

# **FIELD TRIP**

**Devonian and Carboniferous Shales  
of Eastern Kentucky**

**September 27, 1997**

**Start & End:  
Hyatt Regency Hotel  
Lexington, Kentucky**

## ROAD LOG

The field trip departs from the Hyatt-Regency Hotel in Lexington at 8:00 AM; the road log begins at the junction of I-75 and I-64 on the east side of the city.

### Mileage

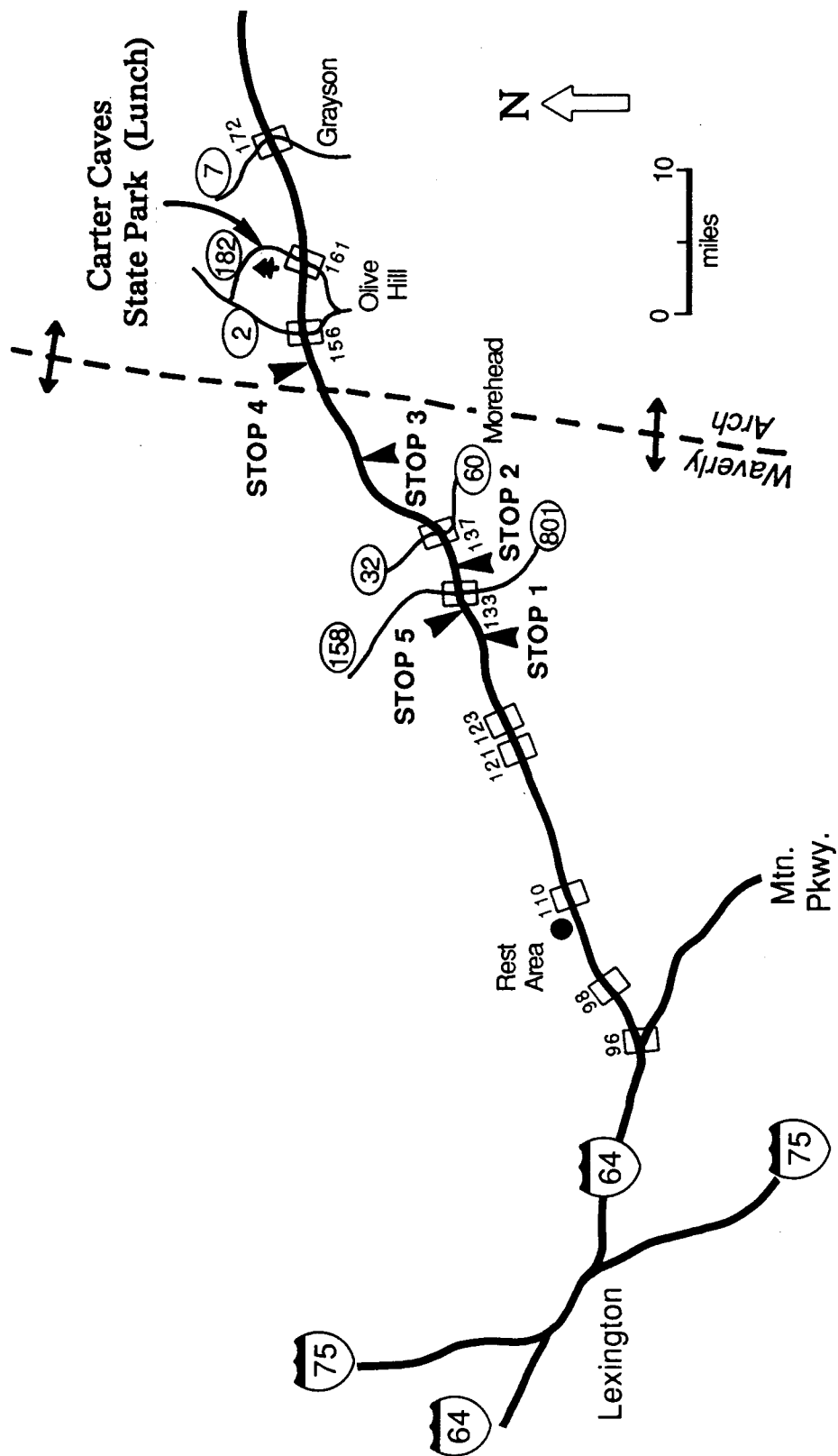
- |           |   |
|-----------|---|
| 0.0       | I-64 diverges from I-75, proceed eastward towards Winchester and Morehead.  |
| 0.8       | Milepost 82   |
| 16.4      | Exit 98 to Mountain Parkway; continue on I-64 east.   |
| 31.6      | Exit 113 (Mt. Sterling).  |
| 33-35     | Exposures of Ordovician Grant Lake Limestone (rubbly) and overlying Bull Fork Formation (planar bedded).  |
| 35.2      | Ordovician-Silurian contact. Gray shales of the Preachersville Member of the Drakes Formation are overlain by rusty limestones of the Brassfield Formation. The Brassfield along Rose Run in this area contains some thin beds of oolitic hematite that supported a small iron industry from 1892 to 1914 (McDowell, 1976).                                   |
| 40.5      | Exit 121 (Owingsville). The remains of the Bourbon or Slate Creek Furnace, the oldest iron furnace west of the Alleghenies, are found just to the south on Ky Rte 36 (McDowell and Weir, 1977). This furnace processed limonitic ore from the Devonian Boyle Dolomite. This ore source was exhausted by 1894 and may have been replaced by the Rose Run ores. |
| 48.7      | Cross Licking River. Milepost 129.  |
| 50.0      | Overpass.   |
| 50.2      | <b>STOP 1. Devonian Black Shales of the Huron Member of the Ohio Shale.</b>   |
| 51.0-51.1 | Well-displayed cyclic bedding in the Huron Member.  |
| 51.7-52.0 | Three-lick Bed and overlying Cleveland Member are well displayed on the north side of the roadway. We will stop at this locality on our way back to Lexington in the afternoon.   |
| 52.4      | Exit 133 (Sharkey). Excellent exposures of the Sunbury Shale and the Henley (shale) and Farmers (turbidite siltstones) of the Borden Formation. The   |

Bedford Shale is also exposed at the base of the outcrop. This exposure will be Stop 5 in the afternoon.

- 53.9 Farmers Member turbidites pass upwards into shales of the Nancy Member of the Borden.
- 54.3 Contact of the Farmer's-Henley with the Sunbury Shale.
- 55.3 **STOP 2. Mississippian Sideritic Gray Shales of the Nancy Member of the Borden Formation.**
- 56.8 **EXIT 137.** Turn south towards Morehead. Stop for coffee.
- 57.8 Reenter I-64 eastbound.
- 64.5 Milepost 144. The shales of the Nancy Member are followed by shallower-water siltstones of the Cowbell Member of the Borden Formation (all Mississippian).
- 65.8 Farther up the delta slope, the Cowbell passes into the Nada Member, which contains shallow water red and green shales. Above the Nada are limestones of the Slade Formation.
- 66.6 Well-developed redbeds showing well-oxygenated conditions at the top of the delta mass.
- 66.8 Exposures of Upper Mississippian carbonates. This group of rocks is designated as the Slade Formation by Ettensohn (1992) and corresponds to the undifferentiated Newman Limestone of the USGS quadrangles for eastern Kentucky. Please see Ettensohn (1992) for detailed descriptions of this part of the section along I-64.
- 67.9 Good outcrops of the carbonate section at weigh station.
- 69.1 **STOP 3. Cyclic Deposits (Tidalites?) of the Pennsylvanian Breathitt Formation.**
- 71.8 Breathitt Formation lies directly on eroded Borden Formation, so the entire Upper Mississippian section is missing here. We will re-encounter the Mississippian carbonates on the east limb of the Waverly Arch.
- 72.9 Good exposures of typical sand-shale lithologies of the Breathitt. At this position we are close to the crest of the Waverly Arch.
- 74.7 Milepost 154.

- 75.3 Exposures of sideritic black shales of the Breathitt Formation. We will examine the equivalent outcrops on the north side of the roadway this afternoon.
- 76.7 Exit 156 (Vanceburg and Olive Hill). Note the reappearance of the carbonate section from here eastwards.
- 82.1 **EXIT 161.** Turn left under the interstate and proceed east on US 60 towards Carter Caves State Park.
- 83.5 **LEFT ONTO KY RTE 182.**
- 83.8 Cliffs in Carter Caves Sandstone, an upper Mississippian sand unit thought to represent a N-S oriented tidal channel (Ettensohn, 1981).
- 84.2 More sandstone outcrop, this time the Grayson sandstone member of the Breathitt.
- 85.4 Grayson sandstone disconformably overlying green shales of the Mississippian Paragon Formation that in turn overlie Carter Caves Sandstone.
- 86.0 Cross-bedded Mississippian limestone (Warix Run Member of the Slade Formation).
- 86.4 **LEFT INTO CARTER CAVES STATE PARK.**
- 88.3 Park Lodge, **LUNCH.** See McGrain (1966) for a description of the caves.
- 90.2 Leave park, rejoin Ky Rte 182, turn south (right) towards I-64.
- 92.9 Intersect U.S. 60, turn right towards I-64.
- 94.4 Enter I-64 westbound.
- 99.8 Exit 156 (Olive Hill).
- 101.0 **STOP 4. Pennsylvanian Sideritic Black Shales of the Breathitt Formation.**
- 103.9 Milepost 152.
- 107.2 Pennsylvanian cycles of stop 3.
- 109.8 Last Mississippian carbonate exposure.
- 118.5 Exit 137 (Morehead)

- 120.9 Nancy Member exposures.
- 123.2 **EXIT 133.** Proceed across the road at the top of the overpass and onto the entrance ramp to I-64 westbound.
- 123.8 **STOP 5. Borden gray shale, Sunbury black shale, Henley gray shale, and Farmers siltstone turbidites.**
- 124.1 **STOP 5a. Three-lick bed and Cleveland Member of Ohio Shale.**
- 126.5 Milepost 130.
- 148.8 Rest Area.
- 176.2 Return to I-64 -- I-75 join.



