Lithologic Descriptions of Cores and Exposures of Devonian Shale and Associated Strata in Ohio along Lake Erie

by

Ronald F. Broadhead[1/], Roy C. Kepferle, and Paul Edwin Potter[1/]

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INTRODUCTION

The rock stratigraphic framework of the Devonian shale in northern Ohio shows greatest variation from west to east, normal to depositional strike (Harris, de Witt, and Colton, 1978, p. 162; Janssens and de Witt, 1976, p. 2-3; Wallace, Roen, and de Witt, 1977). Thus, the detailed description of available cores and exposures along this line should afford a basis for comparing rock units with known occurrences of natural gas in the local area. Extrapolation of these data could serve as a tool for predicting potential finds of gas along depositional strike, where gas distribution is controlled by stratigraphy.

The locations of nine cored drill holes and eleven outcrops from which samples were studied are shown in figure 1. In this paper, we describe 5600 feet of core and 756 feet of outcrop section as a basis for further study.

The shale units along Lake Erie are separated by recognizable differences in content of olive-black shale, gray shale, or greenish-gray shale and siltstone. Boundaries between laterally gradational units are necessarily somewhat arbitrary. The eastward increase in

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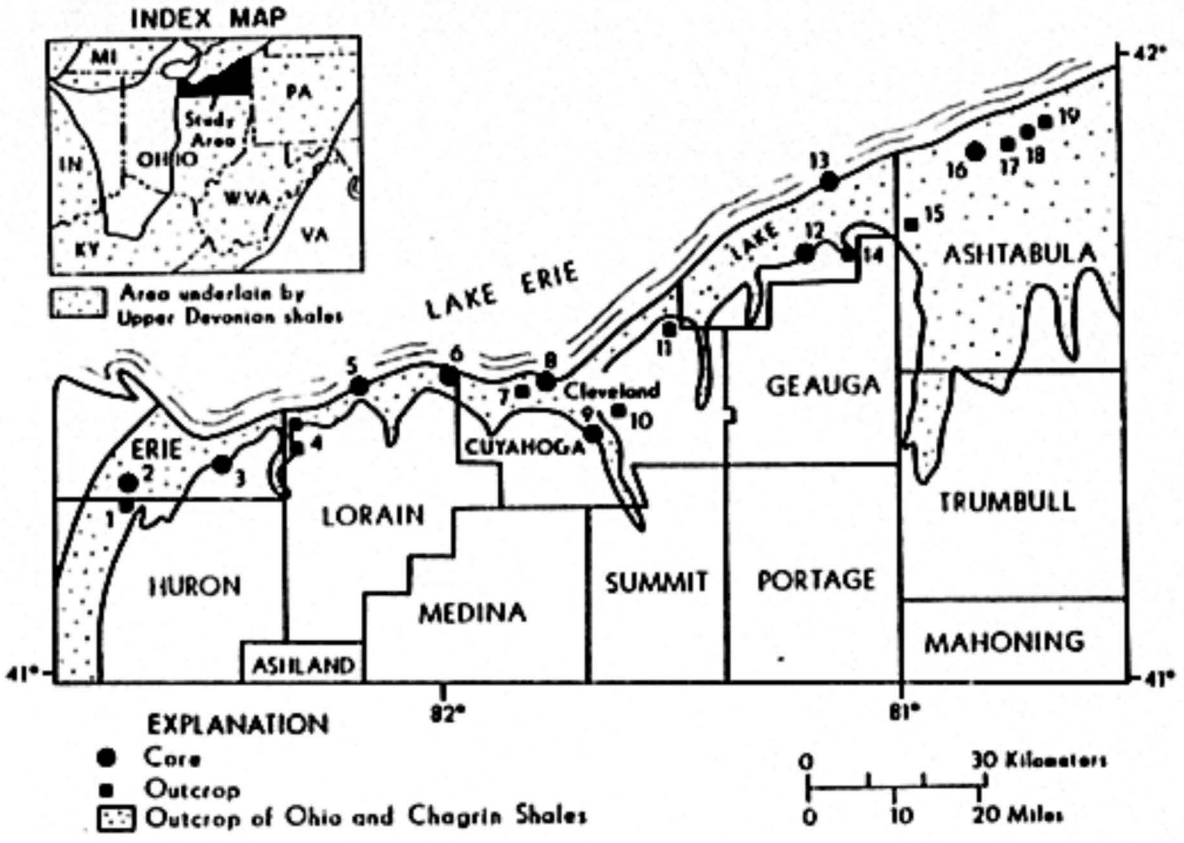


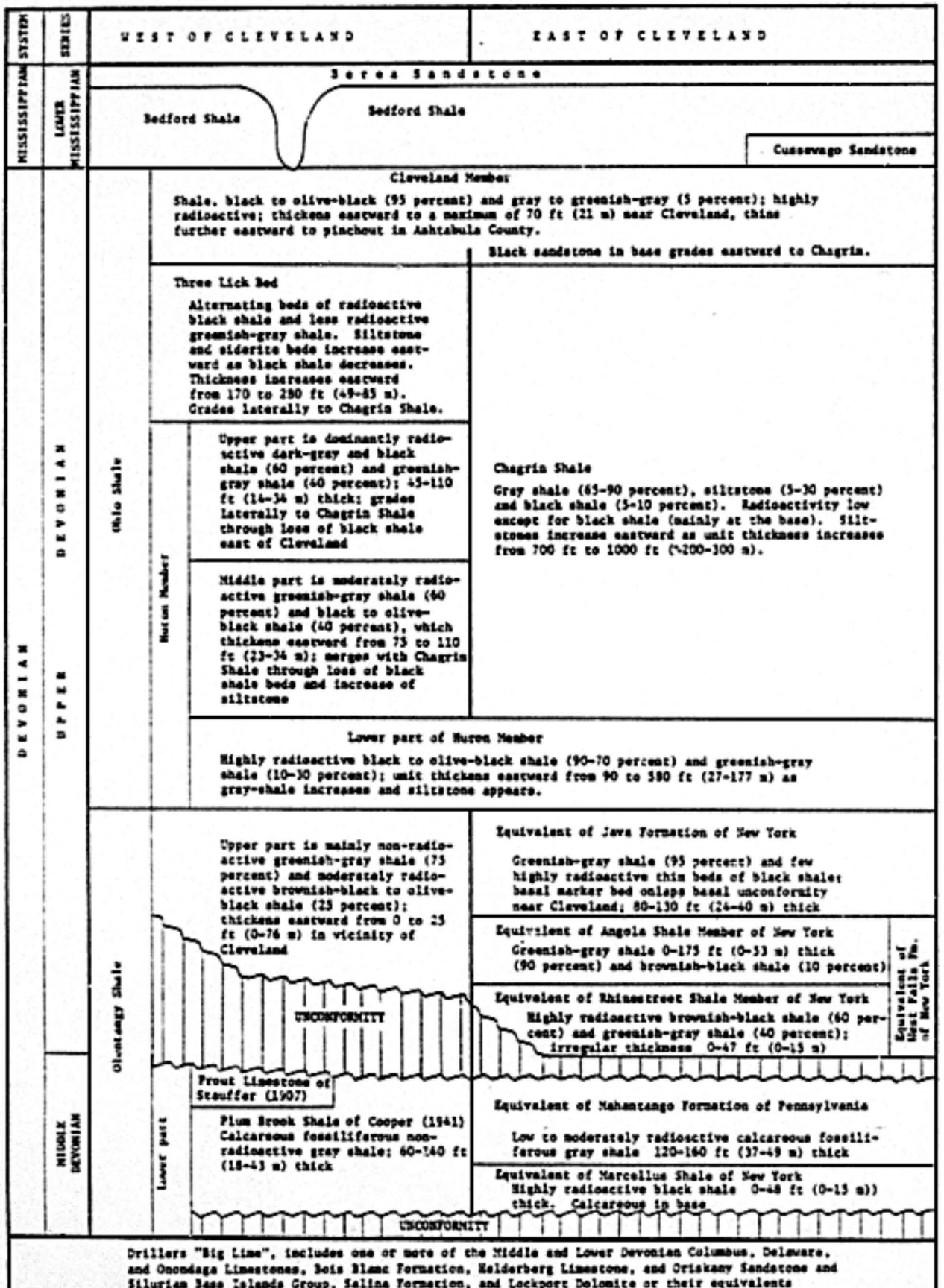
Figure 1. Map showing the study area, regional distribution of Upper Devonian shale, locations of cores and measured outcrop sections in the Ohio and Chagrin Shales along Lake Erie, northern Ohio.

thickness of the shale sequence is accompanied by an increase in the proportion of gray shale and siltstone, and the stratigraphic names in the east differ from those in the west (figs. 2 and 3).

The stratigraphic names are used to reflect natural subdivisions for surface and subsurface mapping. No new names are introduced here, although the usage of Three Lick Bed equivalent of the Ohio Shale for the upper, western extension of the Chagrin Shale follows that of Frank Majchszak (written communication, 1979). The good subsurface correlation of units in northern Ohio with those in northern Pennsylvania and western New York is shown in figure 4.

Gamma-ray logs of cores and outcrops were made by using a hand-held scintillometer as described elsewhere (Provo and others, 1978; Ettensohn and others, 1979) and are an important supplement to the lithic descriptions. The gamma-ray logs are especially helpful in correlating surface units with subsurface units.

Figure 2. STRATIGRAPHY AND LITHOLOGY OF DEVONIAN SHALE ALONG LAKE ERIE IN NORTHERN OHIO



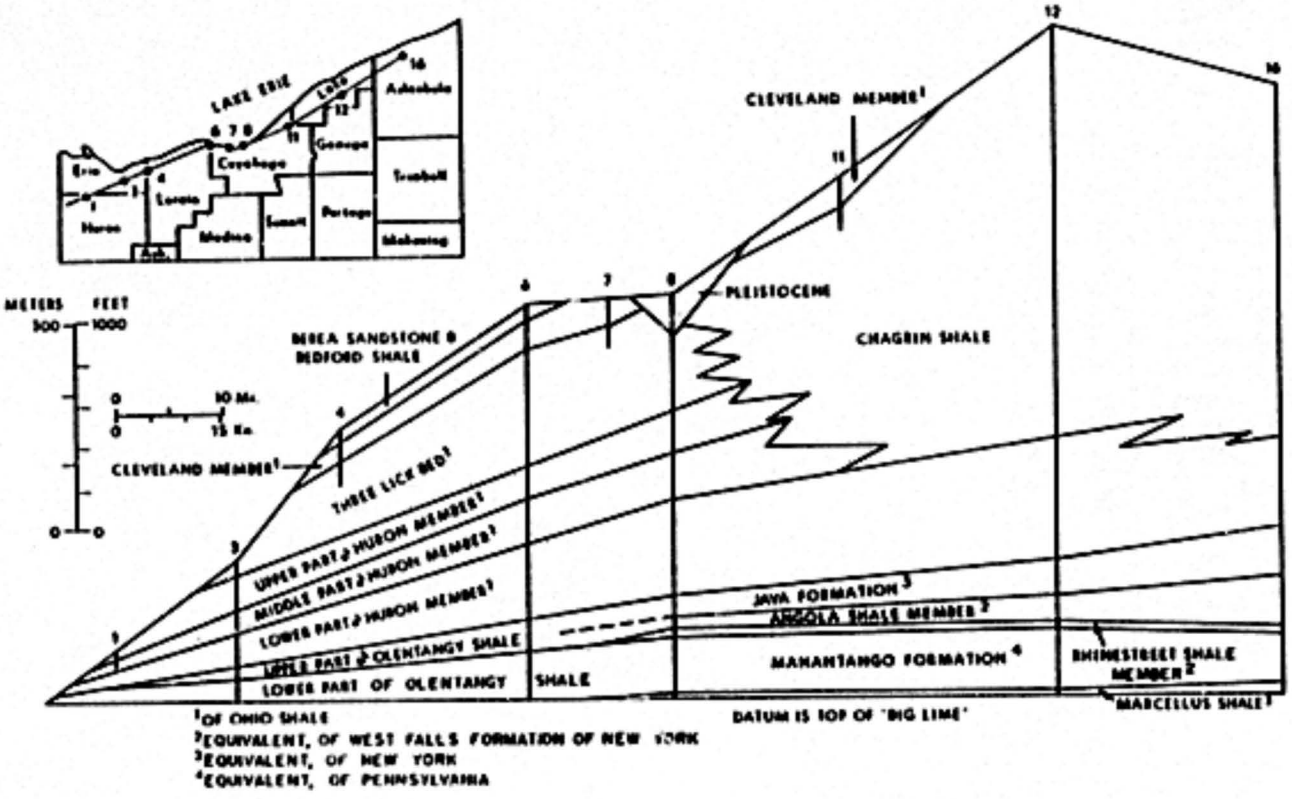


Figure 3. Stratigraphic cross section through Middle and Upper Devonian rocks along Lake Erie.

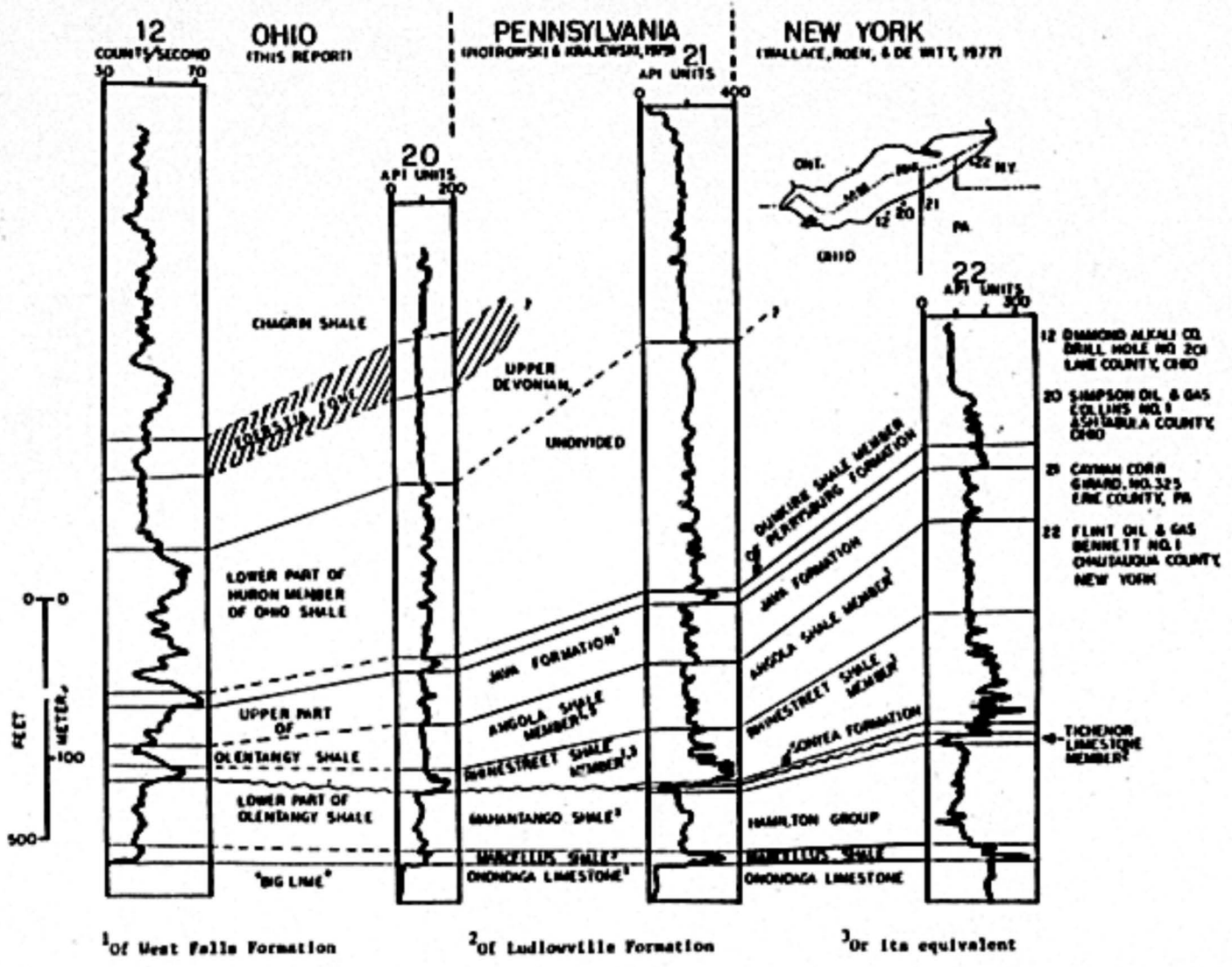


Figure 4. Four gamma-ray logs used for subsurface correlation of Olentangy Shale in Ohio with lithologic equivalents in Pennsylvania and New York.

