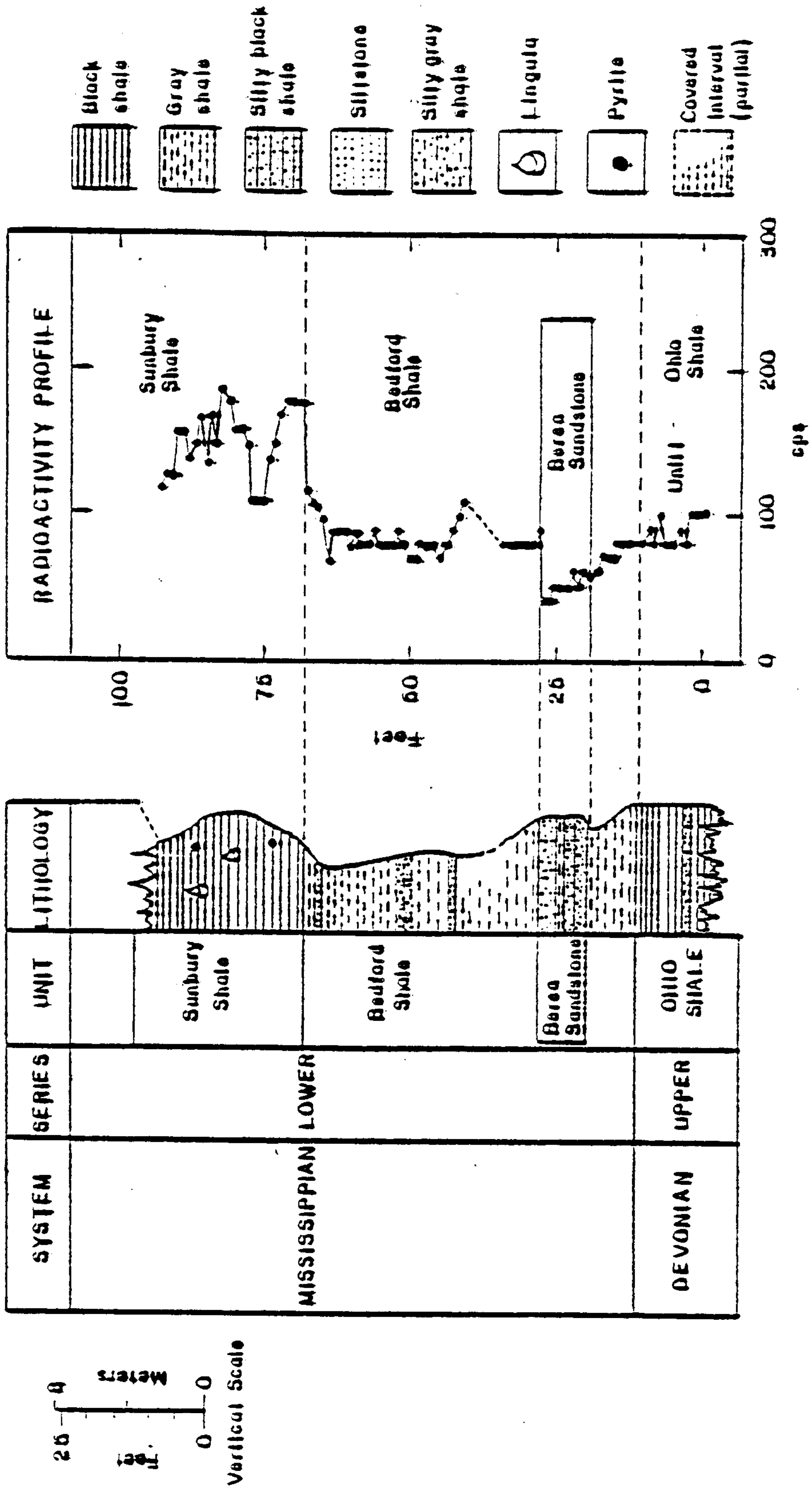
PK #1 Section

LETCHER COUNTY SECTION (LT #1)

This section contains the complete Bedford-Berea sequence and partial sections of the Ohio Shale and Sunbury Shale. The section is located in a road cut about 4 kilometers (2.5 miles) west of Cumberland in Letcher County, Kentucky, along highway 160. The section is on the Louellen Quadrangle (section 2-F-78, 2750' FSL x 850' FEL). The top of the Ohio Shale is 463.6 meters (1520 feet) above sea level. A brief description was taken along with a radioactive profile on April 15, 1978 by Frank R. Ettensohn and Dennis Swager.

	Thickness Meters	(Feet)
Sunbury Shale (incomplete):		
(1) Shale, brownish-black (5 YR 2/1) to black (N1), silty; contains abundant <u>Lingula</u> and <u>Orbiculoidea</u> brachiopods; forms cliff and talus covered slope.	7.3	(24.0)
(note: The top of the Sunbury is covered, but the thickness here is very close to the total thickness of the Formation).		
Bedford Shale:		
(2) Shale, dark greenish-gray (5 GY 4/1), silty; contains some small siltstone beds in upper 6.1 m (20'); contact with the Sunbury had to be trenched; forms steep talus covered slope.	8.6	(28.0)
(3) Covered interval within the Bedford Shale.	2.14	(7.0)
(4) Shale, dark greenish-gray (5 GY 4/1); same as unit 2, but without siltstone beds	2.14	(7.0)

	Thickness Meters	(Feet)
Berea Sandstone:		
(5) Sandstone and siltstone, light brown (5 YR 5/6); wavy bedding; forms a prominent ledge.	2.5	(8.0)
(note: The Berea seems to be pinching out within the Bedford shale. It is possible that some of the siltstone beds in the upper Bedford are Berea equivalents.)		
Bedford Shale (continued):		
(6) Shale, dark greenish-gray (5 GY 4/1) same as unit 4	2.5	(8.0)
Total Bedford Shale.	15.4	(50.0)
Ohio Shale (incomplete):		
(7) Shale, brownish-black (5 YR 2/1), silty, fissile; contains phosphate nodules and pyrite nodules; contains some folded and faulted beds; forms a cliff with suggestion of "couplet weathering."	3.7	(12.0+)
Approximate thickness of section	28.9	(94.0)