## **INTRODUCTION - Devonian and Carboniferous Shales of Eastern Kentucky**

The I-64 highway has excellent exposures of a number of types of shales characteristic of the Devonian-Carboniferous. We will take advantage of these exposures to examine the nature of those shales that have been influenced by low-oxygen conditions. The transect will reveal a large scale cyclic alternation of black and gray shales, that, on closer examination breaks down into finer and finer and more and more complex cyclicity. We will also be able to see certain interbedded lithologies, particularly prodelta siltstone turbidites, that represent the proximal equivalents of these shales.

Figure i shows the overall stratigraphy of the area. Notice that most of the time is taken up in Mississippian carbonates, whereas most of the rock thickness is in the Devonian Ohio shale and the Mississippian Borden Formation. The Chesterian section is strongly eroded beneath the basal Pennsylvanian unconformity in this area.

A clue to the types of shales we will be seeing is color. Figure ii shows one interpretation of the environmental significance of shale colors. Note that there are 3 types of gray shales -- pyritic, sideritic, and glauconitic, and 2 types of black shales -- one dominated by pyrite, one by siderite. On the outcrop scales, it is the combination of diagenetic mineralogy and color that enables one to assign a shale to an environment, not one factor alone.

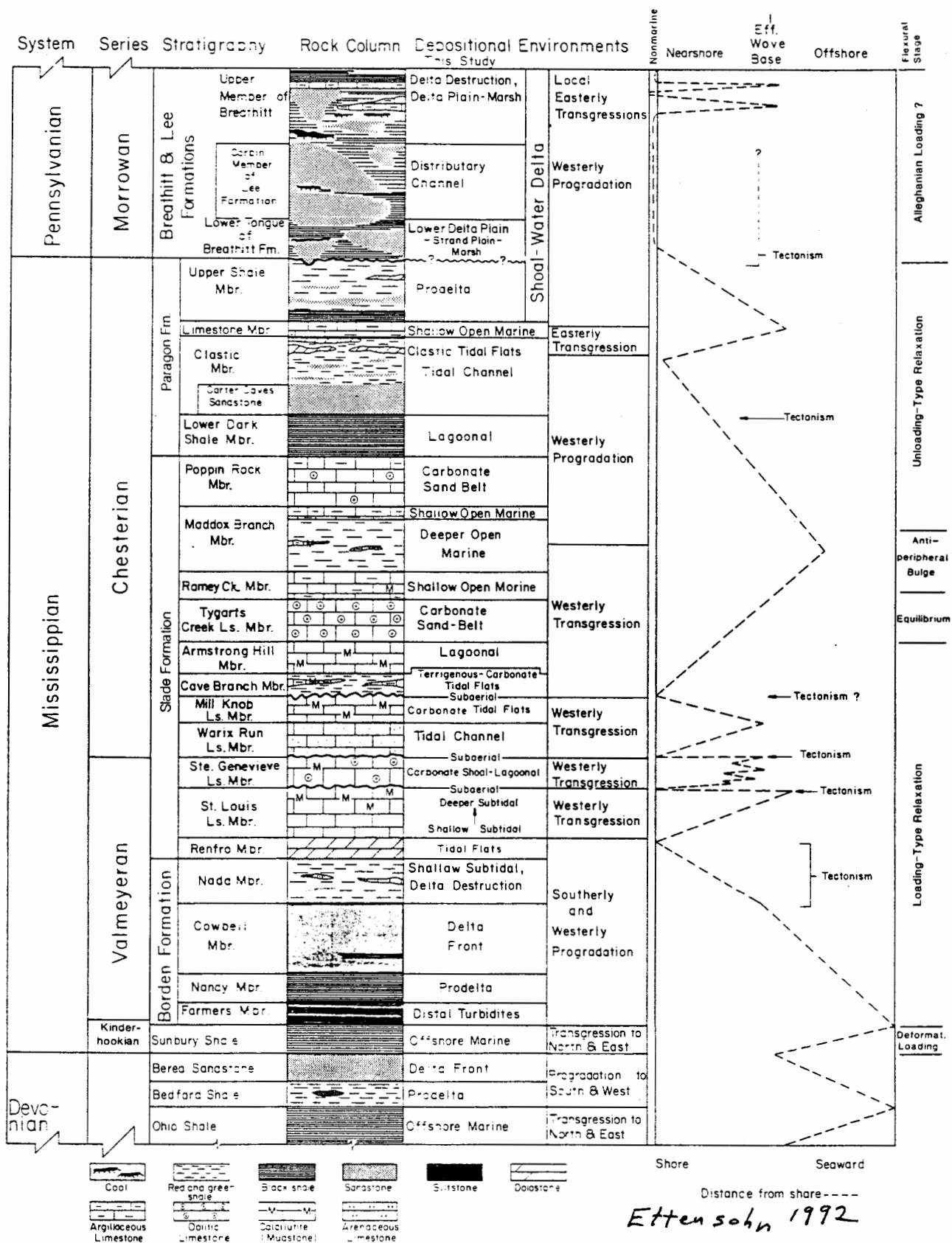
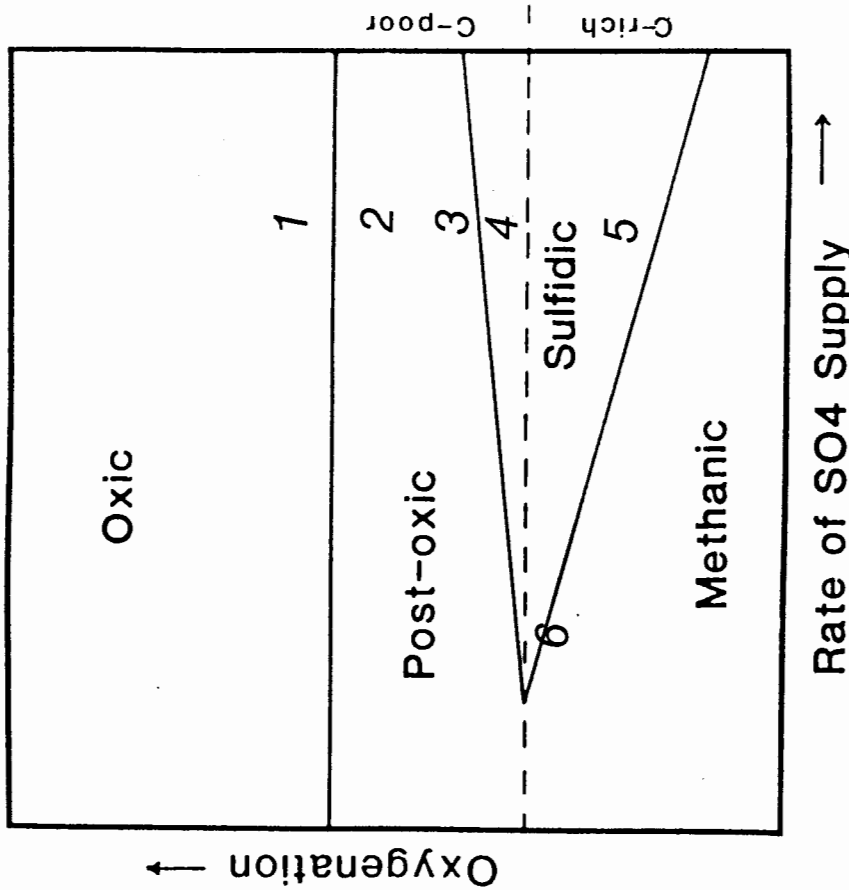


Figure i. Stratigraphy of the Devonian-Carboniferous section exposed along I-64 east of Lexington, with Etnensohn's inferred flexural stages.