ACKNOWLEDGMENTS

Core measurements were facilitated by the able assistance of Greg Hinterlong, University of Cincinnati, who also made scintillometer profiles of several cores; James Harrell, also of the University, assisted in the examination of the Whiskey Island core. Frank Majchszak, Dr. Richard Carlton, and Ed Rothman of the Ohio Division of Geological Survey provided access to the Prout Station core and the core of Avon drill hole no. 3 of the International Salt Company. Dilip Paul, International Salt Company, made available the core of the Whiskey Island drill hole. Lloyd J. Charlesworth, then at the University of Toledo, permitted logging of the Diamond Alkali and Gerald No. 1 cores. David Watson and Adrian Cook of the Ohio Edison Company accompanied us while we logged the Erie Nuclear Power Plant core. Ken Snyder was most helpful at the Perry Nuclear Power Plant. Vijay Khosla and Jon Peterson, Herron Testing Labs, permitted inspection of several cores. Jean Carrol, Debbie Moorman, and Wanda Osborne, all of the University of Cincinnati, Department of Geology, typed the manuscript. Illustrations were drafted by Roger Potts.

The U.S. Department of Energy provided support under contracts EY-76-C-05-5201 and EX-76-C-01-2287. The descriptions are part of the research completed by Broadhead for the requirements for a thesis in Geology at the University of Cincinnati (Broadhead, 1979).

DESCRIPTIONS OF SECTIONS AND CORES

Lithologic names used in the following section descriptions are based on visual inspection. Colors refer to those of the rock color chart (Goddard and others, 1948) and are of the dry rock, except where otherwise noted. Qualitative descriptions of bedding thickness (e.g., thinly bedded) are from Ingram (1954). Designations such as Tb, Tbc, etc., are used to describe Bouma sequences in siltstone beds. Lower case letters refer to the specific Bouma units present; for example, Tbc indicates a siltstone bed containing a b Bouma unit overlain by a c Bouma unit (Bouma, 1962, Fig. 8). The symbols used in the sections shown in the rest of this report are explained in figure 5.

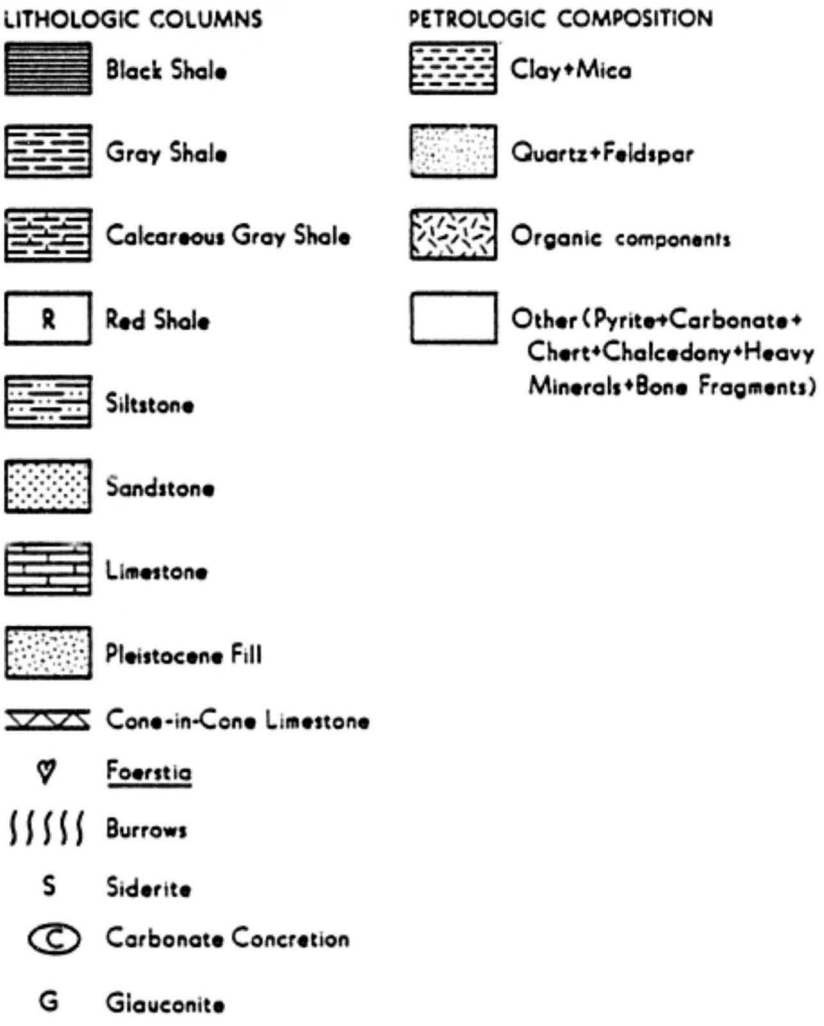


Figure 5. Explanation of symbols used in figures in the rest of this report.

Huron River section, Huron County, Ohio

(Locality 1, fig. 1)

Excellent section (fig. 6) of Huron Member of Ohio Shale exposed along the West Branch of the Huron River about 2.5 miles northeast of Monroeville in Ridgefield Township, Kimball quadrangle, Huron County, Ohio (Ohio Coordinate System: North Zone, 1,952,000 ft E, 587,200 ft N). Base of section is at the base of the cliff south of the intersection of the Huron River with Lamereaux Road. This section is at the type locality of the Huron Member of the Ohio Shale as designated by Newberry (1870). Described and measured with hand-level and tape by R.F. Broadhead on July 23, 1978.

	Thickness (feet)	
	Unit	Cumulative
Devonian (incomplete):		
Ohio Shale (incomplete, 54.3 ft+):		
Upper part of Huron Member (incomplete, 24 ft+):		
50. Shale, black (N1); weathers a grayish red (10R4/2) and light brown (5YR5/6); silt is present as sparse laminae a few grains thick or as disseminated grains; petroliferous; parts into brittle plates 1 to 10 mm thick. Lower contact is abrupt and planar. Top of unit is overgrown with grass and trees. Contains large, black, spheroidal to ovoid carbonate concretions 4 to 5 feet in diameter. Unit is a conspicuous bed of shale, which is more resistant to weathering than the interbedded units exposed. Foerstia found near base of unit.....	24.0	24.0
Middle part of Huron Member (incomplete 30.3 ft+):		

Units 1 through 49 consist of an intercalation of medium-gray (N4-N5) shale with very dark gray (N2) and black (N1) shales. The medium-gray shales contain small amounts of disseminated silt and weather dark reddish brown (10R3/4) and light brown (5YR5/6). The shale typically parts in plates 1 to 6 mm thick below unit 30. Above unit 30, partings are 1 to 20 mm thick. Units weather and produce blocky, tabular, or platy weathering expressions. White and yellow sulfate minerals are common on weathered surfaces. Thin coatings of sulfate minerals are commonly found on weathering surfaces. Pyrite is seldom seen. The medium-gray shale beds are less resistant to weathering than the dark shales and are plastic when wet and weathered. The dark-shale beds weather grayish red (10R4/2) to light brown (5YR5/6). They part in 1- to 6-mm-thick brittle plates. Silt is present both as dissemi-

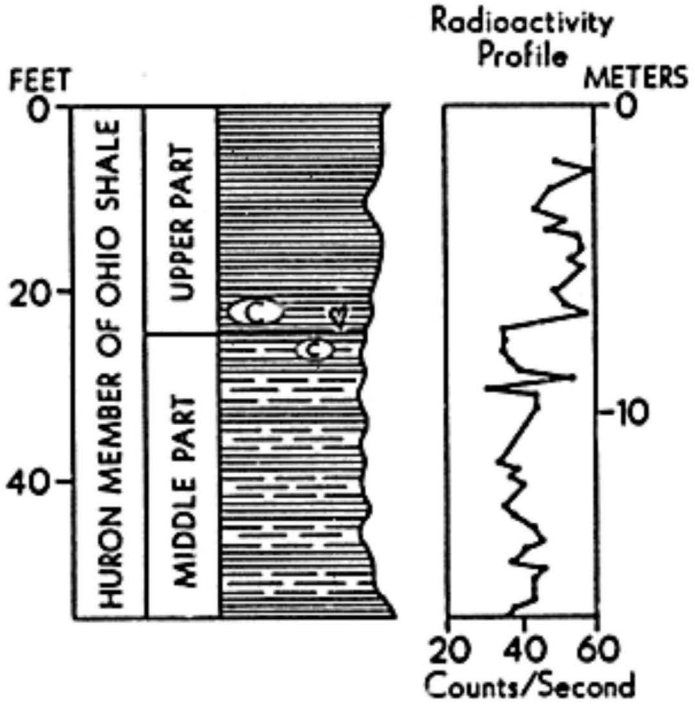


Figure 6. Lithologic and radioactivity profiles of the Huron River section (locality 1, fig. 1).

nated grains and as thin white to light-gray laminae a few grains thick. Contacts between the beds of light and dark shale are abrupt. Individual beds are laterally continuous and have uniform thickness except in the lower 10 feet of the section where they commonly pinch and swell and where light and dark shales intertongue. Although bedding contacts in the upper parts of unit 1 through 49 are planar or slightly undulatory, near the base of the section amplitudes are commonly 6 or 8 inches and some are greater, and wavelengths are from 6 to 20 feet. A few high-angle soft-sediment faults are present in the lowermost 10 feet.

Described below are thicknesses of beds 1 through 49 and features of individual beds that are exceptions to the generalized descriptions given above.

Devonian--continued: Ohio Shale--continued: Middle part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
49. Shale, medium-gray, containing sparse globular pyrite and some fine-grained, medium-gray, carbonate concretions that have the form of flattened spheroids as much as 2 ft in diameter and 1 ft thick	1.7	25.7
48. Shale, black	0.2	25.9
47. Shale, medium-gray	0.6	26.5
46. Shale, black	0.1	26.6
45. Shale, medium-gray	0.5	27.1
44. Shale, black	0.2	27.3
43. Shale, medium-gray	0.4	27.7
42. Shale, black	0.2	27.9
41. Shale, medium-gray	0.7	28.6
40. Shale, black	0.1	28.7
39. Shale, medium-gray	0.1	28.8

Devonian--continued: Ohio Shale--continued: Middle part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
38. Shale, black	0.2	29.0
37. Shale, medium-gray	0.2	29.2
36. Shale, black	0.1	29.3
35. Shale, medium-gray	0.1	29.4
34. Shale, black, sparse pyrite	0.8	30.2
33. Shale, medium-gray	0.9	31.1
32. Shale, black	0.2	31.3
31. Shale, medium-gray	0.4	31.7
30. Shale, black	1.9	33.6
29. Shale, medium-gray, containing 5 percent black shale laminae	5.3	38.9
28. Shale, black	0.2	39.1
27. Shale, medium-gray	0.2	39.3
26. Shale, black	0.2	39.5
25. Shale, medium-gray, containing 5 percent black shale laminae, which pinch and swell	2.2	41.7
24. Shale, black	0.4	42.1
23. Shale, medium-gray	0.2	42.3
22. Shale, black	1.0	43.3
21. Shale, medium-gray	0.1	43.4
20. Shale, black	0.2	43.6
19. Shale, medium-gray	0.2	43.8
18. Shale, black	0.3	44.1

Devonian--continued: Ohio Shale--continued: Middle part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
17. Shale, medium-gray, containing 5 percent black shale laminae, which are laterally undulose and uniform in thickness	1.3	45.4
16. Shale, black	0.2	45.6
15. Shale, medium-gray	0.7	46.3
14. Shale, black	0.7	47.0
13. Shale, medium-gray	0.2	47.2
12. Shale, black	0.8	48.0
11. Shale, medium-gray	0.2	48.2
10. Shale, black	0.3	48.5
9. Shale, medium-gray	1.3	49.8
8. Shale, black	0.6	50.4
7. Shale, medium-gray	0.8	51.2
6. Shale, very dark gray	0.5	51.7
5. Shale, medium-gray	0.5	52.2
4. Shale, black	0.3	52.5
3. Shale, medium-gray	0.3	52.8
2. Shale, black	0.3	53.1
1. Shale, medium-gray, containing 5 percent thin to very thin black-shale beds, which are laterally undulose lenses 1 to 4 ft long and as thick as 0.1 to 0.3 ft	1.2	54.3

Drill Hole at Prout Station, Erie County, Ohio

(Locality 2, fig. 1)

The lower part of the Huron Member of the Ohio Shale and the Olentangy Shale (fig. 7) are represented in core from Prout Station, in lot Q-3 of Oxford Township, Kimball quadrangle, Erie County, Ohio, 1 1/2 miles east of Bloomingville (Ohio Coordinate System: North Zone, 1,946,400 ft E, 613,550 ft N). Surface elevation: approximately 697 feet. The hole was drilled in 1957 by the Ohio Division of Geological Survey. Logged by R.C. Kepferle and R.F. Broadhead on May 3, 1979. Cored interval 9-130 ft.