Black shale
Gray shale
Silty black shale
Siltstone
Silty gray shale
Lingula
Pyrite
Covered interval (partial)
RADIOACTIVITY PROFILE
Sunbury Shale
Bedford Shale
Berea Sandstone
Unit I
Ohio Shale
0
100
200
300
cps
100
75
50
25
0
Feet
LITHOLOGY
UNIT
SERIES
SYSTEM
Sunbury Shale
Bedford Shale
Berea Sandstone
OHIO SHALE
LOWER
UPPER
MISSISSIPPIAN
DEVONIAN
25
Feet
0
8
Meters
0
Vertical Scale

LT #1 Section

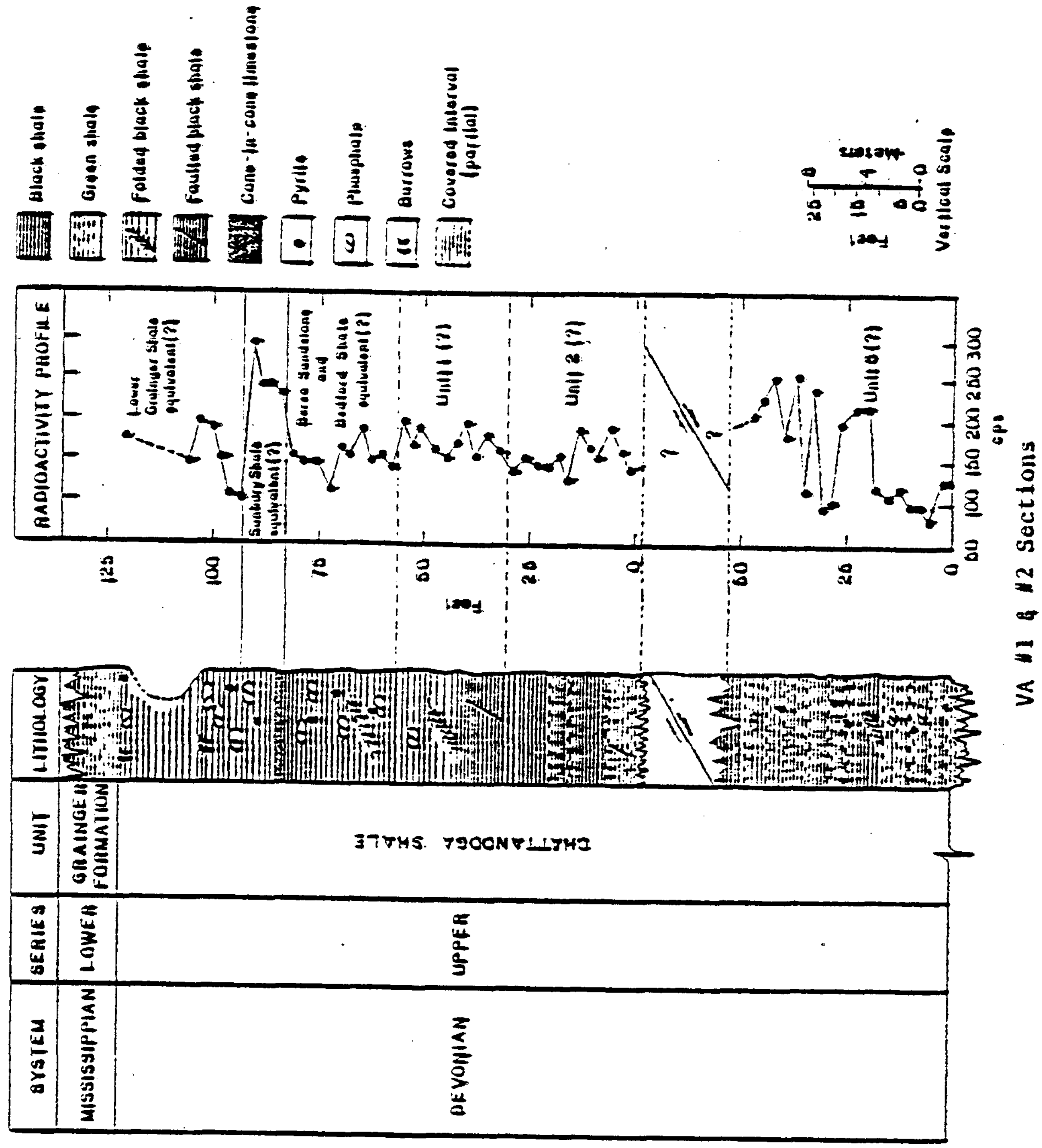
CUMBERLAND GAP SECTION (VA #1 and VA #2)

These sections contain partial exposures of the Chattanooga Shale and the Grainger Formation. The base of section VA #1 is in a road-cut on the east side of Highway 25E about 1.6 kilometers (1.0 miles) south of the Kentucky - Virginia line near Cumberland Gap in Lee County, Virginia. The section is located on the Middlesboro South Quadrangle (section 16-B-71, 400' FSL x 1500' FWL). The section was measured using Abney level, Jacob's staff, tape and Brunton compass. The section was measured, sampled and scintillometer readings taken by Dennis Swager and Mike Miller on December 17, 1977. The single exposure of the Chattanooga Shale is broken down into two separate sections because there is a fault of unknown dispacement or relative motion located about 15.3 meters (50 feet) from the base of section VA #1.

	Thickness Meters	(Feet)
Grainger Formation (incomplete):		
(1) Shale, greenish-gray (5 YR 6/1) to dark greenish-gray (5 YR 4/1); contains siderite nodules; forms talus covered slope.	18.3	(50.0)
(2) Shale, brownish-black (5 YR 2/1), very fissile, laminated with silty layers, contains abundant elliptical phosphate nodules; shale is folded, fractured, faulted and distorted; contains slicken-sides; contains horizontal burrows; beds are dipping from 11° - 16° from horizontal; forms jointed cliff.	0.7	(2.4)
(3) Covered interval within the Chattanooga Shale.	4.6	(15.0)
(4) Shale, brownish-black (5 YR 2/1); same as unit 2; contains pyrite nodules; contains a cone-in-cone limestone bed 10.7 m (35') from base of unit.	16.6	(54.4)