Dominant Diagenetic Process of Organic Matter Decomposition



Diagenetic Products: Fe Minerals and Shale Colors

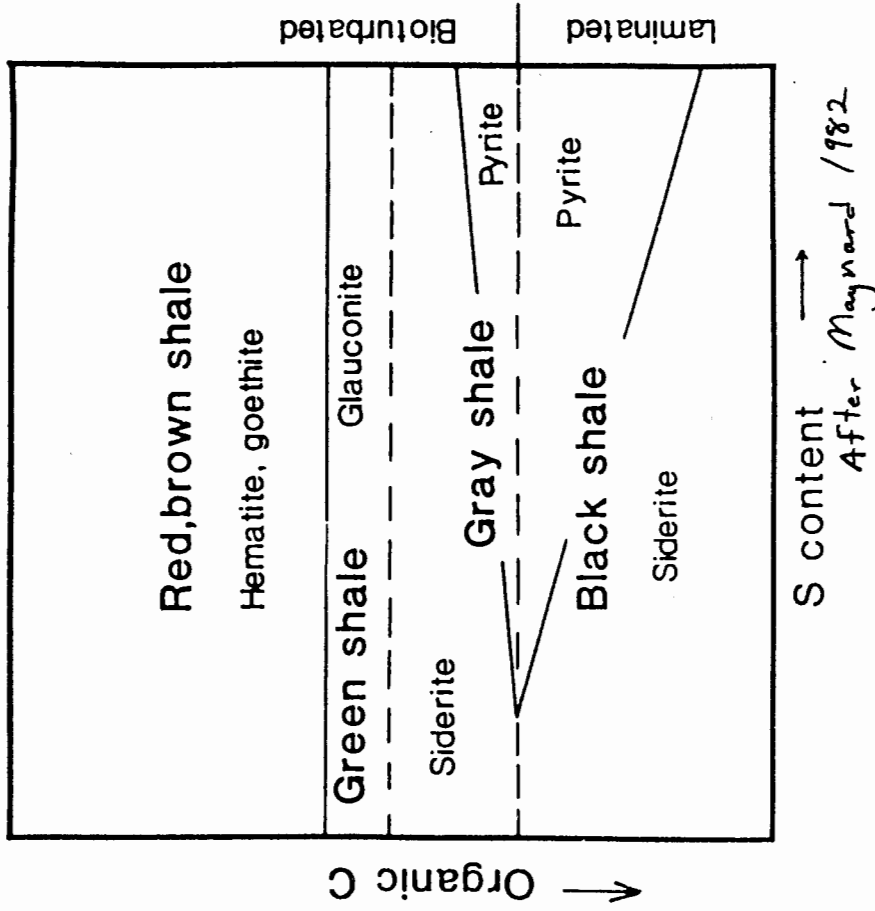


Figure ii. Geochemical environments represented by shales exposed along I-64.

1. Red shales of Nada Mbr. Borden.
2. Green shales of Nada, base of Henley.
3. Gray shales of Nancy. (Stop 2)
4. Gray shales of Borden Fmn. (Stop 5)
5. Black shales of Ohio Sh. (Stop 1, 5a)
6. Black shales of Breathitt Fmn. (Stop 4)

### **STOP 1. Devonian Black Shales of the Huron Member of the Ohio Shale.**

This outcrop exposes a rather complex stratigraphy at the base of the Ohio Shale, and illustrates well the characteristics of transgressive marine black shales (Figure 1-1). The basal two meters or so of the outcrop is the Silurian Crab Orchard Formation. The transition to the Devonian is not the base of the black shale, but instead is marked by a 1 cm bed of pyrite-marcasite with abundant conodonts and quartz grains. According to Ettensohn et al. (1989) this bed represents at least six Frasnian and early Fammenian conodont zones. Above this bed is about a meter of gray shale that can be traced into the Upper Olentangy Shale of Ohio. Therefore the conodont bed represents a merger of several unconformities. The gray Olentangy is overlain by black, highly carbonaceous shales of the Huron Member of the Ohio Shale. The lower part of the Huron has been traced into the Dunkirk Shale of New York using subsurface gamma-ray logs (Wallace et al., 1977), but appears to be somewhat younger than the Dunkirk, indicating a "time-transgressive" transgression (Ettensohn, 1992, p. 76). The black shales from this outcrop were the source of the USGS standard shale SDO-1.

#### **Questions:**

1. Can any "ribbed" weathering pattern be seen in the lower part of the outcrop. These ribs reflect cyclic alternation in high  $C_{org}$ /low  $C_{org}$  contents, usually on a scale of 10 cm or so. Is there any other cyclicity visible?
2. What is the morphology and distribution of pyrite? Is the pyrite confined to the black shale beds? Does it appear to have formed within the sediment or at the sediment-water interface?

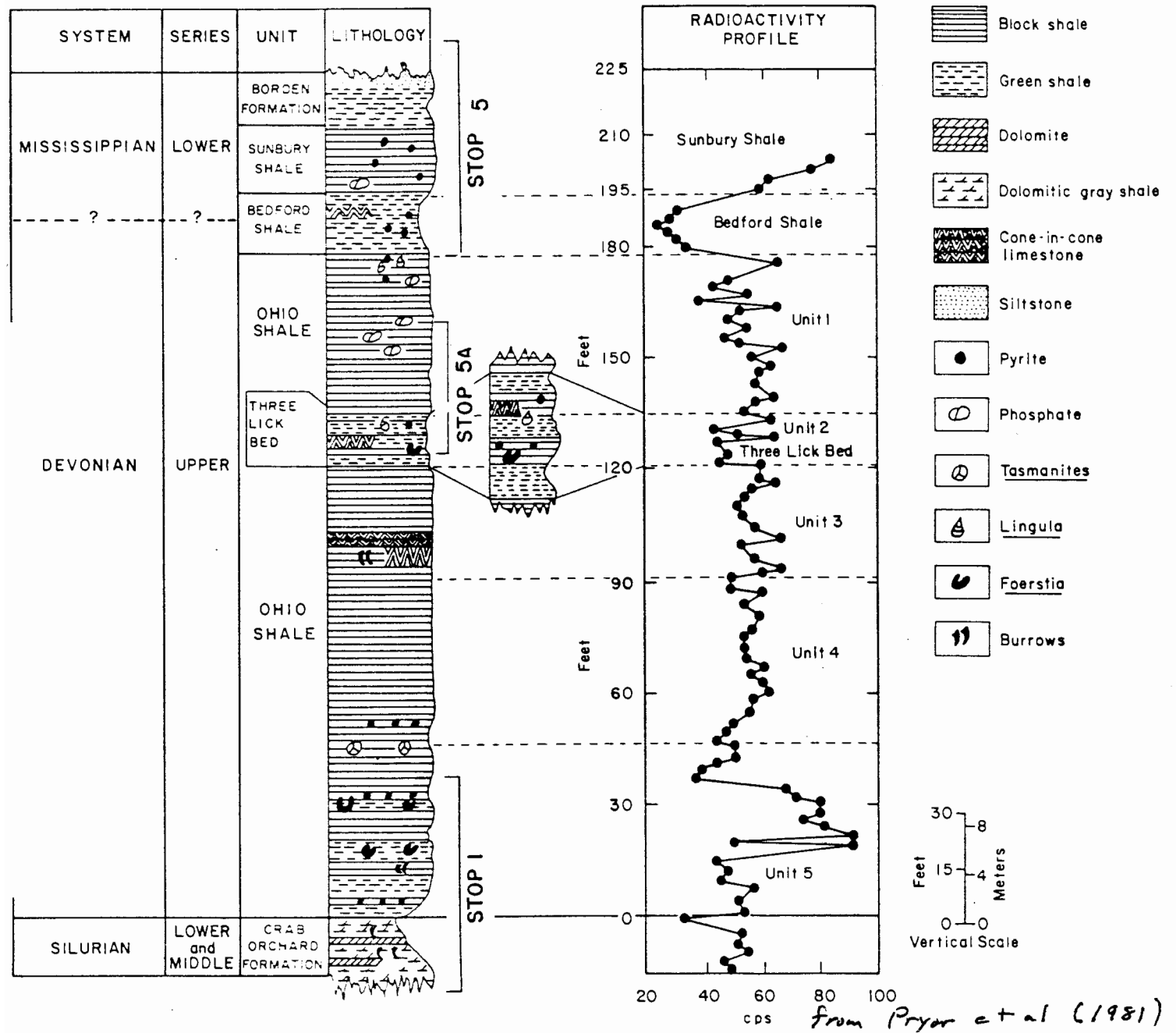
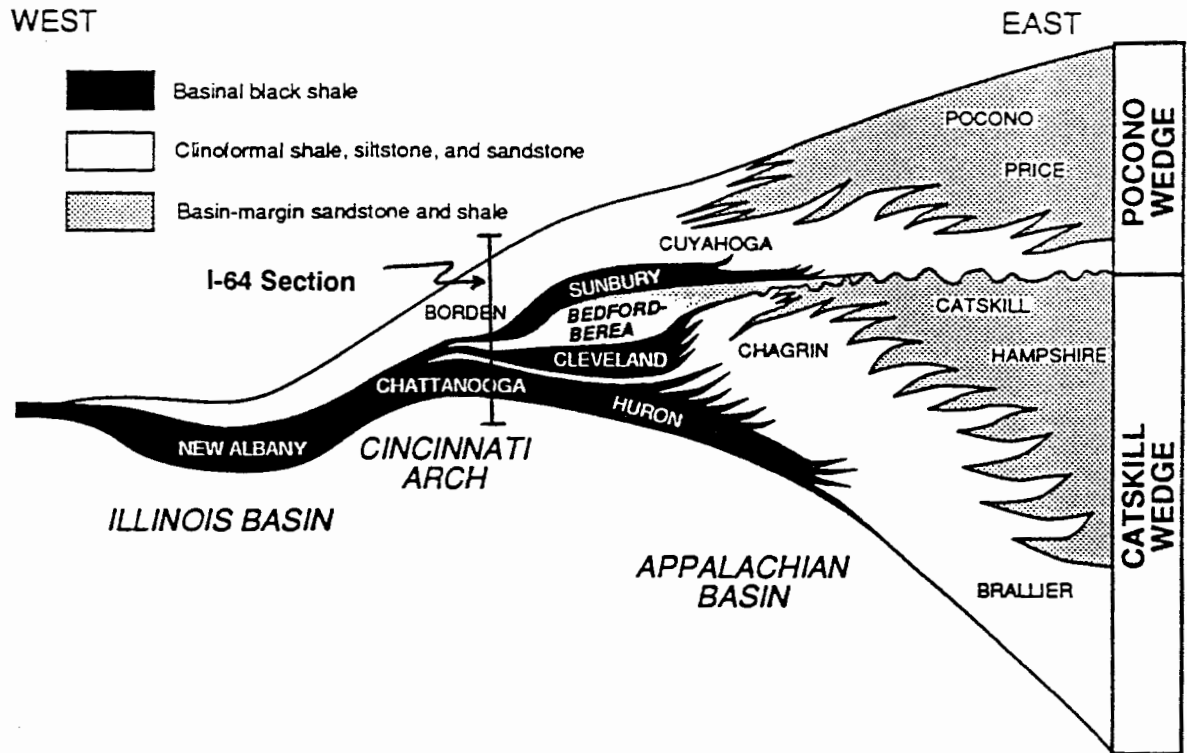