	Thickness (feet)	
	Unit	Cumulative
Devonian (incomplete, 121 ft+):		
Ohio Shale (incomplete, 51.8 ft+):		
Lower part of Huron Member (incomplete, 51.8 ft+):		
12. Shale, medium-dark-gray (N4) to dark-gray (N3) containing abundant Tasmanites and rare pyrite. A bed of greenish-gray (5G5/1) shale 0.1 ft thick is present at 15.5 ft	8.6	8.6
11. Shale, dark-gray (N3), 50 percent, and greenish-gray (5G5/1), 50 percent. Bed thickness ranges from less than 0.1 ft to as much as 0.4 ft. Lower contacts of gray shales are burrowed. Black shales contain abundant Tasmanites and have sharp planar bases	3.7	12.3
10. Shale, greenish-gray (5G5/1), 70 percent, and dark-gray (N3), 30 percent; beds range in thickness from less than 0.1 to 0.6 ft. Basal contacts of gray shales are burrowed. Black shales contain abundant Tasmanites and have sharp and planar lower contacts	7.3	19.6
9. Shale, dark-gray (N3), 60 percent intercalated with greenish-gray shale (5G5/1), 40 percent, in beds mostly thinner than 0.05 ft but with some as thick as 1 ft. The black shales are burrowed and contain abundant Tasmanites	12.0	31.6

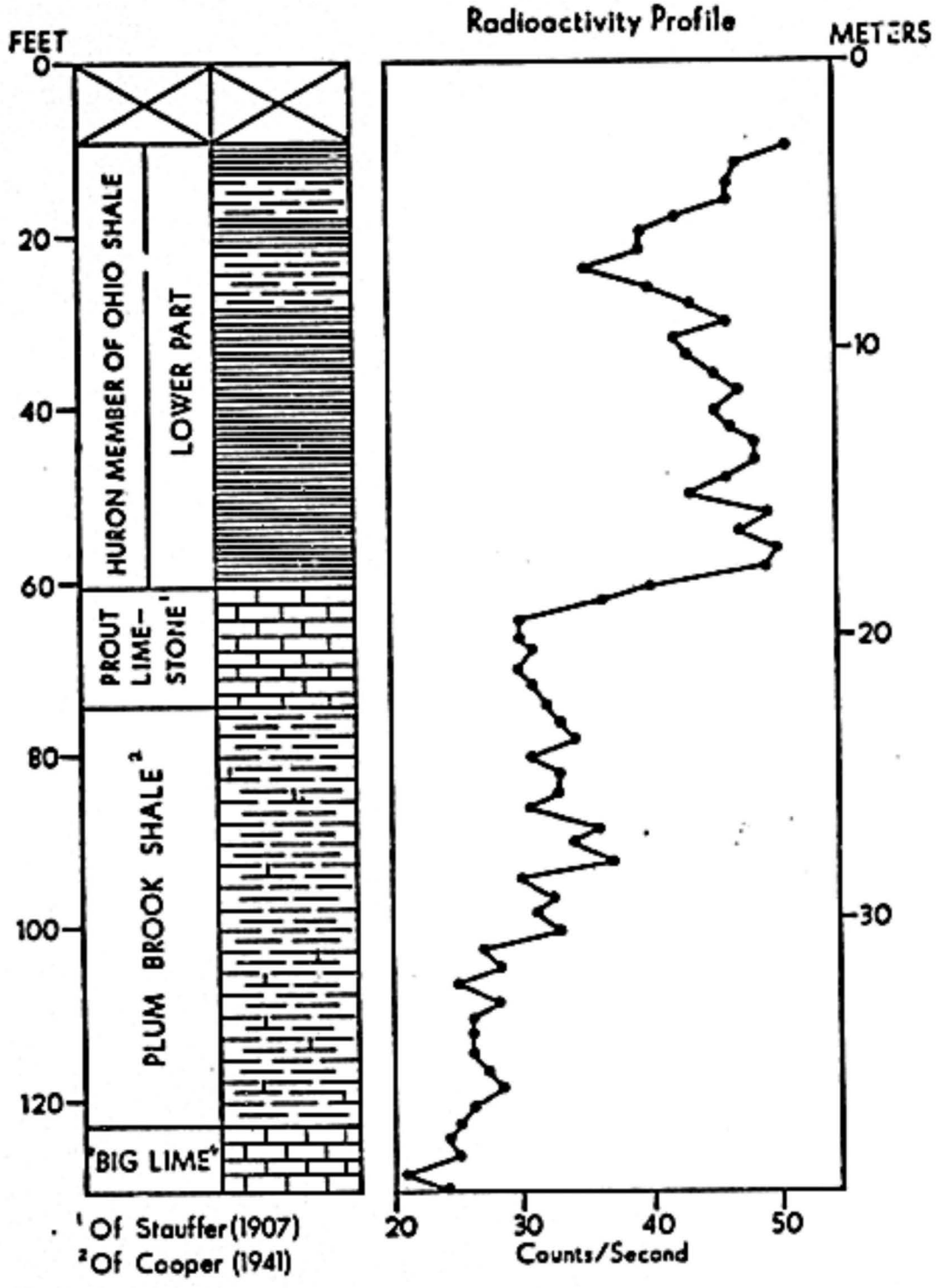


FIGURE 7. Lithologic and radioactivity profiles of the diamond drill core at Prout Station (locality 2, fig. 1).

Devonian--continued:	Thickness (feet)	
Ohio Shale--continued:		
Lower part of Huron Member--continued:	Unit	Cumulative
8. Shale, dark-olive-gray (5Y3/1), pyritic, and some interlaminated greenish-gray shale. Contains common to locally abundant thin calcareous silt laminae and abundant Tasmanites. The base of unit 8 is sharp, planar, pyritic, and glauconitic	20.2	51.8
Prout Limestone of Stauffer (1907) (15.5 ft):		
7. Limestone, light-olive-gray (5Y6/1) vuggy calcirudite	5.0	56.8
6. Limestone (wackestone of Dunham, 1962), olive-gray (5Y5/1) containing pyritized brachiopods and some small chert nodules	1.6	58.4
5. Limestone (mudstone of Dunham, 1962, grading down to wackestone), medium-light-gray (N6) containing thin-shelled brachiopods and small corals	3.8	62.2
4. Limestone (mudstone of Dunham, 1962, grading down to a wackestone), medium-light-gray (N6) containing thin-shelled brachiopods and small corals	3.9	66.1
3. Limestone (mudstone of Dunham, 1962, at top grading to wackestone at base), medium-light-gray (N6) containing thin-shelled brachiopods and small corals	1.2	67.3
Plum Brook Shale of Cooper (1941) (46.7 ft):		
2. Shale, medium-gray (N5), calcareous, containing bryozoans, corals, crinoids, and brachiopods; increasingly calcareous downward. A pyrite layer 0.2 ft thick is present at 109.8 ft	46.7	114.0

Devonian--continued: "Big Lime" (incomplete, 7 ft+):	Thickness (feet) Unit	Cumulative
1. Limestone (wackestone of Dunham, 1962), olive-gray (5Y5/1), siliceous, and fossiliferous, containing abundant brachiopods. Base of unit not reached in core	7.0	121.0

Drill Hole B-19, Erie County, Ohio

(Locality 3, fig. 1)

Drill hole B-19 of the Erie County Nuclear Power Plant is about 1.5 miles northeast of Berlin Heights, Berlin Township, Berlin Heights quadrangle, Erie County, Ohio (Ohio Coordinate System: North zone, 2,006,989 ft E, 611,971 ft N); it was completed November 8, 1978. The core includes the Three Lick Bed of the Ohio Shale (incomplete), the Huron Member of the Ohio Shale, and the Olentangy Shale (incomplete), from a surface elevation of 656.5 feet (fig. 8). Logged and sampled by R.C. Kepferle, R.F. Broadhead, and G. Hinterlong on December 6, 1978.

Devonian (incomplete): Ohio Shale (incomplete 273 ft+): Three Lick Bed (incomplete 41.8 ft):		
15. Clay, silty, mottled light gray and orange	4.0	4.0
14. Shale, gray, badly weathered	1.5	5.5
13. Shale, dark-gray (N3), 95 percent; interbedded with 5 percent thin, 0.1-ft-thick, greenish-gray shale. Dark-gray shale contains a few gray silt laminae and abundant Tasmanites. Contacts between dark and light shales are sharp. A gray, cone-in-cone limestone bed, 0.1 ft thick, is at 12.5 feet	21.7	27.2

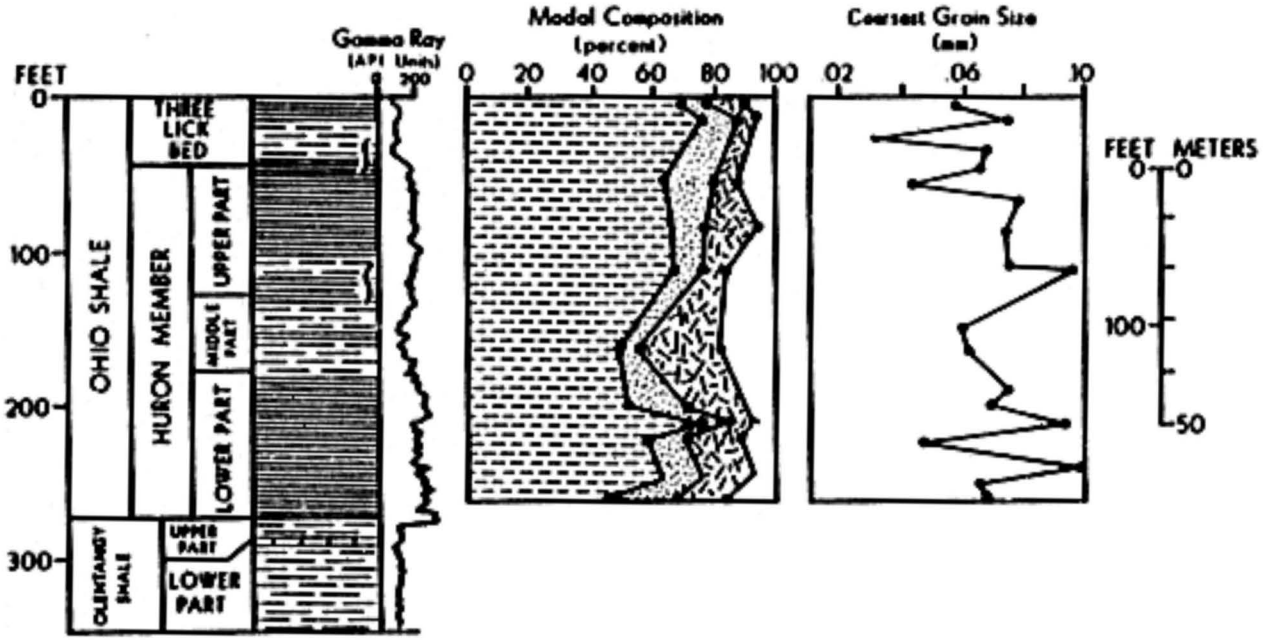


Figure 8. Gamma-ray log and lithologic and petrologic profiles of drill hole B-19, Erie County Nuclear Power Plant (locality 3, fig. 1).

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	Cumulative
12. Shale, medium-gray (N5), 50 percent, and 50 percent olive-black (5Y2/1) shale in thin beds, 0.2 to 0.3 feet thick. Gray shale contains abundant Tasmanites and flattened horizontal burrows. Black shale is pyritic. At 33.3 ft there is a light gray cone-in-cone limestone layer 0.1 ft thick, and at 36.0 ft a 0.1-ft-thick swelling clay	14.6	41.8
Upper part of Huron Member (91.7 ft):		
11. Shale, dark-gray (N3), silty pyritic, containing abundant Tasmanites. Very thin silt laminae exist at 45.5 and 60.1 feet. A few medium-gray (N5) shale beds 0.05 to 0.3 ft thick are present throughout the unit and have abrupt slightly undulose contacts with the dark-gray shale; a few contacts are burrowed. Cone-in-cone limestone layers, each 0.1 ft thick, are at 48.2 and 57.4 feet .	72.4	114.2
10. Shale, medium-gray (N5), 55 percent, thinly interbedded with pyritic, dark-gray (N3) shale beds, which are 0.1 to 1.5 ft thick. Contacts are abrupt	4.1	118.3
9. Shale, olive-black (5Y2/1) and pyritic, 99 percent; contains abundant Tasmanites and is interbedded with a few 0.01- to 0.3-ft-thick beds of medium-gray (N5) shale	15.2	133.5
Middle part of Huron Member (46.9 ft):		
8. Shale, medium-gray (N5), 60 percent, and 40 percent thin interbeds of olive-black (5Y2/1) shale, 0.03 to 0.05 ft thick. Both shale types are pyritic and have abrupt contacts. A thin siderite nodule is present at 145.15 ft and many		

Devonian--continued: Ohio Shale--continued: Middle part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
thin silt laminae are present at 180.3 ft. Top of unit contains a few flattened horizontal burrows	46.9	180.4
Lower part of Huron Member (92.8 ft):		
*7. Shale, olive-black (5Y2/1), 98 percent, silty and pyritic, with a few olive-gray (5Y4/1) shale interbeds, 0.1 to 0.5 ft thick. The interbeds contain horizontal burrows filled with black shale. Very thin silt laminae, generally more than 1 cm apart, are abundant. A 0.3-ft-thick silt layer having an irregular base is at 203.25 ft	25.0	205.4
6. Shale, olive-black (5Y2/1), 80 percent; interbeds of medium-gray (N5) shale, 20 percent, typically range from 0.05 to 0.4 ft in thickness. Black shale is pyritic and contains abundant Tasmanites. Most of the lower contacts are sharp, although a few are gradational. A thin vitrinite layer is at 236.2 ft and two 1-cm-thick silt laminae are at 229.6 and 231.8 ft	40.4	245.8
**5. Shale, olive-black (5Y2/1), 95 percent; medium-gray (N5) shale, 5 percent in beds 0.1 to 0.2 ft thick. Black shale contains abundant Tasmanites and is pyritic. All gray shale beds are bioturbated and have black burrow fillings. Thin pyritic silt layers are present at 251.55, 258.75, 262.35, and 265.00 feet	27.4	273.2

* USGS (U.S. Geological Survey) collection 9981-SD from 205.1-205.3 ft, near base, contains conodont elements Palmatolepis glabra (Anita G. Harris, written communication, Jan. 19, 1979).

** USGS collection 9974-SD from 254.4 ft contains the linguloid brachiopod Barroisella? (J. T. Dutro, Jr., written communication, Dec. 22, 1978).