		Thickness Meters	(Feet)
(5)	Shale, brownish-black (5 YR 2/1), fissile, paper-thin laminae; fractured and faulted; forms a talus covered slope with some resistant ledges.	7.4	(24.3)
(6)	Shale, brownish-black (5 YR 2/1) interbedded with three greenish-gray (5 GY 6/1) mudstones; shale beds are 1.5 m (5.0') thick and mudstone beds are less than 0.5 m (1.5') thick; shale is same as unit 5; mudstones contain pyrite nodules and are fractured; forms cliff with 3 reentrants.	5.9	(19.4)
(7)	Claystone, greenish-gray (5 GY 6/1); contains pyrite nodules; unit is fractured and dips 10° from horizontal; forms a reentrant and had to be trenched.	0.4	(1.3)
(8)	Shale, brownish-black (5 YR 2/1), very fissile, faulted and fractured; contains slickensides; contains a small fault with 0.8 m (2.5') of offset; forms a resistant ledge.	1.0	(3.3)
(9)	Claystone greenish-gray (5 GY 6/1); same as unit 7.	0.7	(2.2)
	Thickness of Chattanooga Shale in VA #2	37.3	(122.4)
(1a)	Shale, brownish-black, fissile, laminated with silty layers; folded and crenulated beds; contains slickensides; dips at 8° from the horizontal; upper part of unit is covered and faulted with unknown displacement.	4.6	(15.0)
(2a)	Interbedded shale and mudstone; shale makes up 40% of total unit; shale beds are up to 1.1 m (3.5') thick; beds are dipping at about 3° from horizontal.	4.9	(16.0)
(3a)	Shale, brownish-black (5 YR 2/1) interbedded with greenish-gray mudstone; shale makes up about 20% of total unit; shale contains pyrite nodules; is fractured with slickensides present; forms reentrant; dipping between 5° and 6° from horizontal.	2.6	(8.5)

	Thickness Meters	(Feet)
(4a) Shale, brownish-black (5 YR 2/1); same as unit 1a; bedding is dipping from 8° to 17° from horizontal.	1.1	(3.5)
(5a) Mudstone, greenish-gray (5 GY 6/1) interbedded with brownish-black (5 YR 2/1) shale; same as unit 3a; beds are dipping at 17° from horizontal.	5.2	(17.0)
Thickness of Chattanooga Shale in VA #1	18.4	(60.0)
Thickness of Chattanooga Shale in total exposure.	55.7	(182.4)
Thickness of total exposure.	71.0	(232.4)



VA #1 & #2 Sections

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

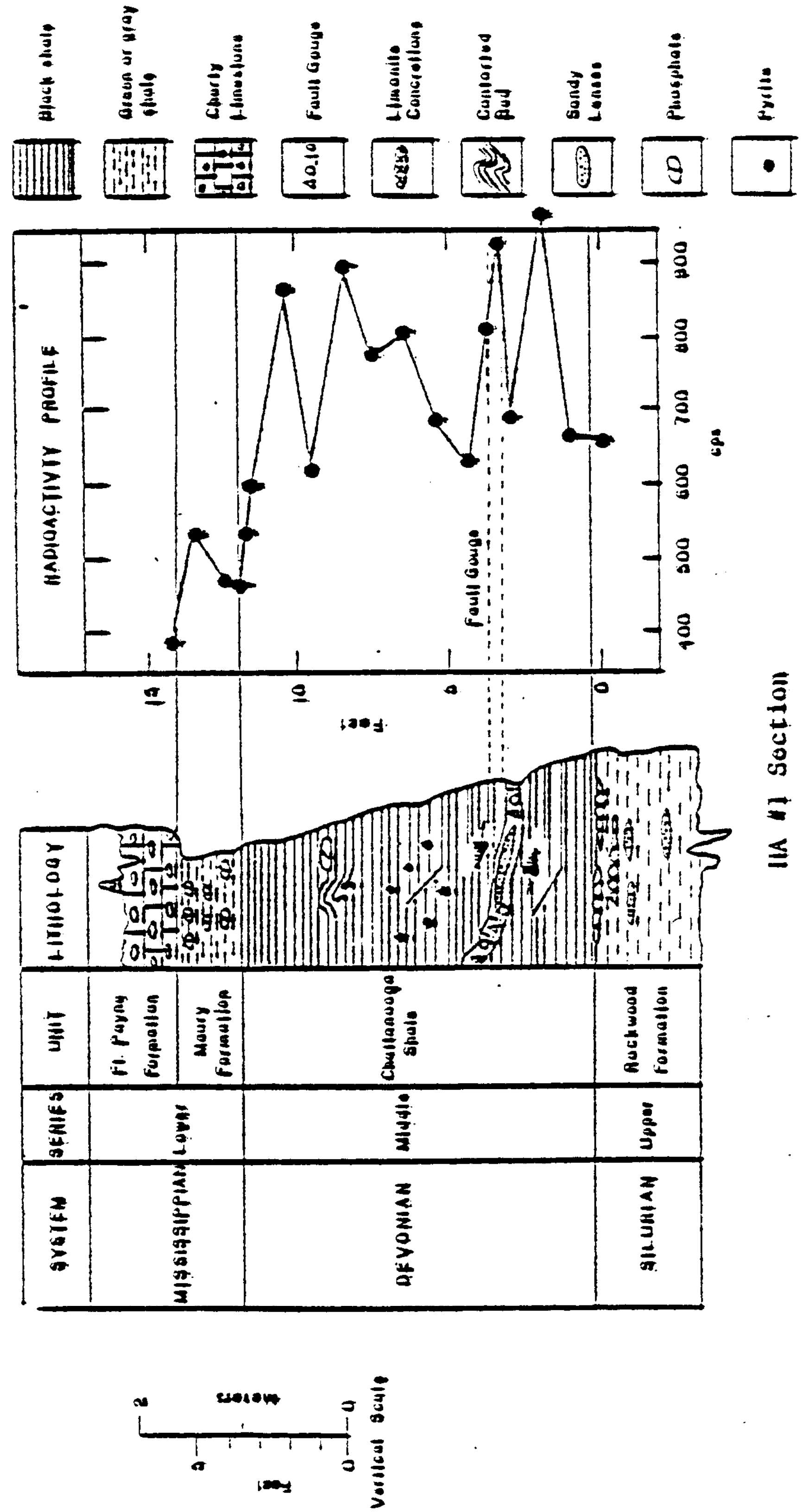
APPENDIX C - DESCRIPTION OF REFERENCE SECTIONS OF TENNESSEE OUTCROP

HAMILTON COUNTY, TENNESSEE SECTION (HA #1)

This section, the type locality of the Chattanooga Shale, is on the side of Cameron Hill in Chattanooga, Hamilton County, Tennessee. The section is on the Chattanooga Quadrangle (section 15-18S-52E, 300' FNL x 850' FEL). Sampling and measurements completed on April 7, 1978. Measurements by Roy Kepferle and description by Frank Ettensohn, Roy Kepferle, Ed N. Wilson and J. Zafar.