Figure 1-1. Stratigraphic section through the Devonian along I-64. The radioactivity profile is a good proxy for organic carbon content. Note the low-C Olentangy shale at the base of the section and the low-C Bedford at the top. Similar, but thinner gray shale intervals mark the Three Lick Bed, which separates the Cleveland Member from the Huron Member of the Ohio Shale.



*after Pashin & Ettensohn 1995*

Figure 1-2. Conceptual stratigraphic model of the Devonian-Carboniferous showing gray shale-black shale cycles in the field trip area that correlate basinward to condensed black shales and proximally to deltaic clastics.

## STOP 2. Mississippian Sideritic Gray Shales of the Nancy Member of the Borden Formation.

The Nancy Member contrasts strongly with the underlying, and presumably laterally equivalent, basinal black shales of the Sunbury Formation. The presence of the intervening prodelta turbidites of the Farmers Member indicates that the Nancy is also a prodelta deposit, but a bit higher on the paleoslope than the Farmers. Chaplin (1980) reported the Nancy in this area to be about 200 feet thick, with transitional boundaries with the Farmers below and the Cowbell Member above. The Nancy increases in silt content and decreases in degree of bioturbation upwards. Siderite is best developed in the lower 20 feet, and commonly occurs as sideritized burrows. Body fossils as well as trace fossils are common and include a highly diverse and abundant cephalopod fauna of both goniatites and nautiloids.

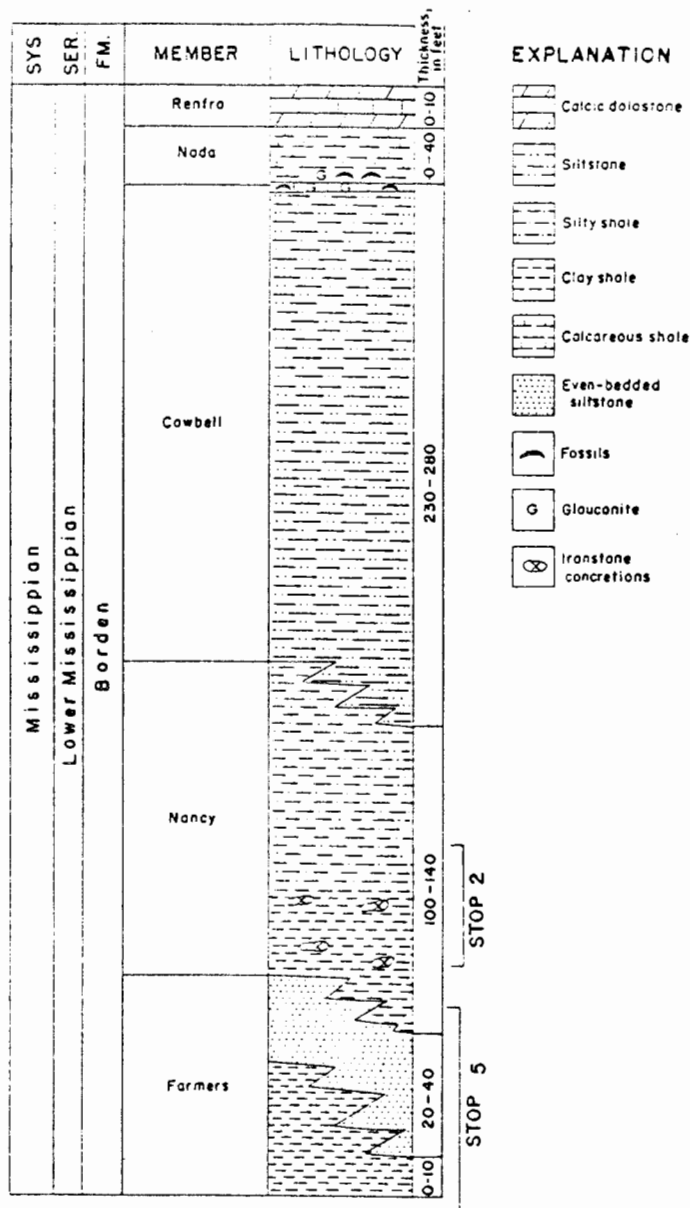
In contrast to the black shale of the Ohio Shale, the Nancy is gray in color, is strongly bioturbated, and contains siderite instead of pyrite as the dominant iron mineral. It has been suggested that siderite is indicative of non-marine conditions, whereas pyrite is the dominant Fe mineral under marine conditions (Berner et al., 1979). These rocks, however, appear to be fully marine and yet highly sideritic. Could it be that siderite in black shales indeed means a non-marine system, whereas siderite is compatible with marine (i.e. high sulfur) conditions for gray shales? Carbon isotope data from a few Nancy nodules collected along the Mountain Parkway suggest formation under suboxic (post-oxic) conditions, which would be insufficiently reducing for pyrite formation, but still reducing enough for siderite:

Sample	$\delta^{13}\text{C}$	% insol	X <sub>Fe</sub>	X <sub>Mn</sub>	X <sub>Ca</sub>	X <sub>Mg</sub>
419 A (edge)	-21.6	36.2	.85	.01	.08	.06
B	-21.2	20.3	.83	.02	.09	.06
C	-20.8	17.5	.86	.01	.08	.05
D	-20.8	17.0	.86	.01	.07	.06
E (center)	-19.5	17.3	.86	.01	.07	.06
458	-16.9	24.3	.71	.01	.12	.16
repeat	-16.5					
460	-18.0	29.9	.75	.01	.07	.17

Source: unpublished data of Pat Okita and John Kundtz, University of Cincinnati.

## Questions:

1. Can we see any cyclic deposition in this outcrop, or has bioturbation completely destroyed the evidence?
2. What controls the occurrence of the siderite? Is its distribution cyclic?



*modified from Philley 1970*

Figure 2-1. Generalized stratigraphy of the Borden Formation. This is a generally shoaling-upwards sequence whose lower boundary is the Sunbury flooding surface. This surface passes into an unconformity in West Virginia (Matchen and Kammer, 1994). Note that USGS mapping placed the top of the Borden above the Renfro Member, but Ettensohn (1992) assigned the Renfro to the overlying Slade Formation (Figure i.)