Devonian--continued	Thickness (feet)	
Olentangy Shale (incomplete, 72.8 ft):		
Upper part (10.8 ft):	Unit	Cumulative
4. Shale, greenish-gray (5GY6/1), 75 percent; olive-black (5Y2/1) shale, 25 percent, in beds 0.01 to 0.1 ft thick. Gray shale is silty and pyritic, and contains fish plates. Carbonate nodule near upper contact is 0.7 ft thick. Contacts between gray and black shales are sharp and planar	10.8	284.0
Lower part (incomplete 62.0 ft+):		
3. Shale, medium-gray (N5), calcareous	3.1	287.1
*2. Limestone, medium-dark-gray (N4), finely crystalline, fossiliferous, containing brachiopods	3.7	290.8
1. Shale, medium-gray (N5), calcareous, and uniform. Reported show of gas at bottom of hole, 346 ft	55.2	346.0

Vermilion River section, Lorain County, Ohio

(Locality 4, fig. 1)

The Bedford Shale, the Cleveland Member of the Ohio Shale, and part of Three Lick Bed are exposed along incised meanders of the Vermilion River in Brownhelm Township, Vermilion East quadrangle, Lorain County, Ohio (fig. 9). Base of section is on the west bank of the Vermilion River just north of its intersection with U.S. Highway 2 (Ohio Coordinate System: North Zone, 2,046,200 feet E, 633,200 feet N). The lower 55.6 ft were measured there. The upper 72.3 feet of section were measured about 2 miles to the south

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* USGS collection 9975-SD from this unit contains conodonts and brachiopods equivalent to those in zone F of Plum Brook Shale of Cooper (1941) (written communications, J. T. Dutro, Jr., Dec. 22, 1978; A. G. Harris, Jan. 19, 1979).

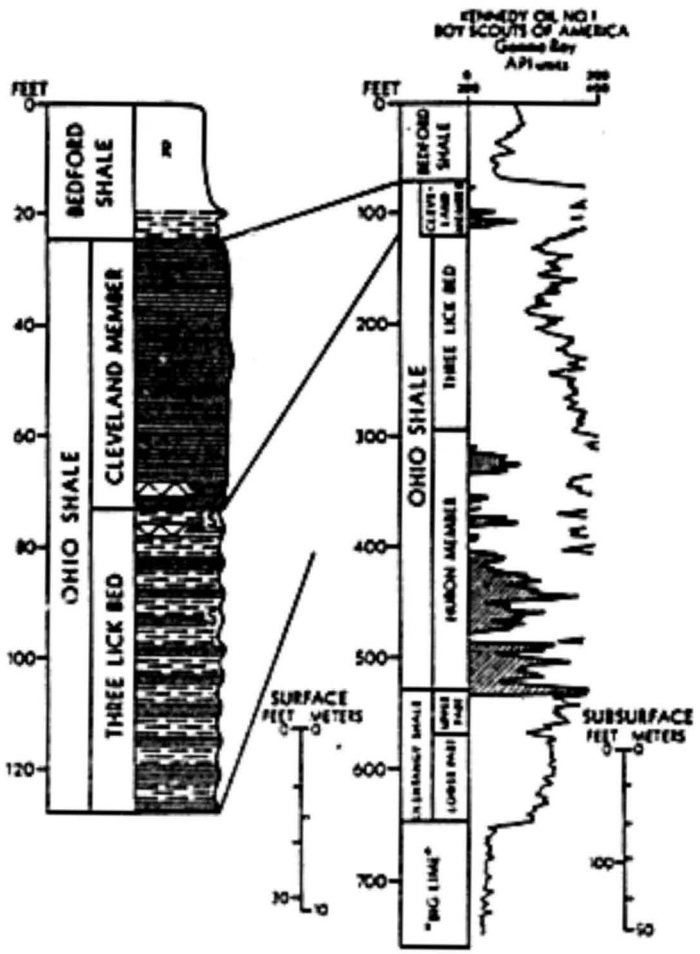

Figure 9. Lithologic profile of the Vermilion River section (locality 4, fig. 1) and correlation with gamma-ray log of the Boy Scouts of America drill hole No. 1 of the Kennedy Oil Co., located about 1 mile from the section.

on the east bank of the river in Mill Hollow Bacon Woods Park (Ohio Coordinate System: North Zone, 2,051,600 ft E, 624,300 ft N). Because of the steep and hazardous nature of the cliff in the park, the Bedford Shale was described only generally, and thicknesses of the Bedford are only approximate. The top of the section is vegetated. Section measured with hand level and tape by R.F. Broadhead on August 26 and 27, 1978.

	Thickness (feet)	
	Unit	Cumulative
Mississippian and Devonian (incomplete):		
Bedford Shale (incomplete 24.3 ft+):		
42. Shale, grayish-red (5R3/ 2), silty, 3- to 6-mm-thick tabular partings	20.0	20.0
41. Siltstone, medium-gray (N5) laterally traceable along meander cuts for at least 0.5 mile	0.3	20.3
40. Shale, medium-gray (N5)	4.0	24.3
Devonian (incomplete):		
Ohio Shale (incomplete):		
Cleveland Member (48.0 ft):		
39. Shale, black (N1), weathers to a dark yellowish-orange (10YR6/6) coating of sulfides. Silt is present as thin laminae a few grains thick and as disseminated grains. Some small, thin medium-dark-gray (N4) cone-in-cone limestone lenses are in the lowermost 10 feet (0.1 ft thick and 2 to 4 ft long). Lower contact is abrupt and defines a very gentle syncline	48.0	72.3
Three Lick Bed (incomplete 55.6 ft+):		

Units 1 through 38 are in the Three Lick Bed of the Ohio Shale, an interbedded unit of medium-gray shales alternating with dark-gray silty shales and a few siltstones and bluish-gray clay shales. The light-colored shales are medium gray (N4-N5), weather dark yellowish orange (10YR6/6) and moderate brown (5YR3/4),

are slightly silty, and weather to form 2- to 9-mm-thick platy, tabular, and blocky chips. The shales are plastic when wet and are less resistant to weathering than are the dark-gray shales. Dark shales are dark gray (N3) to grayish black (N2), are silty, weather dark yellowish orange (10YR6/6) and very dusky red (10R2/2), and typically part into 1- to 5-mm-thick brittle plates. Most boundaries between shale beds are abrupt, but a few are gradational in color. Beds are laterally continuous along the length of the outcrop, a distance of more than 200 feet.

Described below are thicknesses of the individually measured beds 1 through 38 and features of individual beds that differ from the generalized descriptions given above. Because of the hazardous and steep nature of the outcrop, unit 38 was described only in a general manner.

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	Cumulative
38. Shale, medium-gray, silty (60 percent), interbedded with dark-gray shale (35 percent) and siltstone (5 percent). Medium-gray shale forms beds 0.8 to 1.6 ft thick, dark shale forms beds 0.5 to 0.7 ft thick, and siltstone forms beds 0.1 ft thick. Also present are some medium-light-gray (N6) cone-in-cone limestone lenses 0.3 ft thick and 3 ft wide	8.0	80.3
37. Shale, dark-gray	0.3	80.6
36. Shale, medium-gray	0.7	81.3
35. Shale, dark-gray	0.5	81.8
34. Shale, medium-gray	0.2	82.0
33. Siltstone, medium-light-gray (N6), internally homogeneous, with abrupt upper and lower contacts	0.1	82.1

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	Cumulative
32. Shale, medium-gray	1.6	83.7
31. Shale, dark-gray	0.5	84.2
30. Shale, medium-gray	0.3	84.5
29. Siltstone, medium-light-gray (N6), abrupt upper and lower contacts	0.2	84.7
28. Shale, medium-gray, containing 10 percent dark-gray shale laminae.....	3.3	88.0
27. Shale, dark-gray	0.6	88.6
26. Shale, light-bluish-gray (5B7/1) clay shale	0.4	89.0
25. Shale, dark-gray	1.0	90.0
24. Shale, medium-gray	0.7	90.7
23. Shale, dark-gray	1.3	92.0
22. Shale, medium-gray	0.7	92.7
21. Shale, dark-gray	1.8	94.5
20. Shale, medium-dark-gray (N4), containing 5 laterally undulose, nodular, yellowish-gray (5Y7/2) sideritic beds 0.2 ft thick which weather dark yellowish orange (10YR6/6) and very dusky red (5R2/6)	5.2	99.7
19. Shale, dark-gray	13.5	113.2
18. Shale, light-bluish-gray (5B7/1), clayey	0.1	113.3
17. Shale, medium-dark-gray (N4), containing 10 percent 0.1 to 0.2 ft thick beds of dark-gray shale. Lower contact gradational	4.2	117.5
16. Shale, dark-gray	0.9	118.4

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	Cumulative
15. Shale, medium-gray	0.2	118.6
14. Shale, dark-gray	0.1	118.7
13. Shale, medium-gray (N5)	0.2	118.9
12. Shale, medium-dark-gray (N4)	1.9	120.8
11. Shale, dark-gray, lower contact gradational	1.2	122.0
10. Shale, medium-gray	1.4	123.4
9. Siltstone, medium-light gray (N6), internally homogeneous, sideritic. Lower contact abrupt and slightly undulose, upper contact abrupt and planar	0.2	123.6
8. Shale, medium-gray	0.5	124.1
7. Siltstone, medium-light-gray (N6), internally homogeneous, sideritic. Abrupt and planar upper and lower contacts ...	0.2	124.3
6. Shale, medium-gray	0.5	124.8
5. Siltstone, medium-light-gray (N6), internally homogeneous, sideritic, containing subvertical and horizontal tubular burrows a few millimeters in diameter on the sole and inside the bed. Abrupt and planar upper and lower contacts	0.2	125.0
4. Shale, medium-gray	0.1	125.1
3. Siltstone, medium-to light-gray (N6), sideritic calcareous, and pyritic. Internal parallel, slightly undulose laminae (Bouma unit Tbc) having amplitudes of 3 to 5 mm and wavelengths of 5 cm. Contains many vertical to horizontal tubular branching burrows a few millimeters in diameter on the sole and inside the bed	0.3	125.4

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	Cumulative
2. Shale, medium-gray	1.0	126.4
1. Shale, dark-gray. Base not exposed	1.5	127.9

Drill Hole K-6268 B-1, Lorain, Ohio

(Locality 5, fig. 1)

Drill hole K-6268 B-1 was drilled in the city of Lorain, Sheffield Township, Lorain quadrangle, Lorain County, Ohio, on April 26 and 27, 1978 by Herron Testing Labs of Cleveland for foundation studies for a transmission line tower of the United States Steel Corporation. The exact location is unknown. Nineteen feet of core were taken from a depth of 11 ft to 30 ft. Logged and sampled on December 14, 1978 by R.F. Broadhead.

	Thickness (feet) Unit	Cumulative
2. No core	11.0	11.0
Devonian (incomplete): Ohio Shale (incomplete): Cleveland Member (incomplete):		
1. Shale, dark-gray (N3), silty, homogeneous, fractured, pyritic	19.0	30.0

Avon Drill Hole No. 3, Lorain County, Ohio

(Locality 6, fig. 1)

Avon drill hole No. 3 was completed on September 26, 1949, as a salt test for the International Salt Company. The drill hole is approximately 2 miles west of Bay Village in Avon Township, North Olmsted quadrangle, Lorain County, Ohio (Ohio Coordinate System: North Zone, 2,141,000 ft E, 660,000 ft N), surface elevation, 628 ft. Coring commenced at a depth of 50 feet in the Cleveland Member of the Ohio Shale and continued to a total depth of 1673 feet in Silurian rocks. Devonian shale logged by R.F. Broadhead and R.C. Kepferle on May 2 and 3, 1979 (fig. 10).

	Thickness (feet)	
	Unit	Cumulative
43. No core	50.0	50.0
Devonian (incomplete):		
Ohio Shale (incomplete, 699 ft+):		
Cleveland Member (incomplete, 48 ft+):		
42. Shale, dark-gray (N3) to olive-black (5Y2/1), 95 percent and very thin beds less than 0.01 ft thick of greenish-gray (5GY5/1) shale and sparse silt laminae a few millimeters thick	48.0	98.0
Three Lick Bed (283 ft):		
41. Shale, greenish-gray (5GY5/1), 75 percent and thin beds of light-gray (N7) siltstone, 10 percent, and thin beds of dark-gray (N3) shale, 5 percent. Siltstones are cross-laminated and slightly calcareous. Shale from 112 ft to 116 ft is burrowed	28.0	126.0
40. Shale, dark-gray (N3), 80 percent and thin beds of greenish-gray (5GY5/1) shale, 15 percent, and thin silt laminae, 5 percent. The silt laminae are in the lower part of the unit	24.0	150.0

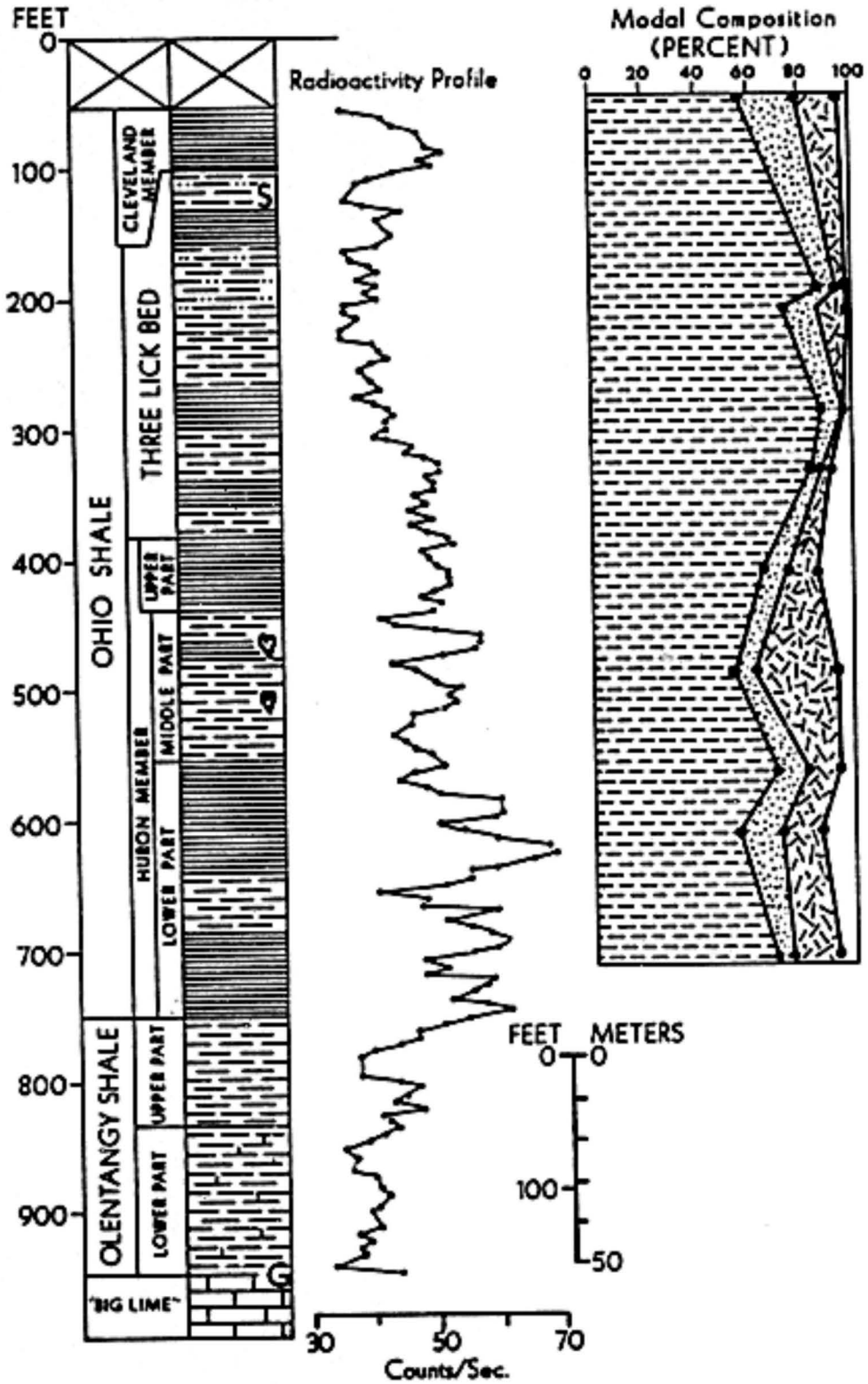

Figure 10. Lithologic, radioactivity, and petrologic profiles of the Avon drill hole No. 3 of the International Salt Co. (locality 6, fig. 1).