	Thickness Meters	(Feet)
Fort Payne Formation (incomplete):		
(1) Limestone, olive gray (5 Y 4/1), fine grained, dense, argillaceous; thin, irregularly bedded; bedded and nodular chert common throughout; disconformably overlies Maury Formation	1.5+	(5.0+)
Maury Formation:		
(2) Shale, greenish-gray (5 GY 6/1), irregularly laminated to massive claystone, silty; upper 0.1 m (0.3') contains quartz geodes (< 0.03 m) and lensoid masses of grayish-green (10 G 4/2) glauconitic clays; underlying parts of shale contain four irregular horizons of platy, cylindrical and nodular phosphate concretions; upper surface weathered to yellowish-orange (10 YR 6/6) color	0.6	(1.9)
(3) Shale, brownish-gray (5 YR 4/1), laminated, silty, silty; contains burrow mottling (?)	0.1	(0.3)
Total Maury Formation	0.7	(2.2)
Chattanooga Shale:		
(4) Shale, light brownish-gray (5 YR 6/1) to grayish black (N2); upper surfaces irregular; mottled due to weathering; upper surfaces weather to a dark yellow-orange (10 YR 6/6) color.	0.1	(0.2)

	Thickness Meters	(Feet)
(5) Shale, brownish-black (5 YR 2/1) to grayish-black (N2), silty; shattered, fractured and slickensided throughout; laminae are contorted and faulted; dull earthy luster except on slip planes which have a hard brilliant luster; rare phosphate nodules; small marcasite nodules common which weather, leaving voids on outcrop surface.	2.3	(7.7)
(6) Fault gouge, moderate yellowish-brown (10 YR 5/4), dusky yellowish brown (10 YR 2/2), and dark yellowish-orange (10 YR 6/6); brecciated, oxidized and weathered shale along a small thrust fault; contains irregular boudins of clayey, yellowish-gray (5 Y 7/1) sandstone	0.2	(0.7)
(7) Shale, brownish-black (5 YR 2/1) to grayish-black (N2), silty; shattered, fractured and slickensided throughout; laminae faulted; dull earthy luster except along slip planes which have hard brilliant luster; basal 0.03 m (0.1') is hard and indurated, contains color mottling and concretionary, bedded limonite masses; disconformably lies on Rockwood Formation	0.9	(3.0)
Total thickness of Chattanooga Shale. . .	3.5	(11.6)
Rockwood Formation:		
(8) Shale and claystone, greenish-gray (5 GY 4/1), light green (5 G 7/4) and dark red (5 R 2/6); contains thin siltstone stringers; uppermost 0.2 m (0.5') contains bedded limonitic concretionary masses; has irregular surface; weathers to a dark yellowish-orange (10 YR 6/6)	1.5	(5.0+)
Approximate thickness of section.	7.3	(23.8)



IIA #1 Section

DEKALB COUNTY, TENNESSEE SECTION (DE #1)

This section contains the standard reference sections of the Gassaway and Dowelltown Members of the Chattanooga Shale. It is exposed in a road cut along the east approach to Sligo Bridge on Tennessee State Route 26, 11.3 kilometers (7 miles) east of Smithville in De-Kalb County, Tennessee. The section is located on the Sligo Bridge Quadrangle (section 8-7S-46E 11,600' FNL x 11,800' FWL). The section was measured and described by Frank R. Ettensohn and Dennis Swager on April 13, 1978.

	Thickness Meters	(Feet)
Fort Payne Formation (incomplete):		
(1) Limestone, olive gray (5 Y 4/1), finegrained, dense, argillaceous; thin, irregularly bedded; bedded and nodular chert common throughout.	3.1+	(10.0+)
Maury Formation:		
(2) Shale, medium bluish-gray (5 B 5/1) to greenish-gray (5 GY 6/1), laminated, silty; contains four horizons of phosphate nodules which occur as balls, discs and plates; third horizon contains reworked, elongate forms; <u>Lingula</u> abundant.	0.6	(2.0)
(3) Sandstone lag, olive black (5 Y 2/1) to olive gray (5 Y 4/1), poorly sorted, argillaceous, pyritic; contains reworked, randomly-oriented phosphate nodules; unconformably overlies an irregular surface on the Chattanooga Shale	0.1	(0.3)
Total Maury Formation	0.1	(2.3)

Chattanooga Shale:

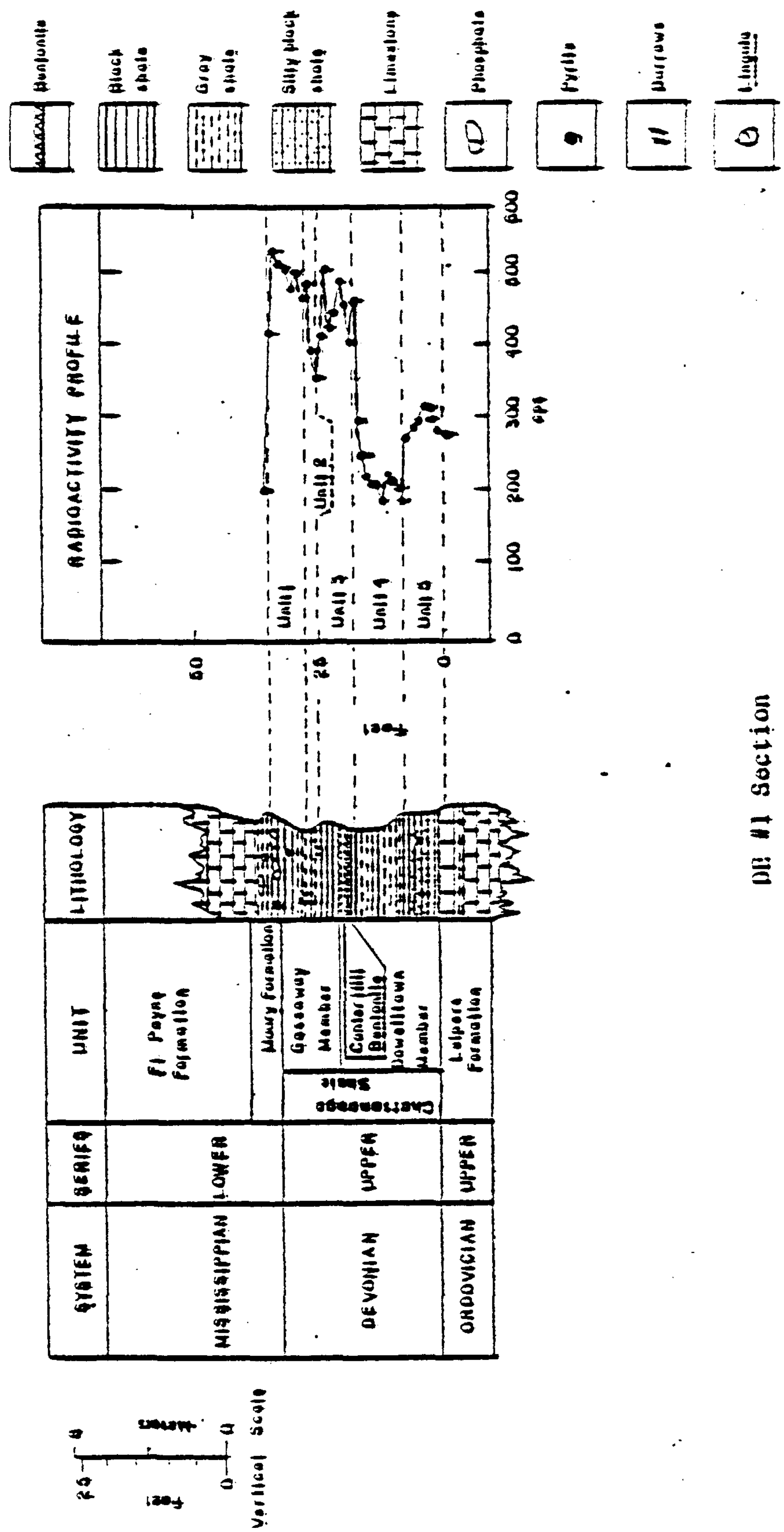
Gassaway Member:

(4) Shale, grayish-black (N2), massive, silty; contains paper-thin brownish-gray silty

		Thickness Meters	(Feet)
	partings; scattered phosphate and pyrite nodules and thin lenses of marcasite; rare coalified, woody fragments; upper surface marked by irregular coating of glauconitic clay.	2.1	(6.9)
(5)	Shale, interbedded olive gray (5 Y 4/1) and grayish-black (N2), silty; gray shale interbeds range from 0.1 m (0.2') to 0.1 m (0.3') thick; gray shales show some burrow mottling; weathers rubbly.	0.7	(2.2)
(6)	Siltstone, light brown (5 YR 5/6), laminated and interbedded with shale, grayish-black (N2), silty; black shales are burrowed and the siltstone is stained with hematite and liesegangs.	0.1	(0.2)
(7)	Shale, grayish-black (N2), silty, massive	0.5	(1.6)
(8)	Shale, interbedded olive-gray (5 Y 4/1) and grayish-black (N2), silty; burrow-mottling; weathers rubbly.	0.1	(0.3)
(9)	Shale, grayish-black (N2), silty, massive; contains paper-thin, brownish-gray (5 YR 4/1) silty laminae; contains a few thin layers of olive gray (5 Y 4/1) shale at the base.	1.7	(5.5)
	Total Gassaway Member	5.1	(16.7)
	Dowelltown Member:		
(10)	Shale, interbedded olive gray (5 Y 4/1) and grayish-black (N2), silty	0.2	(0.6)
(11)	Bentonite (Center Hill), light brownish-gray (5 YR 6/1) silty; contains abundant crystalline material, mica flakes; pyritic, burrowed; possible *Lingula*; weathers with a prominent white (N9) to pale orange (10 YR 8/4) color.	0.1	(0.2)

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978

		Thickness Meters	(Feet)
(12)	Shale, interbedded medium bluish-gray (5 B 5/1) and olive-black (5 Y 2/1), silty; burrow mottled; small marcasite nodules; plant fragments in gray shale; contains prominent dark yellowish orange (10 YR 6/6) silty, limonitic horizon 5 cm thick at 2.8 m (9.2') above base.	3.4	(11.0)
(13)	Shale, grayish-black (N2), silty, massive to laminated; rare pyrite nodules; rare paper-thin brownish-gray (5 YR 4/1) silty laminae; at the unconformably overlying irregular surface on the Leipers Formation, occurs a thin, medium gray (N5) laminated, sandy lag zone < 0.04 m thick	2.1	(7.0)
	Total Dowelltown Member	5.7	(18.8)
	Total Chattanooga Shale	10.3	(35.5)
	Leipers Formation		
(14)	Limestone, brownish-black (5 YR 2/1) at top to bluish-gray (5 B 7/1), silty, argillaceous; contains shale interbeds; burrowed.	1.5+	(5.0+)
	Approximate thickness of section.	16.2	(53.0)


Bentonite
Black shale
Gray shale
Silty black shale
Limestone
Phosphate
Pyrite
Burrows
Lingula
RADIOACTIVITY PROFILE
0
100
200
300
400
500
600
cps
Unit 1
Unit 2
Unit 3
Unit 4
Unit 5
50
25
0
Feet
LITHOLOGY
UNIT
Ft. Payne Formation
Maury Formation
Gassaway Member
Center Hill Bentonite
Dowelltown Member
Chattanooga Shale
Leipers Formation
SERIES
LOWER
UPPER
UPPER
SYSTEM
MISSISSIPPIAN
DEVONIAN
ORDOVICIAN
Vertical Scale