### **STOP 3. Cyclic Deposits (Tidalites?) of the Pennsylvanian Breathitt Formation.**

This stop is included to contrast the shale-shale decimeter cyclicity of the Ohio Shale with a similar scale of cyclic bedding, but one that almost certainly has a different origin. Martino and Sanderson (1993) described these rocks as estuarine deposits with several orders of cyclicity. They identify the basic lamination unit as one mud-draped sand layer, 1.5 to 2.5 cm thick, with these layers assembled into the following cycles:

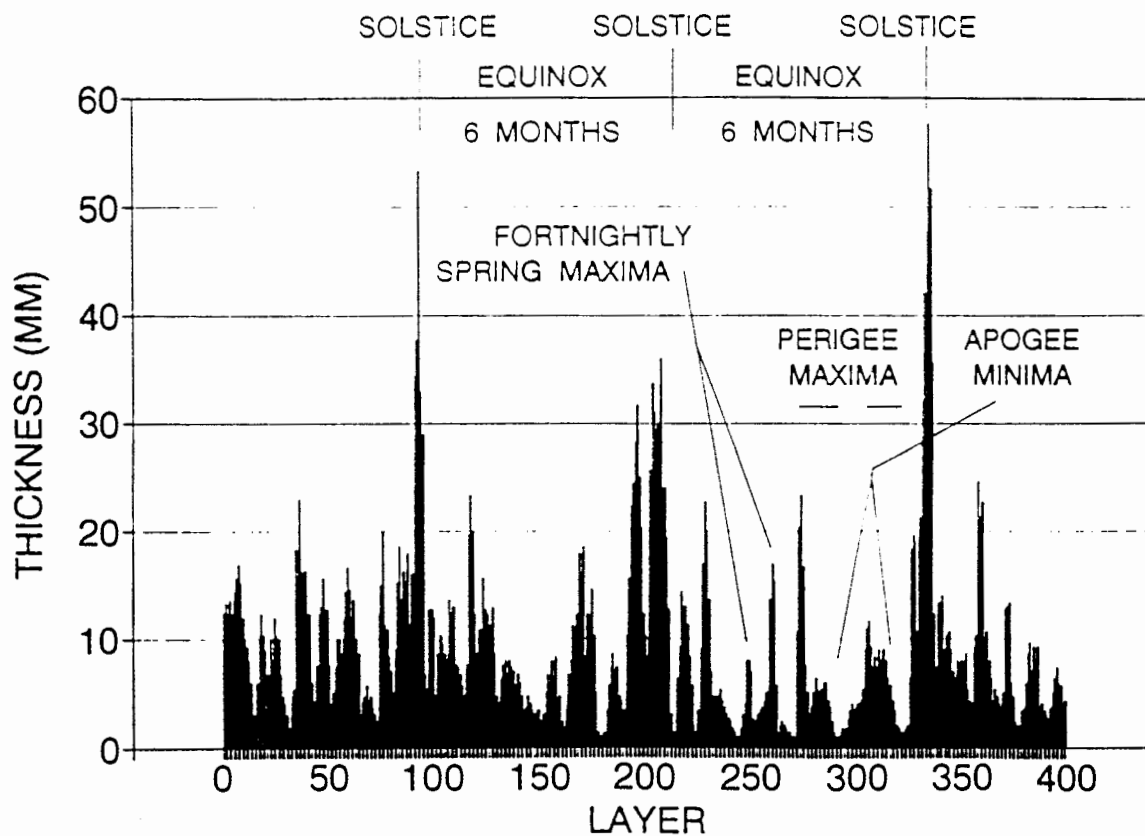
Cycle	Size	Interpretation
First Order	2-3 layers	Daily
Second Order	11-14 layers	Spring-neap
Third Order	24-35 layers	Perigee-apogee
Fourth Order	100-166 layers	Seasonal

See Figure 3-1 for a representation of these orders.

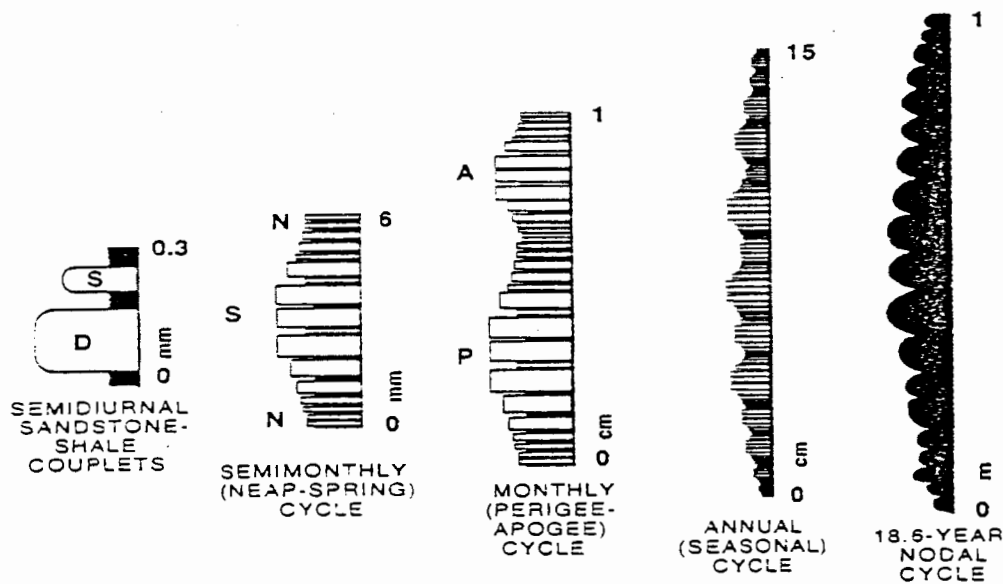
#### **Questions:**

1. The presence of cycles is obvious from a distance. Can they be seen up close? Has bioturbation destroyed our ability to reproduce the cycle measurements?
2. Could the scale be shifted one order? That is, could the apparant daily cycle be the fortnightly one, and so forth?

This last question is prompted by comparison with the paper by Miller and Eriksson (1997), who proposed that similar-appearing rocks of the Mississippian Pride Formation in southern West Virginia have a submillimeter semi-diurnal cycle, with the other tidal overtones appearing in thinner packages than proposed by Martino and Sanderson (Figure 3-2). If the Breathitt rocks should prove to be similar, it would reduce the calculated sedimentation rate by about an order of magnitude.



*Martino + Sanderson 1993*



*Miller + Erickson 1997*

#### STOP 4. Pennsylvanian Sideritic Black Shales of the Breathitt Formation.

This stop is included to contrast the mineralogy and geochemistry of Pennsylvanian black shales of the Appalachian Basin with the Devonian black shales and also with the Pennsylvanian shales of the midcontinent that we will be seeing in core tomorrow. Greb and Chesnut (1992) have described shale-filled channels in the Breathitt as brackish to marine products of initial transgression. The resulting carbonaceous shales are bioturbated and sideritic and may contain Lingula. According to Weber et al. (1979), the siderite changes morphology with salinity:

<u>Morphology</u>	<u>Interpreted environment (from body fossils)</u>
Homogeneous bands	Freshwater
Small nodules	Brackish
Large nodules	Marine

Siderite nodules from the Breathitt along KY 15 near Hazard show much heavier C isotopes than do the fully marine siderites of the Nancy Member of the Borden Formation. The relatively positive values for C suggest that methanogenesis was a much more important component of organic matter diagenesis in these rocks than in the gray shales of the Nancy.

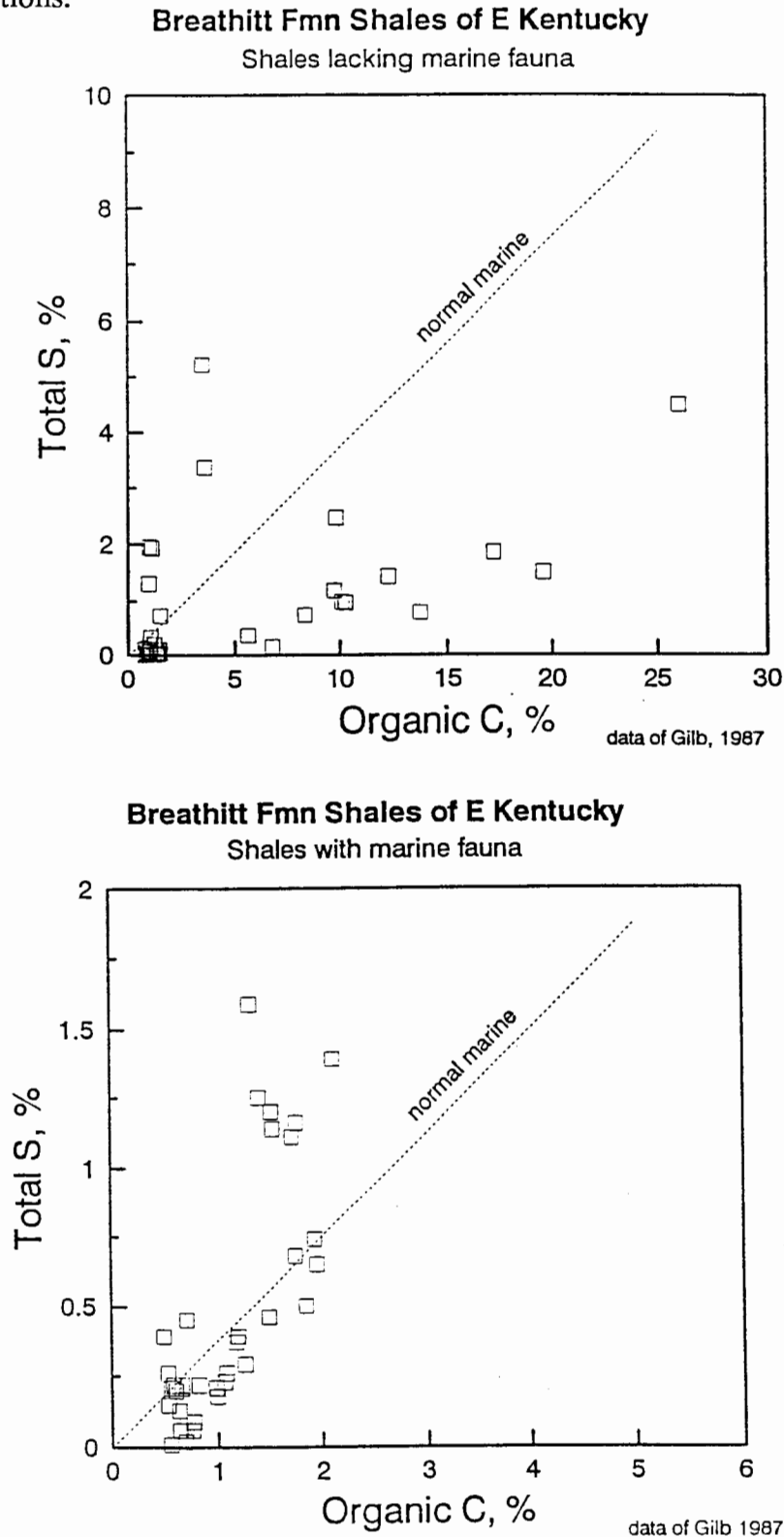
Sample	$\delta^{13}\text{C}$	% insol	$X_{\text{Fe}}$	$X_{\text{Mn}}$	$X_{\text{Ca}}$	$X_{\text{Mg}}$
442	+3.45	22.9	.77	.01	.07	.15
repeat	+3.66					
461	+8.43	21.1	.96	.01	.03	.01
462	+9.75	18.3	.91	.02	.03	.04

Source: unpublished data of Pat Okita and John Kundtz, University of Cincinnati.