Devonian--continued:	Thickness (feet)	
Ohio Shale--continued:		
Three Lick Bed--continued:	Unit	Cumulative
39. Shale, greenish-gray (5GY5/1), 75 percent, interbedded with dark-gray (N3) shale, 10 percent, siltstone, 10 percent and sideritic layers, 5 percent. Shale beds are less than 0.3 ft thick	58.0	208.0
38. Shale, greenish-gray (5GY5/1), 65 percent intercalated with thin siltstone, 20 percent, dark-gray (N3) shale, 10 percent, and thin sideritic bands, 5 percent	9.0	217.0
37. Shale, greenish-gray (5GY5/1), 90 percent, interlaminated with dark-gray (N3) shale, 10 percent, and sparse thin siltstones and sideritic layers. A few Lingula are present	59.0	276.0
36. Shale, greenish-gray (5GY5/1), 80 percent, and beds of dark-gray (N3) shale, 20 percent, and a few sideritic bands and thin silt laminae. Dark-gray shale beds and sideritic bands are less than 0.1 ft thick	22.0	298.0
35. Shale, dark-gray (N3), 60 percent, and 0.2 ft thick beds of greenish-gray (5GY5/1) shale, 40 percent	27.0	325.0
34. Shale, greenish-gray (5GY5/1), 60 percent, and dark-gray (N3) shale, 40 percent, and a few thin silt laminae. Some silt laminae are calcareous and others are sideritic	17.0	342.0
33. Shale, dark-gray (N3), 70 percent, and greenish-gray (5GY5/1), 30 percent	16.0	358.0
32. Shale, dark-gray (N3), 90 percent, and greenish-gray (5GY5/1), 10 percent	23.0	381.0
Upper part of Huron Member (57 ft):		
31. Shale, dark-olive-gray (5Y3/1); grades downward to olive black (5Y2/1). Shale		

Devonian--continued: Ohio Shale--continued: Upper part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
contains abundant Tasmanites, many fish scales, a few olive-gray shale laminae, and a cone-in-cone limestone layer 1 cm thick at 397 ft	57.0	438.0
Middle part of Huron Member (111 ft):		
30. Shale, olive-black (5Y2/1), 50 percent, and greenish-gray (5GY5/1) in beds 0.1 to 0.4 ft thick	10.0	448.0
29. Shale, olive-black (5Y2/1) containing small pyrite nodule at 457 ft and a few Eurypterid claws. Top of Foerstia zone is at 463 ft	18.0	466.0
28. Shale, greenish-gray (5GY5/1), 80 percent, siltstone, 10 percent, and olive-black (5Y2/1) shale, 10 percent. Most shale beds are less than 0.2 ft thick, but some are as thick as 0.3 ft	18.0	484.0
27. Shale, greenish-gray (5GY5/1), 50 percent, and olive-black (5Y2/1), 50 percent ...	14.0	498.0
26. Shale, greenish-gray (5GY5/1), 60 percent, and olive-black (5Y2/1), 40 percent ...	3.0	501.0
25. Shale, olive-black (5Y2/1), 80 percent, and greenish-gray (5GY5/1), 20 percent. Base of Foerstia zone is at 508 feet ..	8.0	509.0
24. Shale, greenish-gray (5GY5/1), 80 percent and olive-black (5Y2/1), 20 percent. Gray shale beds are as thick as 0.5 ft and black shale beds are less than 0.1 ft thick. Contacts between gray and black shales are sharp and planar. Tasmanites and pyrite are abundant in the black shale	40.0	549.0
Lower part of Huron Member (200 ft):		
23. Shale, grayish-black (N2), 90 percent, intercalated with greenish-gray (5GY5/1) shale, 10 percent, in thin beds. Grayish-black shale has about 10 very thin		

Devonian--continued: Ohio Shale--continued: Lower part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
calcareous laminae per 0.1 ft	2.8	551.8
22. Limestone (mudstone of Dunham, 1962, Table 1), dark-gray (N3) containing abundant burrows (Chondrites)	0.4	552.2
21. Shale, grayish-black (N2), 60 percent, and greenish-gray (5GY6/1) shale, 40 percent. Shale beds are as thick as 0.5 ft and contacts between black and gray beds are sharp and planar. Black shale is faintly laminated with slightly lighter and darker colors and contains a few thin calcareous laminae. A calcite concretion from 561 to 562 ft is medium light gray (N6), coarse grained, pyritic, fossiliferous, and faintly laminated ..	22.8	575.0
20. Shale, grayish-black (N2), 95 percent, and beds of greenish-gray (5GY5/1) shale, 5 percent, that are as thick as 0.5 ft. The black shale is faintly laminated and contains abundant Tasmanites	20.0	595.0
19. Shale, grayish-red (10R5/2), 80 percent, thinly interbedded with grayish-black (N2) shale. Grayish-red shale is pyritic and contains a few thin silt laminae. A gray calcite concretion is present from 602.5 to 603 ft	18.0	613.0
18. Shale, brownish-black (5YR2/1) containing sparse Tasmanites and a few thin, burrowed greenish-gray shale laminae	14.0	627.0
17. Shale, greenish-gray (5GY6/1), 80 percent, and pyritic brownish-black (5YR2/1) shale. Lower contacts of gray shales are heavily burrowed and upper contacts of gray shales are sharp and planar	9.0	636.0
16. Shale, brownish-black (5YR2/1), 90 percent, and thin beds of greenish-gray (5GY6/1) shale, 10 percent. Lower contacts of gray shales are burrowed and basal contacts of black shales are abrupt and planar	9.0	645.0

Devonian--continued: Ohio Shale--continued: Lower part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
15. Shale, greenish-gray (5GY6/1), 90 percent, interbedded with brownish-black (5YR2/1) shale, 10 percent. Gray shale is pyritic and has burrowed basal contacts. Black shale has sharp, planar basal contacts	16.0	661.0
14. Shale, brownish-black (5YR2/1), 95 percent, and very thin beds of bioturbated greenish-gray (5GY6/1) shale, 5 percent	12.0	673.0
13. Shale, greenish-gray (5GY6/1), 50 percent, and brownish-black (5YR2/1) shale, 50 percent	5.0	678.0
12. Shale, greenish-gray (5GY6/1), 90 percent, interbedded with brownish-black (5YR2/1) shale, 10 percent	4.0	682.0
11. Shale, brownish-black (5YR2/1), 60 percent, intercalated with greenish-gray (5GY6/1) shale, 40 percent. Basal contacts of gray shales are burrowed and bases of black shale beds are sharp and planar	20.0	702.0
10. Limestone (mudstone of Dunham, 1962), greenish-gray	2.0	704.0
9. Shale, brownish-black (5YR2/1), 70 percent, interbedded with greenish-gray (5GY6/1) shale, 30 percent. Basal contacts of gray shales are burrowed. Black shales have abrupt and planar bases.	9.0	713.0
8. Shale, olive-black (5Y2/1), 90 percent, interbedded with greenish-gray (5GY6/1) shale, 10 percent. All black shale beds are less than 2 ft thick and all gray shale beds are less than 0.1 ft thick. Black shales contain sparse to locally abundant Tasmanites and sparse pyrite nodules and pyrite laminae	36.0	749.0
Total Huron Member of Ohio Shale		368 ft

Devonian--continued:	Thickness (feet)	
Olentangy Shale (196.5 ft):		
Upper part (81 ft):	Unit	Cumulative
7. Shale, greenish-gray (5GY5/1), 95 percent, and thin beds of olive-black (5Y3/1) shale and a few thin calcareous silt laminae. Black shale is pyritic and in thin beds which are separated by 1 to 2 ft of gray shale. Contacts between gray and black shales are gradational and burrowed. Thin beds of medium-light-gray (N6) limestone (mudstone of Dunham, 1962) at 755.5 ft and 765 feet are about 0.5 ft thick	22.0	771.0
6. Shale, greenish-gray (5GY6/1), 85 percent, olive-black (5Y2/1) shale, 13 percent, and greenish-gray limestone (mudstone of Dunham, 1962), 2 percent. Black shale beds are less than 0.2 ft thick. Contacts between black and gray shales are gradational. Gray shale contains small irregular calcite nodules (burrow fills?) less than 2 cm thick. The limestone beds are less than 0.2 ft thick	59.0	830.0
Lower part (115.5 ft):		
*5. Shale, medium-dark-gray (N4), pyritic, calcareous and fossiliferous, containing many thin-shelled brachiopods.....	50.5	880.5
4. Limestone (wackestone of Dunham, 1962), dark-olive-gray (5Y3/1), calcareous. Contains abundant thin-shelled brachiopods	0.5	881.0
3. Shale, medium-dark-gray (N4), calcareous. Contains abundant brachiopods	27.5	908.5
2. Shale, medium-dark-gray (N4), and dark-olive-gray (5Y3/1) alternating in beds less than 0.3 ft thick	37.0	945.5
Total Olentangy Shale		197 ft.

* USGS collection 10006-SD at 880 ft contains Ambocoelia cf. A. umbonata (Conrad) (J. T. Dutro, Jr., written communication, June 18, 1979).

Devonian--continued: "Big Lime" (incomplete, 10 ft+):	Thickness (feet) Unit	Cumulative
1. Limestone (wackestone to packstone of Dunham, 1962), light-brownish gray (5YR6/1) with abundant brachiopods. Pyrite and glauconite are concentrated on upper contact	10.0+	955.5+

Rocky River section, Cuyahoga County, Ohio

Locality 7, fig. 1)

The Cleveland Member and the Three Lick Bed of the Ohio Shale are exposed in a spectacular cliff on the east bank of the Rocky River just west of St. Joseph's Academy in the Rocky River Reservation, City of Rocky River, Lakewood quadrangle, Cuyahoga County, Ohio (Ohio Coordinate System: North Zone, 2,186,400 ft E, 653,400 ft N) (fig. 11). Top of section is vegetated and urbanized. Measured with hand level and tape by R.F. Broadhead on August 22 and 23, 1978.

Devonian (incomplete): Ohio Shale (incomplete): Cleveland Member (incomplete, 62 ft+):	Thickness (feet) Unit	Cumulative
10. Shale, dark-gray (N3), silty, weathers to blackish-red (5R2/2) fissile plates 3- to 15-mm-thick. Contains thin discontinuous wavy silt laminae 1- or 2-mm-thick. Also contains a few laterally continuous and uniform siltstone beds less than 0.1 ft thick having abrupt and planar upper and lower contacts. These bleach white upon weathering	56.0	56.0
9. Shale, medium-dark-gray (N4), 95 percent, and 5 percent medium-light-gray (N6) siltstone. Shale weathers very dusky red (10R2/2) and to 2- to 5-mm-thick plates, is silty and micaceous, and contains sparse brachiopods. Siltstones are in beds 0.05 to 0.1 ft thick, are micaceous,		

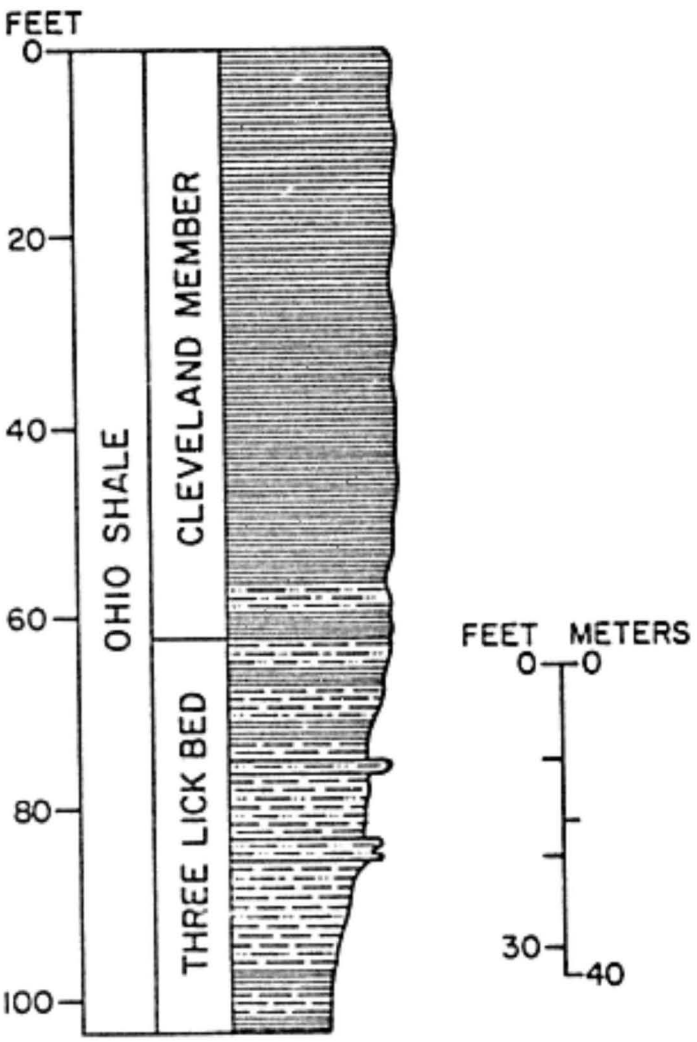

Figure 11. Lithologic profile of the Rocky River section (locality 7, fig. 1).