DH #1 Section

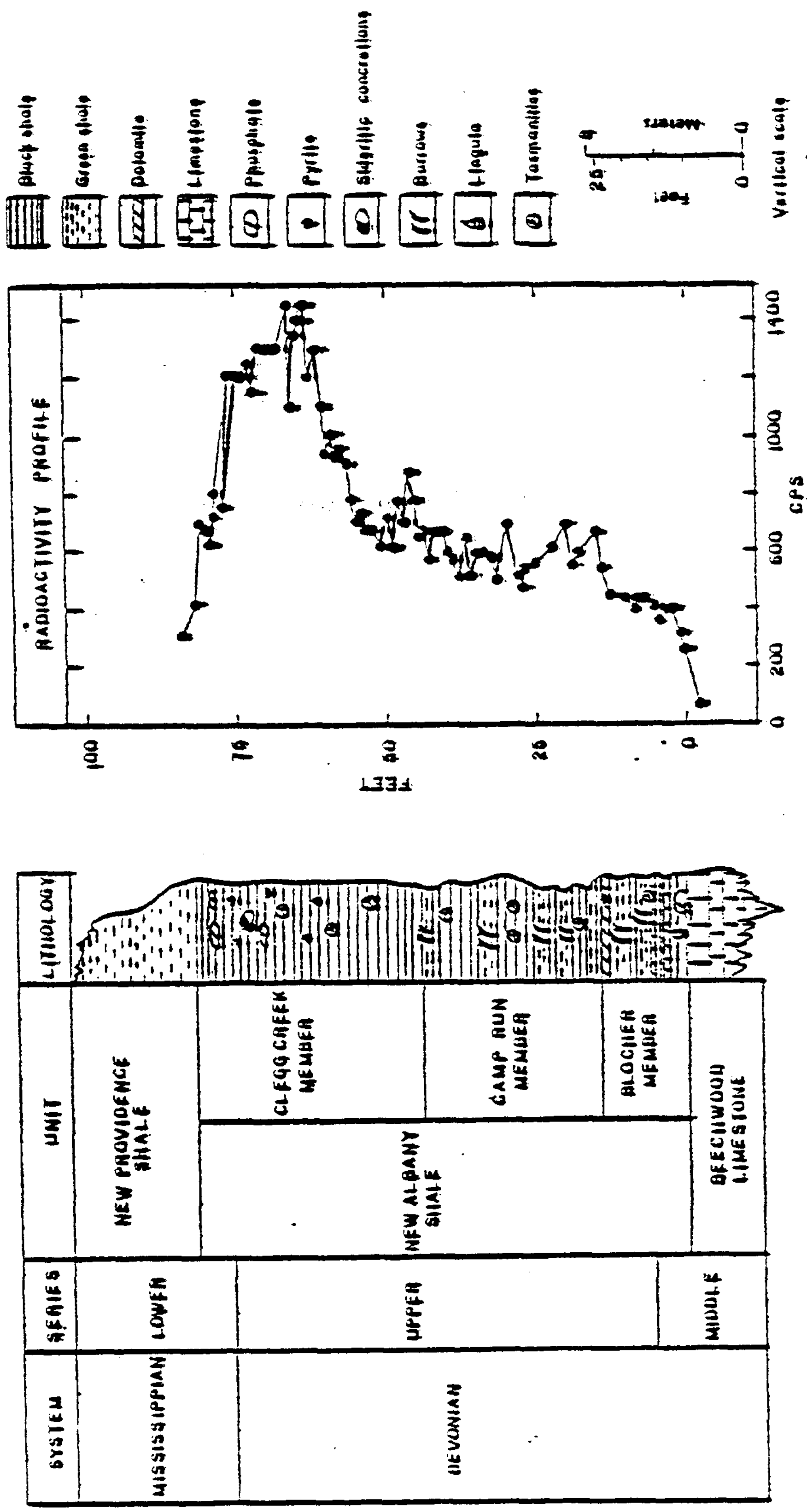
BULLITT COUNTY SECTION (BU #1)

This exposure contains the complete New Albany Shale and partial sections of the Beechwood Member of the Sellersburg Limestone and the New Providence Shale. The base of the section is exposed in the bed of Slate Run Creek at the Sugar Tree picnic area of Bernheim Forest. It is on the Shepherdsville Quadrangle (section 4-Q-47 3000' FSL x 1300' FWL). The elevation at the base of the New Albany Shale is 169.3 meters (555 feet) above sea level. The section was measured using Abney level, Jacob's staff and scintillometer on June 5 and July 13, 1978 by Frank Ettensohn, Dennis Swager, Mike Miller and Don Chesnut. Samples were collected, and radioactive readings were recorded on the traverse up the creek bed.

	Thickness Meters	(feet)
Borden Formation (incomplete):		
New Providence Shale Member (incomplete):		
(1) Shale, olive gray (5 Y 4/1) to greenish-gray (5 GY 6/1); contains glauconite, phosphate and siderite nodules; shale is clayey; contains some crinoidal debris; unit forms a low-angle slope	6.1	(20 +)
New Albany Shale (complete):		
(2) Shale, brownish-black (5 Y 2/1), fissile, laminated with silty layers; contains ameboid-shaped phosphate nodules, large carbonate-rich septarian nodules and pyrite nodules; contains dissimenated pyrite throughout; unit forms resistant outcrop and large bedding-plane surfaces are exposed in creek bed.	11.3	(37.0)
(Note: Unit 2 is probably equivalent to the Clegg Creek Member of New Albany Shale)		
(3) Shale, dusky-brown (5 YR 2/2) to dusky yellowish-brown (10 YR 2/2) interbedded with claystone, greenish-gray (5 GY 6/1); claystone beds are less than 0.3 m (1.0') thick and occur between 7.6 m (25') and 4.6 m (15.0') from the base of section;		

	Thickness Meters	(feet)
claystone contains horizontal burrows; unit forms a cliff with "couplet-type" weathering.	9.2	(30.0)
(Note:. Parts of Unit 3 are probably equivalent to the Three Lick Bed of Ohio Shale)		
(4) Shale, brownish-gray (5 YR 4/1) to brownish-black (5 YR 2/1) interbedded with claystone, greenish-gray (5 GY 6/1) and dolomitic shales, dark greenish-gray (5 G 4/1); shale contains abundant <u>Tasmanites</u> and rare <u>Lingula</u>; claystone and dolomitic shales contain horizontal and vertical burrows; thin lag zone at base of section contains phosphate nodules and quartz sand.	4.6	(15.0)
Total New Albany Shale	25.1	(82.0)
Unconformity		
Sellersburg Limestone (incomplete):		
Beechwood Member (incomplete):		
(5) Limestone, light gray (N7), fine-grained, thin, irregular bedded; contains phosphate nodules near the top; contains abundant crinoidal debris; upper surface is very irregular; contact with overlying lag zone is sharp; unit weathers to large slabs	1.5	(5.0)
Total Thickness of Section BU #1.	32.7	(107.0)