#### Questions:

1. Are these shales marine or non-marine? Can a vertical change in salinity be seen?
2. In the midcontinent, black shales ("core shales") represent the maximum transgression in the cyclothem. Can that be the case here?

Figure 4-1. C-S patterns in the Breathitt (Gilb, 1987) show that gray to dark gray shales with calcium carbonate concretions and marine faunas have patterns consistent with marine conditions, but that dark gray to black shales of the type seen at this stop have patterns that, although showing the same positive covariance of C and S that is found in normal marine sediment, have most points lying well below the marine line, indicating lower S than for fully marine conditions.



**STOP 5. Bedford gray shale, Sunbury black shale, Henley (Borden) gray shale, and Farmers (Borden) siltstone turbidites.**

This outcrop shows the key stratigraphic relationships among black shales, gray shales, and gray siltstones for the Devonian-Carboniferous section. The Bedford is the top of an earlier shoaling-upwards section that capped the Devonian shale sequence, and, with the Berea Sandstone, which is developed just to the north and east, represents John Rich's clinothem and undathem (Rich, 1951). See Figure 5-1, which shows the slope position of the Bedford and the wave-influenced position of the Berea. The Sunbury -- Henley + Farmers are the fondothem-clinotherm part of the next sequence. Note that the Bedford here is a pyritic gray shale, the Sunbury is a pyritic black shale, and the Henley and Farmers have pyrite, siderite, and glauconite in gray shales and siltstones. A cm or so thick bed of maracassite in the base of the first turbidite of the Farmers marks the transition from dominantly pyritic gray shale below to dominantly sideritic gray shale and siltstone above.

- Questions:
1. Can the Sunbury be distinguished from the Devonian black shales?
  2. What is the character of the transition from the Sunbury to the Henley? Are they truly part of the same sequence or is there a disconformity?

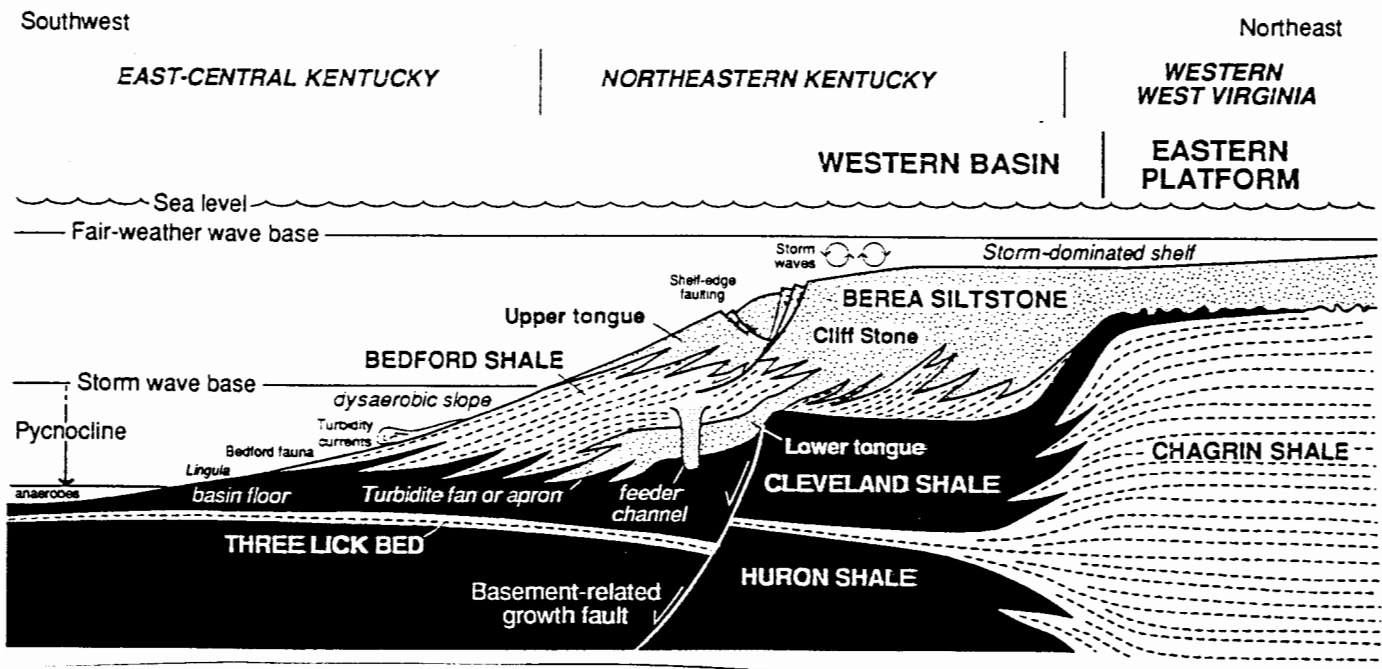


Figure 5-1. Depositional model for the Bedford-Berea showing downslope transition of the gray shales of the Bedford into the black shales of the Cleveland (Pashin and Ettensohn, 1995, fig. 49).