Devonian--continued: Ohio Shale--continued: Cleveland Member--continued:	Thickness (feet) Unit	 Cumulative
and weather to 2-mm-thick partings. They contain very thin wavy laminations and conodonts, molds of brachiopods, and irregular tubular, horizontal burrows a few millimeters in diameter. Lower contacts of siltstones are sharp and planar, marked by rare grooves; upper surfaces are rippled. Internally they are very thinly plane-parallel laminated near base, grading upward through wavy laminae to small-scale low-angle cross laminae (Ttc)	6.0	62.0
Three Lick Bed (incomplete, 40.9 ft+):		
8. Shale, medium-dark-gray (N4), 50 percent, interbedded with medium-gray (N5) shale, 45 percent, and medium-light-gray (N6) siltstone, 5 percent. Medium-gray shale is in beds 0.3 to 0.7 ft thick and is clayey and plastic when wet. Dark-gray shale is silty and parts into 2- to 6-mm-thick plates. It is also in beds 0.3 to 0.7 ft thick. Siltstone beds are 0.1 to 0.2 ft thick, are laterally continuous and uniform, and have sharp contacts with bounding shales; beds are either cross-laminated (Tc) throughout or are plane-parallel laminated in the lower half and cross-laminated at the top (Tbc)	12.7	74.7
7. Siltstone, medium-light-gray (N6), 90 percent, interbedded with dark-gray (N3) shale, 10 percent. Siltstone beds are less than 0.2 ft thick and laterally continuous and uniform; sharp plane-parallel lower contacts are marked by a few groove and load casts; upper contacts are sharp and rippled. Siltstone beds have undulose parallel laminae (Tb) near the base which grade up into small-scale cross-laminae and ripples (Tc). Shale interbeds are thinner than 0.1 ft ..	0.7	75.4

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	Cumulative
6. Shale, medium-light-gray (N6), and dark-gray (N3), in distinct laterally continuous and uniform interlaminae 2- to 8-mm-thick	0.7	76.1
5. Shale, medium-gray (N5), 90 percent, and intercalated siltstone, 10 percent. Shale is silty in beds 0.1 to 0.4 ft thick, weathers dark yellowish orange (10YR6/6); beds are thinner than 0.2 ft and are laterally continuous and uniform. They have a gradation from plane-parallel lamination (Tb) at the base to cross-lamination (Tc) near the top of the bed...	4.6	80.7
4. Shale, medium-gray (N5), 80 percent, interbedded with medium-light-gray (N6) siltstone, 20 percent. Shale is silty, contains very thin planar or lensoid silt laminae and weathers to dark-yellowish-orange (10YR6/6), 2- to 4-mm-thick fissile chips. Contacts with siltstones are sharp. Siltstone is micaceous in beds less than 0.1 ft thick, which are laterally continuous and uniform and have sharp, planar, groove-marked lower contacts. Beds are either internally cross-laminated (Tc) and have rippled upper surfaces or are plane-parallel laminated (Tb) and have planar upper contacts	2.1	82.8
3. Siltstone, light-greenish-gray (5Y8/1), 70 percent, and interbeds of medium-dark-gray (N4) shale, 30 percent. Siltstones are micaceous, weather moderate yellowish brown (10YR5/4) and contain abundant wood fragments (2 mm long x 0.5 mm wide) oriented parallel to bedding and concentrated in laminae. Some siltstones are calcareous; bed		

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	 Cumulative
are 0.1 to 0.3 ft thick, are laterally continuous, have sharp planar lower contacts marked by many grooves, and have abrupt rippled upper contacts. All beds have small-scale cross-lamination in the upper parts (some with slightly convolute cross-laminae; all tops of cross-sets are truncated) and contain parallel wavy laminae in the lower part (Tbc sequence of Bouma, 1962). In two beds, the rock is massive below the parallel laminae (sequence Tabc of Bouma, 1962). Some siltstones have tubular branching, linear or curving, horizontal burrows 1 cm in diameter on their soles; generic assignment is Paleodictyon. Shale is silty in thin laterally continuous beds less than 0.2 ft thick	1.7	84.5
2. Shale, medium-dark-gray (N4), 70 percent, and medium-light-gray (N6) siltstone, 30 percent. Dark-gray (N3), petroliferous, silty shale with very thin discontinuous silt laminae is present from 91.1 ft to 91.7 ft. Medium-dark-gray shale weathers to very-dusky-red (10R2/2) 5- to 7-mm-thick chips, which are plastic when wet and weathered, and contain very thin silt laminae. Shale beds are laterally continuous, dark reddish brown (10R3/4), and uniformly 0.1 to 1.1 ft thick. Siltstones are micaceous, and weather dark yellowish orange (10YR6/6). Siltstone beds are laterally continuous and uniform, 0.3 to 0.4 ft thick, have sharp lower contacts which are marked by flutes or grooves, and have abrupt upper contacts, most of which are lunate rippled but some are planar. Internally, siltstones are either plane-parallel laminated (Tb), ripple cross-laminated (Tc), or homogeneous (Ta). Sets of ripple cross-		

Devonian--continued: Ohio Shale--continued: Three Lick Bed--continued:	Thickness (feet) Unit	 Cumulative
laminae are festoons, having either truncated or tangential upper contacts; some are slightly convolute. Present in some beds is a sequence of homogeneous bedding at the base overlain by plane-parallel laminae and capped by ripple cross-laminae (Tabc). In most beds, the lower homogeneous part is not present. Several thin light-olive-gray (5Y6/1) sideritic bands are present in shale beds in the uppermost 2 ft and are slightly nodular, laterally continuous, and uniform	12.8	97.3
1. Shale, olive-black (5Y2/1) and medium-gray (N5), 90 percent, and interbeds of medium-light-gray (N6) siltstone, 10 percent. Shale weathers moderate brown (5YR4/4) in platy partings 3- to 9-mm-thick. The olive-black and medium-gray shale are interlaminated, but the olive-black shale predominates. Both shale types are silty and slightly calcareous; the gray shales contain very thin, lensoidal silt laminae. Beds are 0.1 to 1.8 ft thick and are laterally continuous. Siltstones are micaceous, weather moderate yellowish brown (10YR5/4); beds are laterally uniform and continuous, have abrupt lower contacts marked by grooves, and have sharp rippled upper contacts. Some ripples are flat topped. Beds contain wavy or plane-parallel laminae or are cross laminated. Cross-laminae are either tangential to or truncate upper contacts. Soles of siltstones are marked by small load casts, horizontal tubular branching burrows, and casts of resting traces and Cruziana (trilobite trails). Shale beds contain some ovoid light-olive-gray (5Y6/1) sideritic nodules, 2 to 5 cm thick and 10 to 15 cm wide	5.6	102.9

Cleveland No. 1 (Whiskey Island) Drill Hole, Cuyahoga County, Ohio

Locality 8, fig. 1)

The Cleveland No. 1 hole of the International Salt Company is on Whiskey Island in the City of Cleveland, Cuyahoga County, Ohio (Ohio Coordinate System: North zone, 2,141,400 ft E, 660,000 ft N). The hole was drilled as a salt test midway between the two shafts of the mine in 1955 and passes through all the Devonian shale sequence that is present in the area (fig. 12). Most of this sequence was cored. The following core description is derived mainly from a log made by Professor Paul Potter and J.A. Harrell and R.F. Broadhead of the University of Cincinnati and R.C. Kepferle of the U.S. Geological Survey on a visit to the Detroit Mine of the company, where the core is stored. The observations of the Cincinnati group were supplemented by a log made by a company geologist. Depths to formation tops were picked on the basis of the gamma-ray borehole log of the well.

	Thickness (feet)	
	Unit	Cumulative
Holocene and Pleistocene fill:		
8. Soft sand, silt, and clay containing scattered pebbles and a clay hardpan at 76 feet	106	106
Devonian:		
Ohio Shale:		
Three Lick Bed (incomplete, 169 ft+):		
7. Shale, greenish-gray (5GY5/1) to medium-gray (N5), 85 percent; thin beds of cross-laminated siltstones and grayish-red sideritic zones less than 0.1 ft thick, 5 percent; and brownish-gray (5YR4/1) shale in beds 0.1 ft thick, 10 percent. Abundant Tasmanites	169	275
Huron Member (400 ft):		
6. Shale, dark-gray (N2-N4), 50 percent; and medium-gray (N5) and greenish-gray (5GY4/1) shale in beds 0.05 to 0.3 ft thick. Abundant Tasmanites and sparse pyrite and wood fragments in the darker shale. Most contacts between the light and dark shale beds are burrowed; Foerstia at 350 feet	400	675

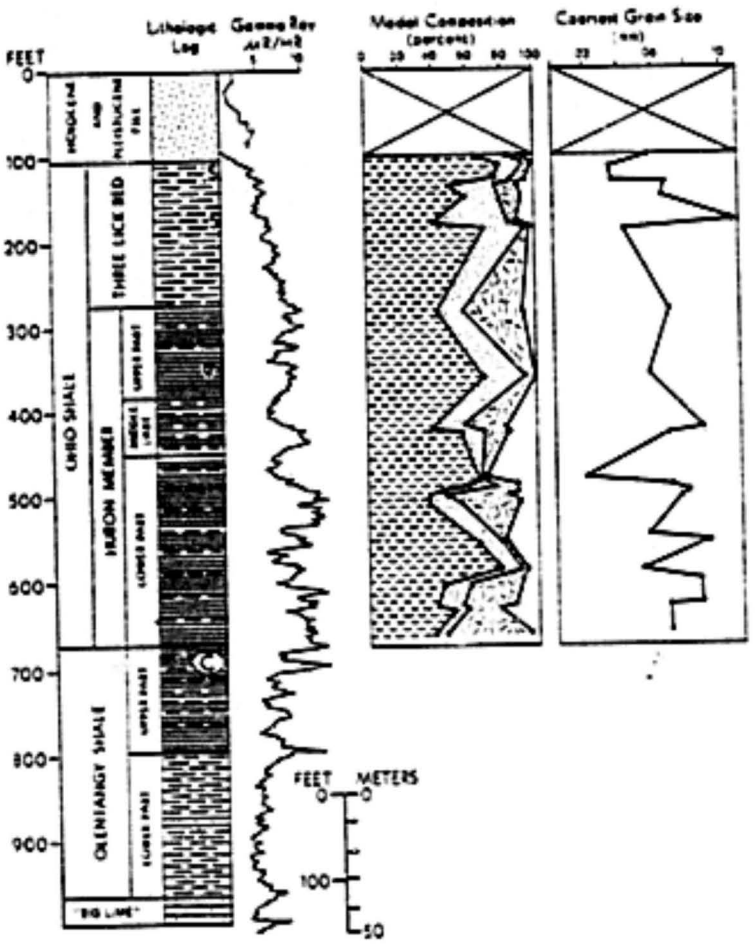

Figure 12. Lithologic column, gamma-ray borehole log, and petrologic profile of the Cleveland No. 1 (Whiskey Island) drill hole, International Salt Co. (locality 8, fig. 1).

	Thickness (feet)	
	Unit	Cumulative
Devonian		
Olentangy Shale (290 ft):		
Upper part (123 ft):		
Equivalent of Java and West Falls Formations, as differentiated below:		
Equivalents of Java Formation and Angola Shale Member of West Falls Formation (100 ft):		
5. Shale, black (N1), pyritic, containing 50 percent greenish-gray (5GY4/1) shale in laminae and beds as thick as 0.5 ft. Concretion from 702 to 703 ft has dark sparry carbonate filling and some sphalerite and/or barite. Shale from 707 to 775 ft is 90 percent light olive gray to greenish gray, pyritic and calcareous and contains 10 percent pyritic black shale in beds less than 0.4 ft thick. Most contacts between the green and black shales are mottled	100	775
Equivalent of Rhinestreet Shale Member of West Falls Formation (23 ft):		
4. Shale, black, pyritic, 80 percent, and 20 percent medium-gray to greenish-gray shale. Light-colored shales are in beds less than 1 foot thick, are calcareous, and contain sparse irregular masses of limestone	23	798
Lower part (167 ft):		
Equivalents of Mahantango Formation and Marcellus Shale, as differentiated below:		
Equivalent of Mahantango Formation (157 ft):		
3. Shale, light-gray (N7-N8), slightly calcareous, sparse pyrite, abundant brachiopods	157	955
Equivalent of Marcellus Shale (10 ft):		
2. Shale, dark-brown, pyritic, containing thin beds of dark-brown petroliferous limestone in lowermost 3 ft	10	965

	Thickness (feet)	
Devonian--continued	Unit	Cumulative
"Big Lime" (incomplete):		
1. Limestone, light-gray to brown, medium to coarsely crystalline, petroliferous, siliceous in places, fossiliferous, containing scattered thin beds of gypsum	Top at 965 feet	

When examined by the Cincinnati group, the core was in poor condition. Many core boxes were missing which represent tne following depth intervals (in feet): 321-350, 459-481.5, 663-685.5, 780.5-803.5, 827-871, and 924-1215. In addition, the interval from 190.1 ft to 274 ft was missing and does not appear to have been cored. In this interval, the core size changed from NX above to BX below.

Many boxes contained badly weathered core or had much core loss. The box containing the interval from 751 to 780.5 ft was contaminated as more than one core size is present in the box.

Drill Hole K-8191 B-2, Independence, Ohio

Locality 9, fig. 1)

Hole K-8191 B-2, at 4411 Rockside Road, City of Independence, Cleveland South quadrangle, Cuyahoga County, Ohio (Ohio Coordinate System: North Zone, 2,230,200 ft E, 632,300 ft N), was drilled on August 17, 1978, by Herron Testing Lab of Cleveland as an engineering study for a building foundation. The surface elevation was 770 ft. The interval from 10 to 33.8 ft was cored (fig. 13). Logged on November 1, 1978 by R.F. Broadhead and R.C. Kepferle.

	Thickness (feet)	
	Unit	Cumulative
8. Not cored	10.0	10.0
Mississippian and Devonian (incomplete):		
Bedford Shale (incomplete):		
Euclid Siltstone Member (incomplete, 4 ft+):		
7. Sandstone, very fine grained, light olive-gray (5Y6/1), well-indurated, limonite-stained	4.0	14.0

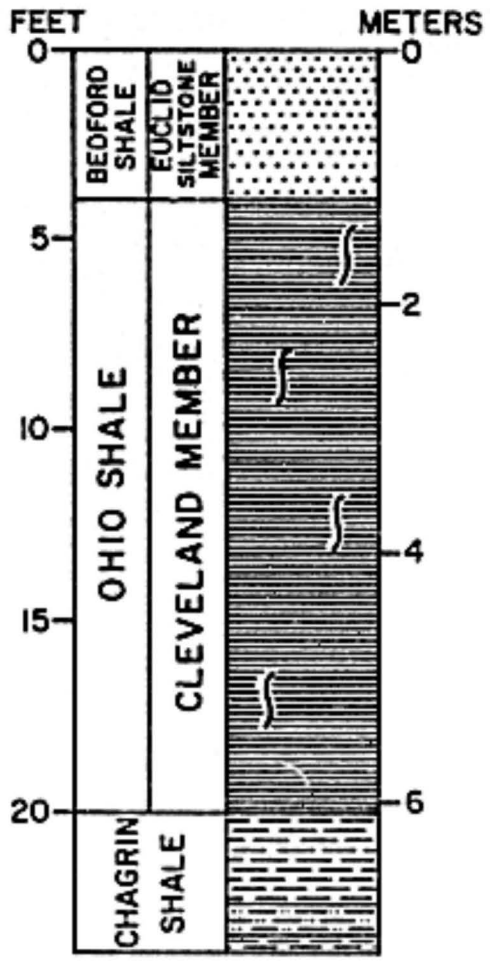

Figure 13. Columnar section of drill core K-8191 B-2 of Herron Testing Labs (locality 9, fig. 1).