UGR File #29
Dennis Ray Swager
Univ. of Kentucky, 1978



BU #1 Section

UGR File #29
Dennis Ray Swager
Univ. of Kentucky
1978

BIBLIOGRAPHY

Alvord, D. C., 1971, Geologic map of the Hillier Quadrangle, Kentucky-Virginia and part of the Clintwood Quadrangle, Pike County, Kentucky. U.S. Geol. Survey Map GQ-950.

Avila, John, 1976, Devonian shale as a source of gas in natural gas from unconventional sources: National Research Council, Washington, D.C., p. 73-85.

Breger, I. A. and A. Brown, 1963, Distribution and types of organic in a barred marine basin, New York Acad. Sci. Trans., v. 25, p. 741-755.

Byers, C. W., 1977, Biofacies patterns in euxinic basins: A general model, S.E.P.M. special pub., No. 25, p. 5-17.

Campbell, Guy, 1946, New Albany Shale, G.S.A. Bull., v. 57, p. 826-908.

Cattermole, J. M., 1963, Geologic map of the Burkesville Quadrangle, Kentucky, U.S. Geol Survey Map GQ-220.

Conant, L. C., 1956, Environment of accumulation of the Chattanooga Shale, U.S. Geol. Survey Prof. Paper 300, p. 463-467.

Conant, L. C. and W. E. Swanson, 1961, Chattanooga Shale and related rocks of central Tennssee and nearby areas, U.S. Geol. Survey Prof. Paper 357, 91 p.

Cooper, C. L., 1948, Kinderhook micropaleontology: in Weller, J. M. ed., Symposium on Problems of Mississippian Stratigraphy and Correlation, Jour. Geol., v. 56, p. 353-366.

deWitt, W., Jr., 1951, Stratigraphy of the Berea Sandstone and the associated rocks in northeastern Ohio and northwestern Pennsylvanian, G.S.A. Bull., v. 62, p. 1347-1370.

deWitt, W., Jr., 1970, Age of the Bedford Shale, Berea Sandstone and Sunbury Shale in the Appalachian and Michigan Basins, Pennsylvania, Ohio and Michigan, G.S.A. Bull., 1294-G, 11 p.

Englund, K. J., 1964, Geology of the Middlesboro South Quadrangle, Tennessee-Kentucky-Virginia, U.S. Geol. Survey Map GQ-301.

Ettensohn, F. R., L. P. Fulton and R. C. Kepferle, 1978, Use of the scintillometer and gamma-ray logs for correlation form the sursurface to the surface in black shale: in First Eastern Gas Shales Symposium, Preprints sponsered by Morgantown Energy Research Center, ERDA, Morgantown, W.Va., p. 520-533.

Froelich, A. J., 1973, Geologic map of the Louellen Quadrangle, southeastern Kentucky, U.S. Geol. Survey Map GQ-1060.

Greene, R. C., 1968, Geologic Map of the Panola Quadrangle, Estill and Madison Counties, Kentucky, U.S. Geol. Survey Map GQ-686.

Griffith, C., 1977, Stratigraphy and Paleoenvironment of the New Albany Shale (Upper Devonian) in north-central Kentucky, University of Wisconsin-Madison, Master's Thesis (unpub.), 214 p.

Harvey, R. D., W. A. White, R. M. Eluff, J. K. Frost, and P. B. DuMontelle, 1977, Petrology of the New Albany Shale Group (Upper Devonian and Kinderhookian) in the Illinois Basin, a preliminary report, in First Eastern Gas Shales Symposium Preprints sponsored by Morgantown Energy Research Center, ERDA, Morgantown, W.Va., p. 239-265.

Hass, W. H., 1947, Conodont zones in the Upper Devonian and Lower Mississippian formations of Ohio, Jour. Paleotology, v. 21, p. 131-141.

Hass, W. H., 1956, Age and correlation of the Chattanooga Shale and the Maury Formation, U.S. Geol. Survey Prof. Paper 286, 47 p.

Heckel, P. H., 1977, Origin of phosphatic black shale facies in Pennsylvanian cyclotherms of mid-continent North America, A.A.P.G. Bull., v. 61, No. 7, p. 1945-1068.

Hoover, K. V., 1960, Devonian-Mississippian Shale sequence in Ohio, Ohio Geol. Survey., Infor. Circular No. 27, 154 p.

Hoskins, J. H. and A. T. Cross, 1951, The structure and classification of four plants from the New Albany Shale, Am. Midland Naturalist, v. 46, p. 684-716.

Huddle, J. W., 1933, Marine fossils from the top of the New Albany Shale in Indiana, Amer. Jour. Sci. (5), v. 25, p. 303-314.

Huddle, J. W., 1934, Conodonts from the New Albany Shale of Indiana, Amer. Paleontology Bull., v. 21, No. 72, p. 1-136.

Kepferle, R. C., 1968, Geologic Map of the Sheperdsville Quadrangle, Bullitt County, Kentucky, U.S. Geol. Survey Map GQ-740.

Keyes, C. R., 1938, Age of the Chattanooga Black Shales, Pan-American Geol., v. 70, p. 364-366.

Lewis, R. Q., Sr., 1971, Geologic Map of the Delmer Quadrangle, Pulaski County, Kentucky, U.S. Geol. Survey Map GQ-909.

Lewis, T. L. and J. F. Schwietering, 1971, The distribution of the Cleveland Shale in Ohio, G.S.A. Bull., v. 82, p. 3477-3482.

Lineback, J. A., 1968, Subdivisions and depositional environments of the New Albany Shale (Devonian-Mississippian) in Indiana, A.A.P.G. Bull., v. 52, p. 1291-1303.