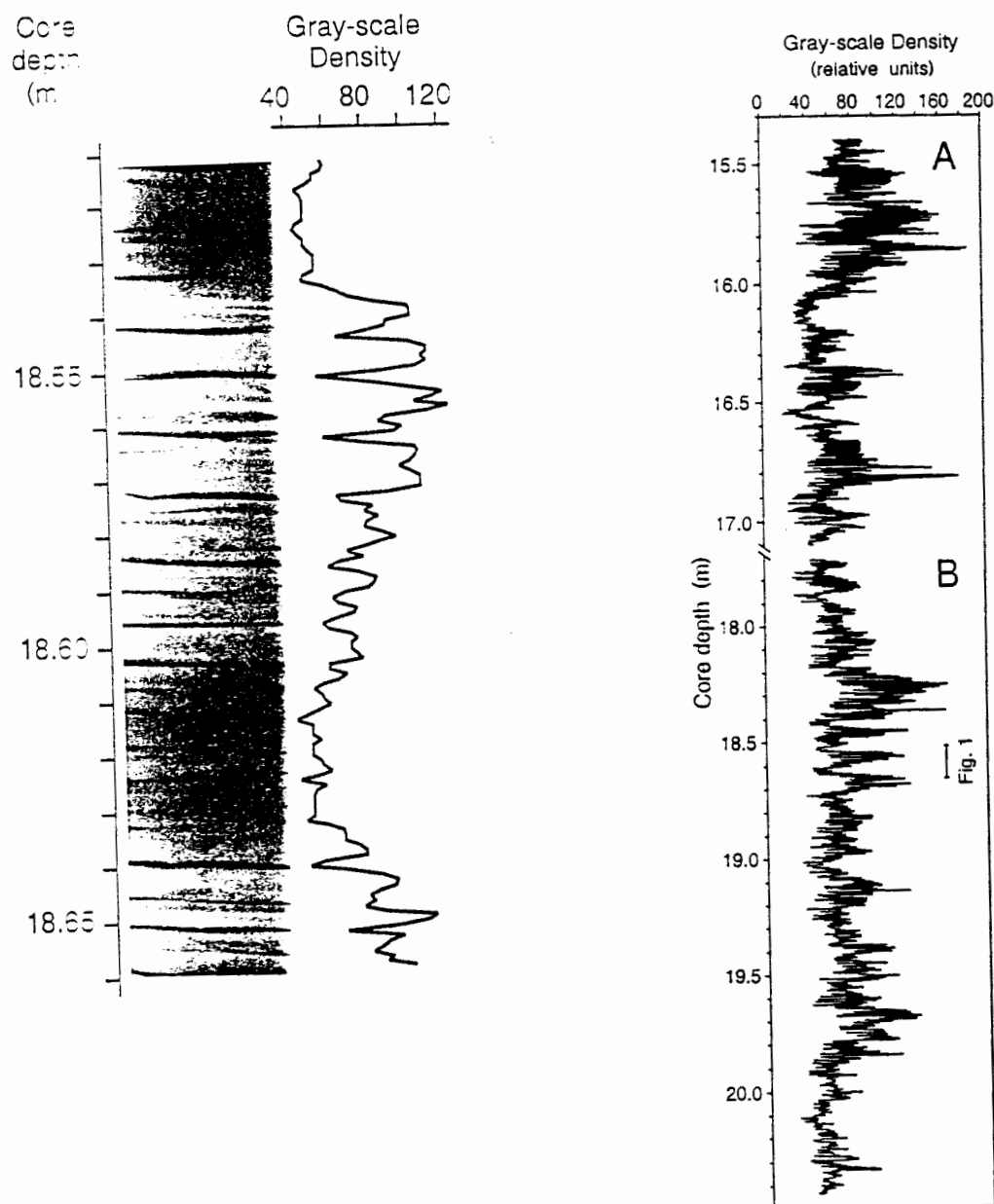
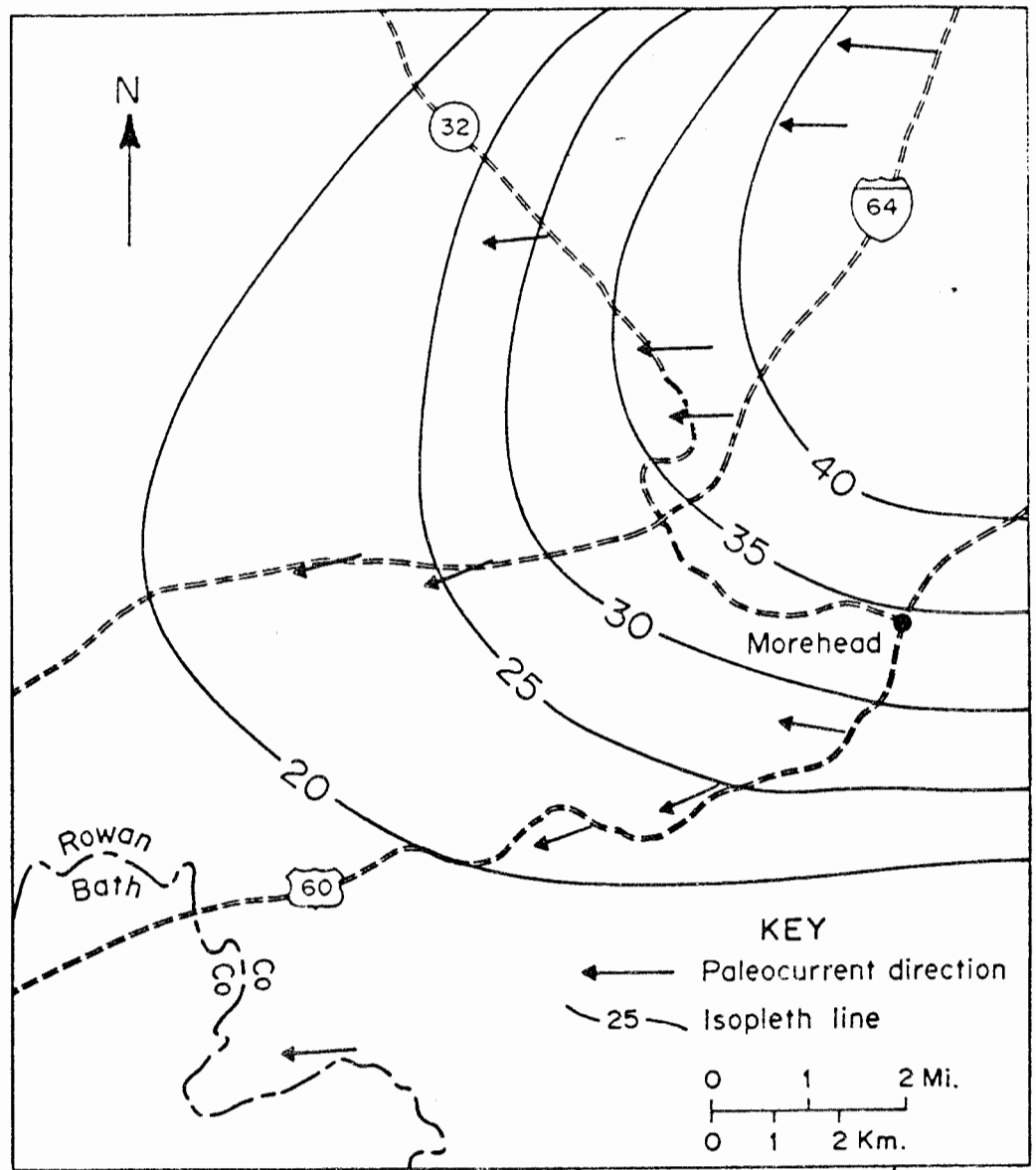


Figure 5-2. The Sunbury Shale displays a fine-scale cyclicity that is revealed by x-radiography. Paired gray and black laminae form couplets that average 4.5 mm in thickness and are bundled into dm-scale alternations. In the outcrop, this dm-scale cyclicity is revealed by differential weathering. The gray-scale density corresponds to rock density and hence to organic content: high GSD values indicate low TOC (Algeo and Woods, 1994).



*Maynard & Lauffenburger 1978*

Figure 5-3. Farmers turbidites decrease in number to the west, which is also the dominant paleocurrent position.

**STOP 5a. Three Lick Bed and Cleveland Member of Ohio Shale.**

This exposure is the type section of the Three Lick Bed, an important marker horizon in the Devonian shale sequence (Provo, et al. 1978). It is the far distal equivalent of the Chagrin Shale (Fig. 1-2), and separates the Huron Member from the Cleveland Member of the Ohio Shale. The lower part of the Huron Member that we saw at stop 1 is a transgressive black shale, whereas the Cleveland is regressive. In the subsurface, the Huron is characterized by a sharp gamma-ray log increase at the base that fades gradually upwards. In contrast the Cleveland gamma-ray has lower API values and lacks the sharp basal kick (Figure 5a-1). The Cleveland, like the Sunbury at the previous stop, has a pronounced dm-scale cyclicity revealed by weathering.

**Questions:**

1. Is the scale of cyclicity here different from that in the Sunbury?
2. What is the significance of the cone-in-cone calcite layers?

# GEOLOGICAL SOCIETY OF KENTUCKY NO. 1 BLACK SHALE HOLE

KGS and USGS Oil Shale Hydrogeology Cooperative Project

## NATURAL GAMMA

logged by: J.Hamilton and R.Smath  
24MAR81  
RATE-100  
TIME CONSTANT-2  
RATE OF ASCENSION-10 feet per minute  
VARIABLE SPAN-3.58  
POSITION-9.91

## SP-RESISTIVITY

logged by: J.Hamilton and R.Smath  
24MAR81  
SELF POTENTIAL-200 millivolts  
RESISTIVITY-100 ohms  
RATE OF ASCENSION-10 feet per minute

25-Q-68  
2700FNL 4300FEL  
elev.-approx. 760'