Devonian--continued:	Thickness (feet)	
Ohio Shale (incomplete):		
Cleveland Member (16 ft):	Unit	Cumulative
6. Shale, olive-black (5Y2/1), silty, micaceous, burrowed. Most burrows are horizontal; these are 20 percent of the rock	2.0	16.0
5. Sandstone, black (N1), fine-grained, clayey, burrowed. Burrows are horizontal to subhorizontal tubes 0.5 to 3 cm thick and have irregular, rough boundaries	14.0	30.0
Chagrin Shale (incomplete, 318 ft+):		
4. Shale, medium-dark-gray (N4), miceaceous	2.5	32.5
3. Siltstone, light-olive-gray (5Y6/1), and calcareous, extremely contorted parallel laminae and contorted discontinuous shale wisps. Upper and lower contacts are sharp and contorted	1.0	33.5
2. Shale, medium-dark-gray (N4)	0.1	33.6
1. Siltstone, light-olive-gray (5Y6/1), with burrow mottling of shale and siltstone	0.2	33.8

Valley View section, Cuyahoga County, Ohio

Locality 10, fig. 1)

Cleveland Member of Ohio Shale, Bedford Shale, Euclid Siltstone Member of Bedford Shale, and Berea Sandstone exposed in a roadcut of Ohio Route 17, 3/4 mile east of its junction with Interstate Highway 77 in the city of Valley View, Cleveland South quadrangle, Cuyahoga County, Ohio (Ohio Coordinate System: North zone, 2,239,300 ft E, 637,900 ft N) (fig. 14). The Cleveland is underlain by gray Chagrin Shale which is not exposed at the roadcut but is exposed at a quarry 1/2 mile to the north on the east bank of the Cuyahoga River. The top of the section is at the base of the Berea Sandstone. Section measured with hand level and tape by R.F. Broadhead on April 22, 1978.

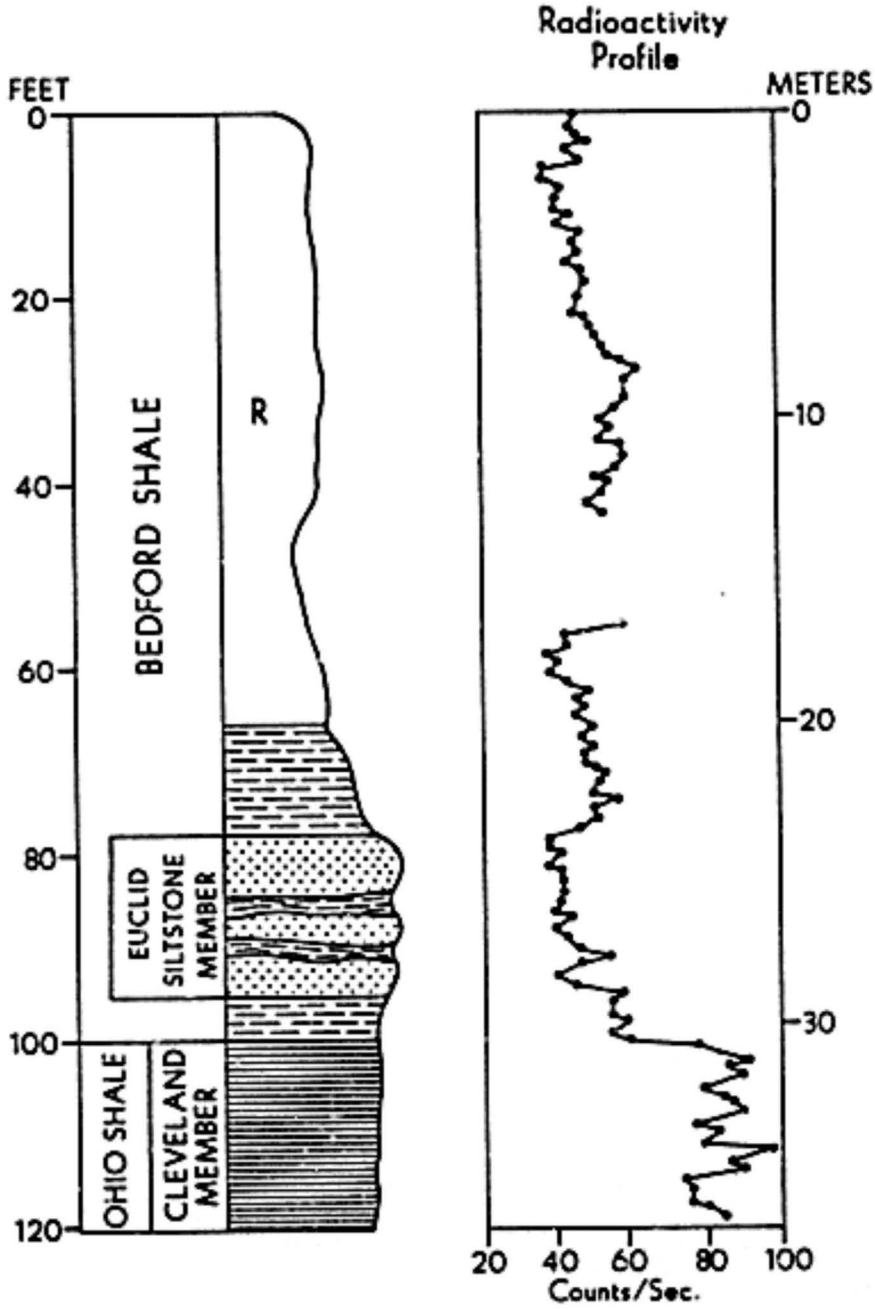

Figure 14. Lithologic column and radioactivity profile of the Valley View section (locality 10, fig. 1).

Mississippian and Devonian (incomplete):	Thickness (feet)	
Bedford Shale (100.0 ft):	Unit	Cumulative
5. Shale, grayish-red (10R4/2), slightly silty; breaks into 3- to 8-mm-thick tabular partings when weathered; internally homogeneous except for alignment of clays parallel to bedding; clayey and plastic when wet and weathered; very poorly exposed	66	66
4. Shale, medium-light-gray (N6), 80 percent, and thin beds of medium-light-gray (N6) siltstone, 20 percent. Siltstone, more abundant near the base of the unit, in very thin beds about 0.05 ft thick, which are slightly undulose and have sharp planar basal contacts and sharp upper contacts that are rippled or planar. Soles are marked by small grooves, flutes, prod marks, and some load casts. Siltstones are internally plane-parallel laminated (Tb) or contain small-scale, low-angle, ripple cross-laminae (Bouma units Tb or Tbc). Some siltstones are laterally continuous for more than 30 feet. Abrupt, planar lower contact	12	78
Euclid Siltstone Member (17.2 ft):		
3. Sandstone, yellowish-gray (5Y7/2), 95 percent, and 5 percent very thin interbeds of silty medium-gray shale. Sandstone is very fine grained and is in thin to very thick beds, of which most are laterally continuous along the length of the outcrop (about 200 ft) and have sharp planar upper and lower contacts; however, some are thin and discontinuous and have undulose contacts. Siltstones that rest on clay interbeds have grooved and fluted soles with some load casts and ball-and-pillow structures. Thick beds have flow rolls and contain a few small clay clasts. Shale beds are lenticular and discontinuous. Basal contact is abrupt and planar	17.2	95.2

Mississippian and Devonian--continued:	Thickness (feet)	
Bedford Shale--continued:		
Lower tongue (4.8 ft):	Unit	Cumulative
2. Shale, medium-gray (N5), 80 percent, intercalated with medium-light-gray (N6) siltstone, 20 percent. Shale is in thin to medium beds having abrupt, plane-parallel upper and lower contacts. Siltstones occur as thick laminae to very thin beds, which are laterally continuous and uniform for at least 50 feet. Upper and lower contacts are planar and sharp. The upper and lower contacts of unit 2 converge to the east at an angle of 3°	4.8	100.0
Devonian:		
Ohio Shale:		
Cleveland Member (incomplete, 21.1 ft+):		
1. Shale, grayish-black (N2), weathers moderate brown (5YR3/4) and brownish black (5YR2/1). Exposed surface consists of alternating layers 0.6 to 1.9 ft thick of greater and lesser resistance to weathering. Base of unit 1 not exposed	21.1	121.1

Euclid Creek section, Cuyahoga County, Ohio

(Locality 11, fig. 1)

The Chagrin Shale and the Cleveland Member of the Ohio Shale are exposed on the east bank of Euclid Creek in the Euclid Creek Reservation, 3/4 mile south of where U.S. Highway 20 crosses Euclid Creek in the City of Cleveland, East Cleveland quadrangle, Cuyahoga County, Ohio (Ohio Coordinate System: North zone, 2,264,320 feet E, 689,920 feet N) (fig. 15). Base of section is in the creek bed at the base of the cliff. Top of section is at the top of the cliff and is heavily vegetated. Measured with hand level and tape by R.F. Broadhead on August 25, 1978.

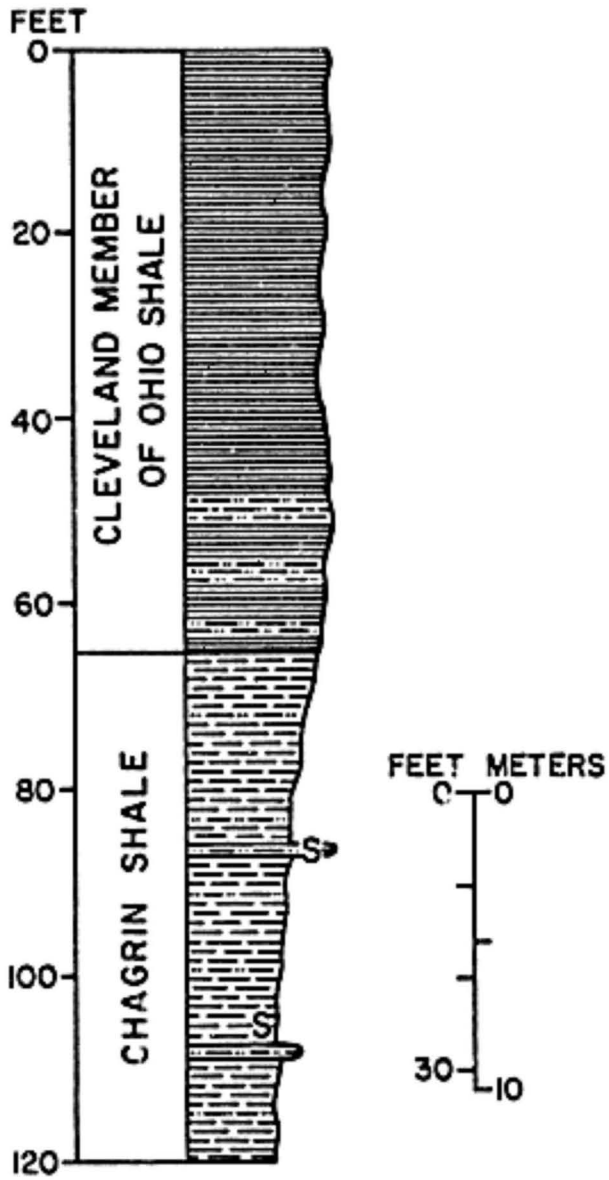

Figure 15. Lithologic column of the Euclid Creek section (locality 11, fig. 1).

Devonian (incomplete):	Thickness (feet)	
Ohio Shale (incomplete):		
Cleveland Member (incomplete 65 ft+):	Unit	Cumulative
10. Shale, olive-black (5Y3/1), silty, internally homogeneous. Parts into brittle plates 3 to 6 mm thick	48	48
9. Shale, olive-black (5Y3/1), 90 percent, and beds of medium-light-gray (N6) siltstone, 10 percent. Shale is silty, and is in beds 1 to 4 feet thick; parts into brittle plates 2 to 6 mm thick. Siltstone weathers grayish red (10R4/2) and is in well-indurated beds 0.1 to 0.3 ft thick; internal parallel wavy laminae have amplitudes of 1 cm and wavelengths of 10 to 20 cm. Contacts of siltstones with shales are abrupt and planar to very slightly undulose, conforming to the internal lamination of the siltstones. Soles of siltstones have small oriented load casts and groove casts. Some siltstones part parallel to bedding, exhibiting parting lineation. Lower contact of unit 9 is a black shale resting abruptly with a planar surface on the gray shale below	17	65
Chagrin Shale (incomplete, 55.1 ft+):		
8. Shale, medium-gray (N5), 95 percent, beds of medium-light-gray (N6) siltstone, 5 percent. Shale contains some silt laminae a few grains thick. Siltstone weathers dusky-red (5R3/4) and moderate yellowish brown (10YR5/4) and is in very thin beds, generally less than 0.1 ft thick, which are laterally continuous and uniform. Contacts between siltstones and shales are abrupt	20.8	85.8

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
7. Siltstone, medium-light-gray (N6), weathers grayish red (5R4/2); dense and sideritic. Unit consists of three thin beds separated by thin dark-gray shale partings. Beds are internally homogeneous except for horizontal and subhorizontal tubular curving burrows both on the soles and inside the beds. These are a few millimeters in diameter. Beds are laterally continuous and uniform and have sharp, planar, and parallel upper and lower contacts	0.5	86.3
6. Shale, medium-gray (N5), 95 percent, and thin, laterally continuous and uniform beds of medium-light-gray (N6) siltstone, 5 percent	17.8	104.1
5. Shale, medium-gray (N5), 90 percent, and beds of medium-light-gray (N6) siltstone, 10 percent. Shale contains a few thin silt laminae a few grains thick. Siltstones are laterally continuous and pinch and swell between 0.05 and 0.2 feet in thickness; tops are rippled, and bases are planar and sharp. Most siltstones are internally homogeneous (Ta Bouma units) but some have small-scale cross-laminae (Tc). Some siltstones are dense and siderit[illegible] .	1.9	106.0
4. Shale, medium-gray (N5), 95 percent, intercalated with 5 percent medium-light-gray (N6) siltstone. Siltstones are dense, homogeneous, and sideritic laterally continuous beds which have abrupt planar basal contacts and sharp rippled upper contacts. Beds pinch and swell between 0.05 ft and 0.2 ft thick owing to the rippling	1.1	107.1

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
3. Shale, medium-gray (N5), 70 percent, and medium-light-gray (N6) siltstone in laterally continuous beds less than 0.2 ft thick, 30 percent. Siltstones are sideritic, dense, and internally homogeneous. Upper and lower contacts are sharp and abrupt; the basal surfaces are planar and the upper surfaces are slightly undulose	0.7	107.8
2. Siltstone, medium-light-gray (N6), mostly internally homogeneous (Ta) but containing some plane-parallel (Tb) lamination. Bed is laterally continuous but varies in thickness from 0.1 ft to 0.5 ft. Both upper and lower surfaces are undulose and abrupt. This is a very prominent bed in the outcrop	0.2	108.0
1. Shale, medium-gray (N5), 90 percent, and beds of medium-light-gray (N6) siltstone, 10 percent. Shale weathers light brown (5YR5/6) and contains about 5 percent thin silt laminae each a few grains thick. Shale beds are 0.2 to 1.2 ft thick, laterally continuous and uniform. Siltstone weathers moderate yellowish brown (10YR5/4) and dark reddish brown (10R3/4). Some beds are cross laminated or plane-parallel laminated (Tb) but most are dense, sideritic, and internally homogeneous (Ta). Most siltstones are laterally continuous for at least 50 feet but some pinch out; few pinch and swell between 0.05 and 0.2 ft in thickness. Basal contacts are sharp and planar; some have small load casts. Upper contacts are abrupt and most are rippled	12.1	120.1

Drill Hole No. 201, Lake County, Ohio

(Locality 12, fig. 1)

Drill hole No. 201 was completed in November 1953 by the Diamond Alkali Company. It is approximately 3.5 miles south of Painesville in Concord Township, Mentor quadrangle, Lake County, Ohio (Ohio Coordinate System: North Zone, 2,338,560 ft E, 728,530 ft N) at a surface elevation of 882 ft. Coring commenced at a depth of 87 feet in the Chagrin Shale and continued to a total depth of 3104 feet in Silurian rocks. Devonian shale logged by R.F. Broadhead and R.C. Kepferle on May 18 and 19, 1979 (fig. 16).