Lineback, J. A., 1970, Stratigraphy of the New Albany Shale in Indiana, Ind. Geol. Survey Bull. 44, 73 p.

McDowell, R. C., 1975, Geologic map of the Farmers Quadrangle, east-central Kentucky, U.S. Geol. Survey Map GQ-1236.

McFarlan, A. C. and W. H. White, 1952, Boyle-Duffin-Ohio Shale relationships, Kentucky Geol. Survey Bull. 10, p. 1-24.

Miller, R. L., 1965, Geologic Map of the Big Stone Gap Quadrangle, Virginia, U.S. Geol. Survey Map GQ-424.

Morris, R. H., 1965, Geologic Map of the Burtonville Quadrangle, Kentucky, U.S. Geol. Survey Map GQ-396.

Morris, R. H. and K. L. Pierce, 1967, Geologic Map of the Vanceburg Quadrangle, Kentucky-Ohio, U.S. Geol. Survey Map GQ-598.

Newberry, J. S., 1870, Report on the progress of the Geological Survey of Ohio in 1869, pt. 1. p. 3-53.

Patchen, D. G. and R. E. Larese, 1976, Stratigraphy and Petrology of the Devonian "Brown" shale in West Virginia, in Devonian Shale Production and Potential, editor Schumaker, MERC/SP-7612.

Peck, J. H., 1967, Geologic Map of the Tollesboro Quadrangle, Lewis and Fleming Counties, Kentucky, U.S. Geol. Survey Map GQ-661.

Provo, L. J., 1977, Stratigraphy and sedimentology of the radioactive Devonian-Mississippian shales of the central Appalachian Basin, University of Cincinnat, Ph.D. dissertation (unpub.), 177 p.

Provo, L. J., R. C. Kepferle and P. E. Potter, 1977, Three Lick Bed: Useful stratigraphic maker in the Upper Devonian Shale in eastern Kentucky, U.S.D.E.D.A., Morgantown Research Center, Rept. of Inv. MERC/RI-77/1, 58 p.

Read, C. B., 1936, The flora of the New Albany Shale (pt. 1), U.S. Geol. Survey Prof. Paper 186-E, p. 149-161.

Read, C. B., 1937, The flora of the New Albany Shale (pt. 2), U.S. Geol. Survey Prof. Paper 186-E, p. 81-104.

Rich, J. L., 1951, Probable fondo origin of the Marcellus-Ohio-New Albany-Chattanooga bituminous shale, A.A.P.G. Bull., v. 35, p. 2017-2040.

Rock-color chart Committee, 1948, (rev. ed., 1963), Rock Color Chart: National Research Council, distributor.

Savage, T. E., 1930, On the age of the New Albany Shale, Science, v. 71, p. 537.

Schopf, J. M. and J. F. Schwietering, 1970, The Foerstia Zone of the Ohio and Chattanooga Shales, G.S.A. Bull, 1294-H.

Schwietering, J. F. and D. W. Neal, 1978, Occurrence of Foerstia (Protosalvinia) in Lincoln County, West Virginia, Geology, v. 6, p. 493-494.

Simmons, G. C., 1967, Geologic Map of the Clay City Quadrangle, Powell and Estill Counties, Kentucky, U.S. Geol. Survey Map GQ-663.

Stockdale, P. B., 1939, Lower Mississippian rocks of the east-central interior. G.S.A., Spec. Pub. 22, 248 p.

Strom, K. M., 1939, Land-locked waters and the deposition of black muds, in Trask, P. D., ed., Recent Marine Sediments, Am. Ass. Petro. Geol. p. 356-372.

Swanson, V. E., 1956, Uranium in Marine black shales of the United States, U.S. Geol. Survey Prof. Paper 300, p. 451-456.

Swartz, J. H., 1925, The age and stratigraphy of the Chattanooga Shale in northeastern Tennessee and Virginia, Am. Jour. Sci., v. 17, p. 431-438.

Taylor, A. R. and R. Q. Lewis, Sr., 1971, Geologic Map of the Liberty Quadrangle, Casey County, Kentucky, U.S. Geol. Survey Map GQ-946.

Thaden, R. E. and R. Q. Lewis, Sr., 1963, Geologic of the Creelsboro Quadrangle, Kentucky, U.S. Geol. Survey Map GQ-204.

Theissen, R., 1925, Microscopic examination of Kentucky oil shales in Oil Shales of Kentucky, Kentucky Geol. Survey, Geol. Report, v. 21, Ser. 6, p. 1-48.

Twenhofel, W. H., 1939, Environments of origin of black shales, Am. Ass. Petro. Geol. Bull., v. 23, p. 1178-1198.

Weir, G. W., 1967, Geologic Map of the Berea Quadrangle, east-central Kentucky, U.S. Geol. Survey Map GQ-649.

Weir, G. W., 1976, Geologic Mpa of the Means Quadrangle, east-central Kentucky, U.S. Geol. Survey Map GQ-1324.

White, D. and T. Stadnichenko, 1923, Some mother plants of petroleum in Devonian black shales, Econ. Geol., v. 18, No. 3, p. 238-252.

Whitehead, N. H., 1978, Lithostratigraphy, depositonal environments and conodont biostratigraphy of the Muldraugh Formation (Mississippian) in southern Indiana and north-central Kentucky, Southeastern Geology, v. 19, No. 2, p. 83-109.

Winslow, M. R., 1962, Pant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio, U.S. Geol. Survey Prof. Paper 364, 93 p.

UGR File #29
Dennis Ray Swager
Univ. Of Kentucky
1978

VITA

The author was born on June 25, 1954 in Richland County, Illinois. He attended Henderson County High School in Henderson, Kentucky from 1968 to 1972. After graduation he attended the Henderson Community College and was awarded an Associate of Science Degree in 1974. He then transferred to the University of Kentucky in Lexington and recieved a Bachelor's of Science Degree in Geology in 1977. In August of 1976, he enrolled in the Graduate School at the University of Kentucky where he recieved a Master's Degree in Geology.

Mr. Swager was the co-recipient of the 1976 W. A. Tarr award from the Chi Chapter of Sigma Gamma Epsilon at the Geology Department of the University of Kentucky. An abstract co-authored by Mr. Swager was accepted by the Geological Society of America at their southeastern sectional meeting in 1978, and was published by the Society.

Dennis Ray Swager