Scale  
0  
10 Feet

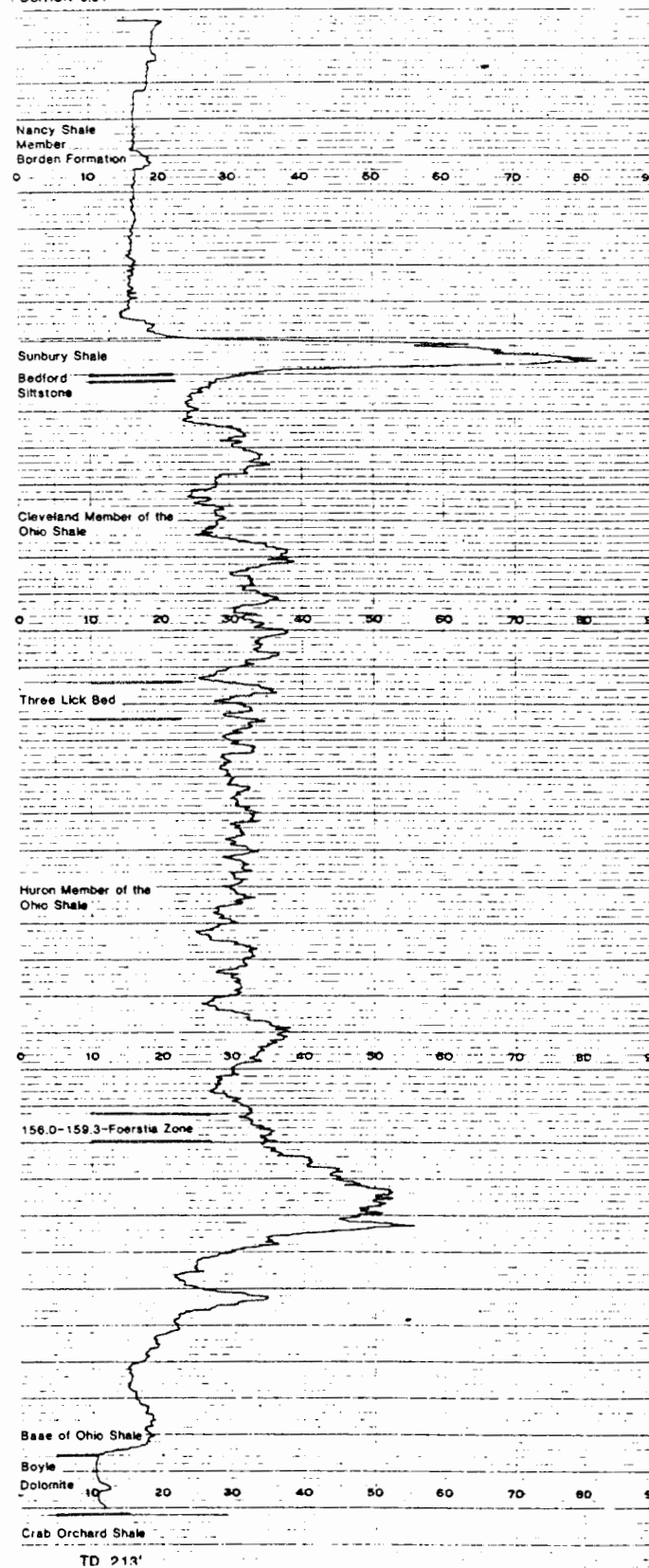
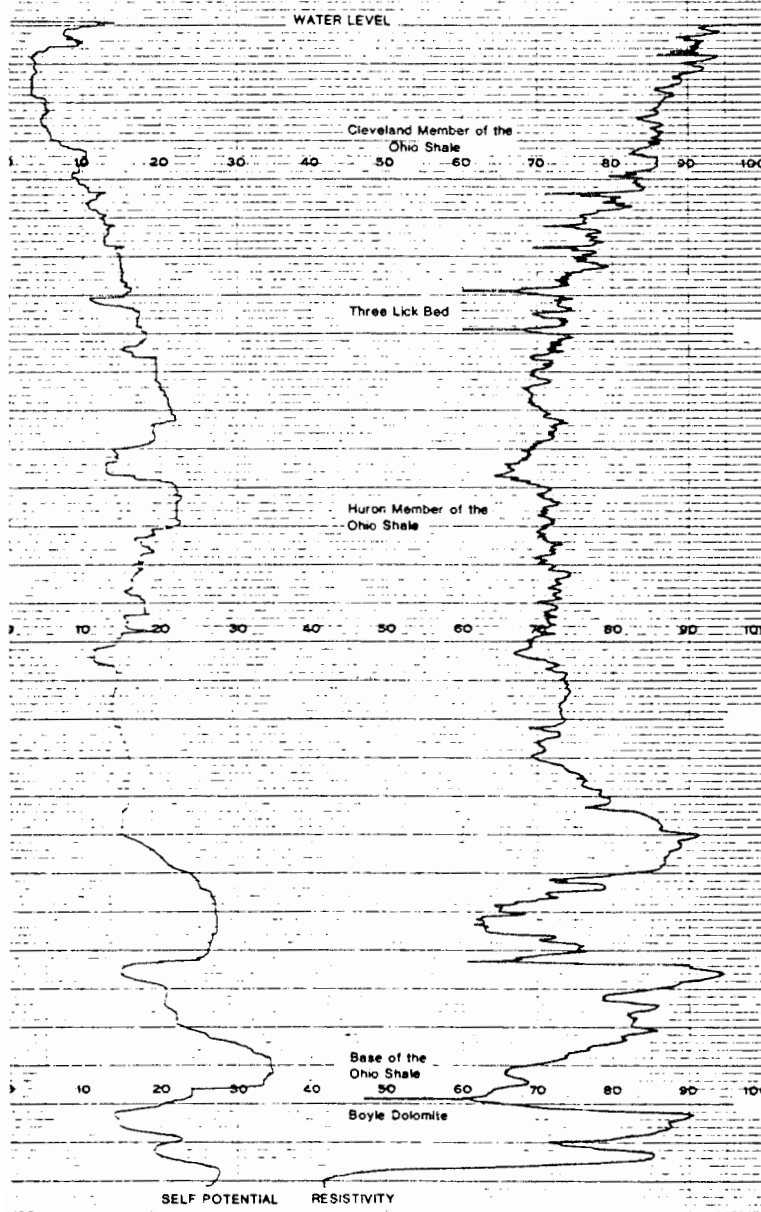
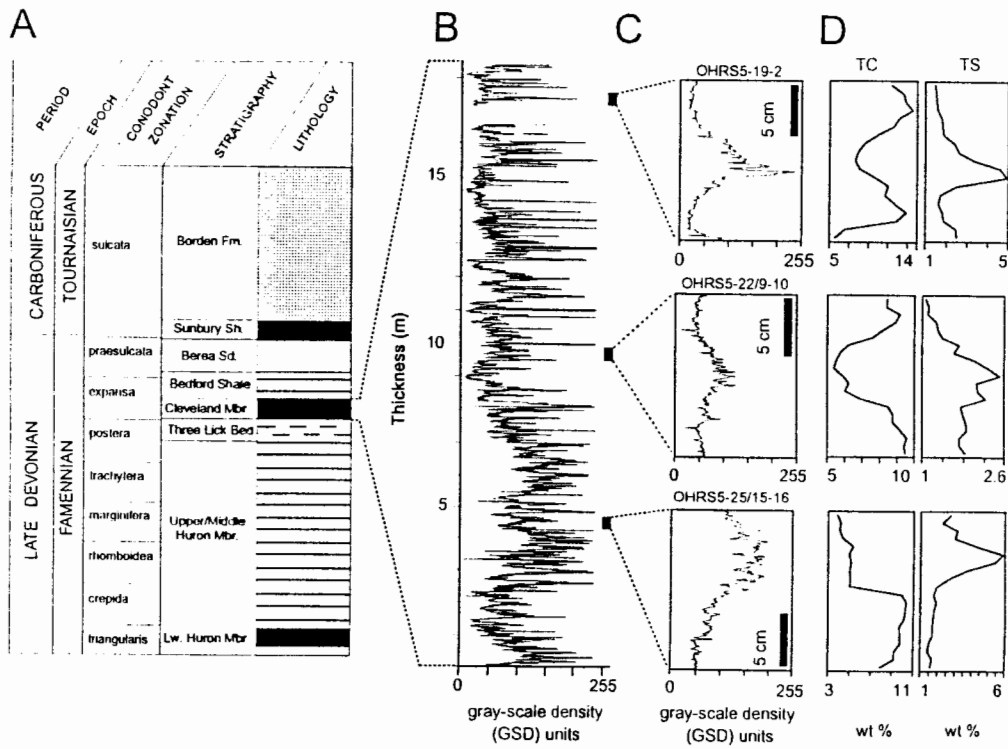


Figure 5a-1. Gamma-ray log for the Devonian shale sequence from Powell County.



## MEM POWER SPECTRUM

## SPECTRAL CONTOUR MAP

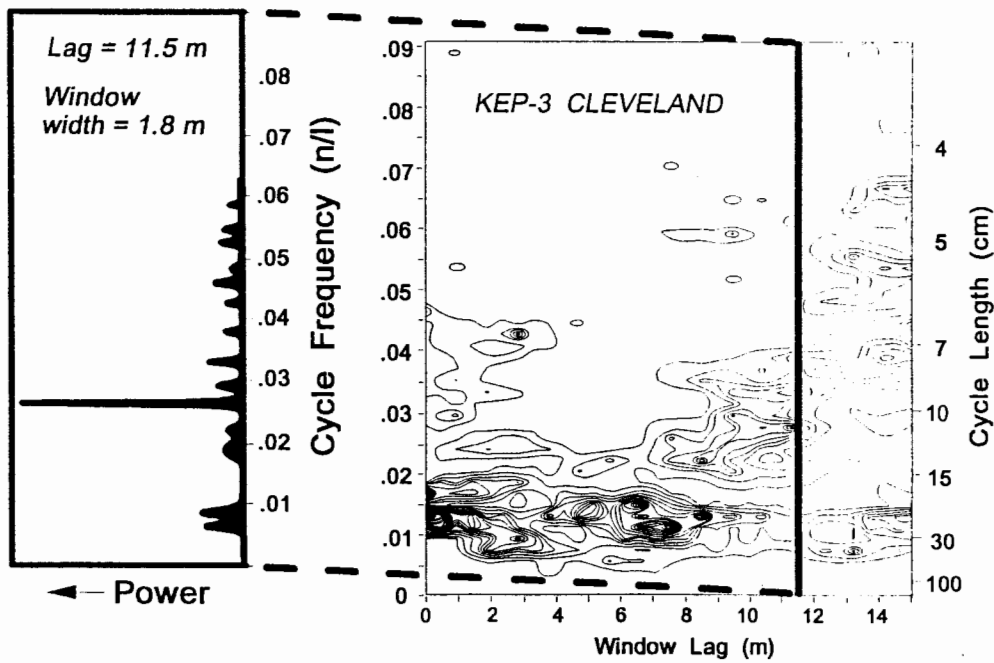


Figure 5a-2. Cyclicity in the Cleveland shale as revealed by x-radiography.