	Thickness (feet)	
Devonian (incomplete):	Unit	Cumulative
48. No core	87.0	87.0
Chagrin Shale (incomplete, 907.5 ft+):		
47. Shale, medium-gray (N5), grades downward to medium dark gray (N4); contains less than 5 percent siltstone beds and less than 5 percent sideritic layers. Shale contains small wood fragments and is very burrowed but plane-parallel lamination is locally predominant. Most siltstone laminae are less than 0.1 ft thick and are more abundant in the lower half of the unit; some are sideritic. Some sideritic layers are plane-parallel laminated. Unit 47 has a gradational lower contact	148.0	234.0
46. Shale, medium-dark-gray (N4), and beds of siltstone which increase in abundance from 5 percent at the top of the unit to 15 percent at the bottom. Sideritic layers are less than 5 percent. Siltstone is in thin, rippled beds or bundles of silt laminae 0.1 to 0.3 ft thick. Both shales and siltstones are bioturbated ...	57.0	292.0

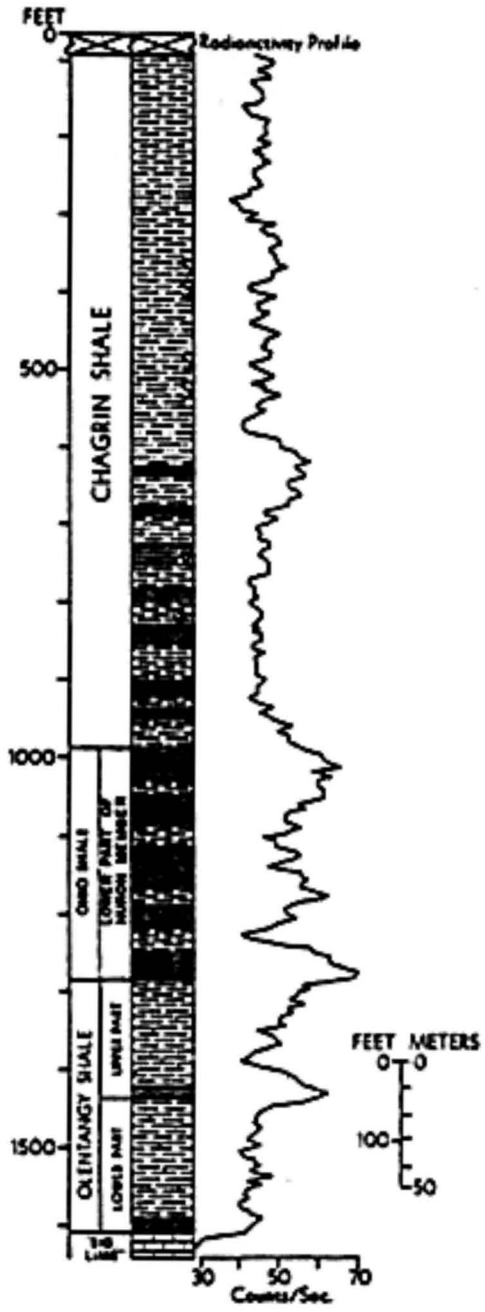

Figure 16. Lithologic and radioactivity profiles of the Diamond Alkali Co. drill hole No. 201 (locality 12, fig. 1).

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
45. Shale, medium-dark-gray (N4), 95 percent, less than 5 percent siltstone and sparse sideritic layers which increase in abundance downward	68.0	360.0
44. Shale, medium-dark-gray (N4), 85 percent, sideritic layers, 15 percent, and minor siltstone. Sideritic layers are less than 0.1 ft thick	37.0	397.0
43. Shale, medium-dark-gray (N4) to olive-gray (5Y4/1), 90 percent, interbedded with light-gray siltstone, 10 percent, and a few sideritic layers. Siltstone beds are micaceous and are less than 0.05 ft thick. Most are rippled; others are sideritic	83.0	480.0
42. Shale, medium-dark-gray (N4), 80 percent, thinly interbedded with siltstone, 10 percent, and sideritic layers, 10 percent	53.0	533.0
41. Shale, greenish-gray (5GY5/1), and abundant siltstone increasing from 15 percent at the top of the unit to 25 percent near the base. Sideritic beds are 5 percent and decrease in abundance downward. Siltstone beds are concentrated into bundles 10 ft thick of siltstone and shale	90.0	623.0
40. Shale, medium-dark-gray (N4), 40 percent, interbedded with dark-gray (N3) shale, 30 percent, light-gray (N7) siltstone, 30 percent, a few sideritic layers, and a few thin laminae of olive-black (5Y2/1) shale. Shale beds are 0.1 to 0.2 ft thick and siltstone beds are less than 0.1 ft thick	97.0	720.0

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
39. Shale, medium-dark-gray (N4), 60 percent, intercalated with dark-gray (N3) shale, 35 percent, and light-gray (N7) siltstone, 5 percent. Shale beds are 0.1 to 0.2 ft thick and some siltstones are as thick as 0.2 ft, but most are thinner. Siltstone beds are either cross laminated or plane-parallel laminated	19.0	739.0
38. Shale, dark-gray (N3), 80 percent, interbedded with medium-gray (N5) shale, 15 percent, and siltstone, 5 percent. Shale and siltstone beds are less than 0.1 ft thick. Top of Foerstia zone is at 743 ft	4.0	743.0
37. Shale, medium-gray (N5) to light-olive-gray (5Y6/1), 75 percent, interbedded with dark-gray (N3) shale, 20 percent, and siltstone, 5 percent, and a few sideritic layers. Shale beds are thin to thick. Most siltstone beds are less than 0.1 ft thick but some are as thick as 0.6 ft. Many siltstone beds are calcareous and are either planar laminated (Tb), wavy laminated (Tb-Tc), or cross laminated (Tc). Sideritic bands are 0.05 to 0.1 ft thick. Base of Foerstia zone is at 819.7 feet	141.0	884.0
36. Shale, dark-gray (N3), 60 percent, thinly interbedded with medium-gray (N5) shale, 35 percent, and thin planar siltstone laminae, 5 percent	6.0	890.0
35. Shale, medium-dark-gray (N4) to olive-gray (5Y4/1), 70 percent, thinly interbedded with dark-gray (N3) shale, 25 percent, and siltstone 5 percent.		

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
Siltstone beds are as thick as 0.2 ft..	21.0	911.0
34. Shale, dark-gray (N3), 60 percent, intercalated with olive-gray (5GY4/1) to medium-gray (N5) shale, 40 percent, and minor thin siltstones	28.0	939.0
33. Shale, medium-gray (N5) to medium-dark-gray (N4), 60 percent, is interbedded with dark-gray (N3) shale, 40 percent. Dark-gray shale beds have a maximum thickness of 0.3 ft and a few medium-gray beds are as thick as 0.5 ft. Bedding contacts are sharp and planar ..	25.5	964.5
32. Shale, dark-gray (N3), 70 percent, and medium-gray (N5), 30 percent, as thin beds. Bedding contacts are gradational across a few millimeters.....	4.5	969.0
31. Shale, medium-gray (N5), to medium-dark-gray (N4), 80 percent, interbedded with dark-gray (N3) calcareous, sideritic siltstone, 20 percent. Siltstone beds are 0.2 ft thick	25.5	994.5
Lower part of Huron Member (296.7 ft):		
30. Shale, brownish-black (5YR2/1), pyritic, 95 percent, intercalated with medium-gray (N5) shale, 5 percent, and rare siltstone laminae. Medium-gray (N5) shale is in beds no thicker than 0.6 ft	34.0	1028.5
29. Shale, medium-gray (N5), 80 percent, brownish-black (5YR2/1) shale, 20 percent, and a few thin planar silt laminae. Brownish-black shale beds are 0.3 ft thick	6.5	1035.0
28. Shale, brownish-black (5YR2/1), containing bed of medium-gray (N5) shale 1.0 ft thick at 1044 feet	25.5	1060.5
27. Shale, greenish-gray (5GY6/1), 60 percent and brownish-black (5YR2/1) shale, 40 percent. Gray shale is bioturbated ...	17.0	1077.5

Devonian--continued: Ohio Shale--continued: Lower part of Huron Member--continued:	Thickness (feet) Unit	Cumulative
26. Shale, brownish-black (5YR2/1)	8.0	1085.5
25. Shale, brownish-black (5YR2/1), 50 percent, and greenish-gray (5GY6/1), 50 percent. Lower contacts of green shales are burrowed but bases of black shale beds are sharp and planar	9.5	1095.0
24. Shale, medium-gray (N5), 85 percent intercalated with brownish-black (5YR2/1) shale, 10 percent, and sideritic bands, 5 percent. Black shale beds are 0.2 to 0.6 ft thick and siderite bands are thinner than 0.1 foot	9.2	1104.2
23. Shale, brownish-black (5YR2/1), 95 percent, and indistinct laminae of medium-gray (N5) shale, 5 percent	3.8	1108.0
22. Shale, greenish-gray (5GY6/1), bioturbated and pyritic, containing three sideritic bands less than 0.1 ft thick	10.0	1118.0
21. Shale, brownish-black (5YR2/1), 90 percent, with greenish-gray (5GY6/1) shale, 10 percent, which is in bioturbated beds as thick as 0.4 ft	19.5	1137.5
20. Shale, medium-gray (N5), 80 percent, and brownish-black (5YR2/1), 20 percent. Black shale beds are very thin	10.5	1148.0
19. Shale, brownish-black (5YR2/1)	12.5	1160.5
18. Shale, greenish-gray (5GY6/1), 50 percent, is thickly interbedded with brownish-black (4YR2/1) shale, 50 percent. A (Tc) siltstone 0.05 ft thick containing superimposed sets of cross-laminae at 1163 ft.	12.5	1173.0
17. Shale, brownish-black (5YR2/1)	8.0	1181.0
16. Shale, greenish-gray (5GY6/1), 80 percent, and brownish-black (5YR2/1), 20 percent. Lower contacts of gray shale beds are burrowed but bases of black shales are sharp and planar	15.0	1196.0

	Thickness (feet)	
Devonian--continued:		
Ohio Shale--continued:		
Lower part of Huron Member--continued:	Unit	Cumulative
15. Shale, brownish-black (5YR2/1), 90 percent, interbedded with greenish-gray (5GY6/1) shale, 10 percent. Black shale beds contain burrows infilled with gray shale	32.0	1228.0
14. Shale, greenish-gray (5GY6/1), 85 percent, and thin to medium beds of brownish-black (5YR2/1) shale, 15 percent. Bases of gray shales are burrowed	21.0	1249.0
13. Shale, brownish-black (5YR2/1), containing a thin bioturbated gray shale bed at 1248 feet	11.0	1260.0
12. Shale, greenish-gray (5YR2/1), and a few thin beds of brownish-black (5YR2/1) shale	4.0	1264.0
11. Shale, brownish-black (5YR2/1). Lower 0.3 ft contains abundant botryoidal pyrite	27.2	1291.2
Olentangy Shale (328.4 ft):		
Upper part (158.4 ft):		
Equivalents of Java and West Falls Formations as differentiated below:		
Equivalent of Java Formation (81.1 ft):		
10. Shale, olive-gray (5Y5/1), 90 percent, and beds of black shale, 10 percent, which are 0.1-0.3 ft thick. The olive-gray shale is burrowed and contains small yellowish-gray (5Y8/1) irregularly shaped calcite nodules below 1333 ft	78.0	1369.2
9. Shale, black (N1), basal marker bed of Pipe Creek Shale Member	3.1	1372.3
Equivalent of Angola Shale Member of West Falls Formation (66.7 ft):		
8. Shale, olive-gray (5Y5/1)	1.7	1374.0
7. Limestone (mudstone of Dunham, 1962), olive-gray (5Y5/1), cross-cut by thin calcite veins	0.4	1374.4

	Thickness (feet)	
	Unit	Cumulative
Devonian--continued:		
Olentangy Shale--continued:		
Upper part--continued:		
Equivalent of Angola Shale Member of West Falls Formation--continued:		
6. Shale, medium-light-gray (N6), 70 percent, and beds of olive-gray (5Y5/1) shale, 30 percent. Medium-light-gray shale is bioturbated. Bedding contacts are gradational	64.6	1439.0
Equivalent of Rhinestreet Member of West Falls Formation (7 ft):		
5. Shale, black (N1), micaceous	7.0	1446.0
Lower part (170.0)		
Equivalent of Mahantango Formation and Marcellus Shale, as differentiated below):		
Equivalent of Mahantango Formation (140.0 ft):		
4. Shale, medium-gray (N5), silty, calcareous, slightly pyritic, and burrowed. Contains many brachiopods	140.0	1586.0
Equivalent of Marcellus Shale (30.0 ft):		
3. Shale, dark-gray (N3)	11.0	1597.0
*2. Shale, brownish-black (5YR2/1)	19.0	1616.0
"Big Lime" (incomplete, 32 ft+):		
**1. Limestone (mudstone of Dunham, 1962), light-olive-gray (5Y6/1), stylolitic. Contains sparse brachiopods	32+	1648+

Drill Hole TX-7, Lake County, Ohio

(Locality 13, fig. 1)

Drill hole TX-7 was drilled into the Chagrin Shale for a geologic site study for the Perry, Ohio, Nuclear Power Plant constructed by the Cleveland Electric and Illuminating Company. The drill hole is near the southern shore of Lake Erie approximately 3 miles north of the city of Perry, Perry Township, Perry quadrangle, Ohio (Ohio Coordinate System: North zone, 2,369,200 ft E, 781,600 ft N) at a surface elevation of 618.1

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* USGS Collection 10017-SD at 1607.8 ft contains conodont elements that range in age from latest Early Devonian to earliest Late Devonian (A. G. Harris, written communication, August 22, 1979).

** USGS Collection 10111-SD at 1620 ft contains brachiopods resembling those in the Delaware Limestone (J. T. Dutro, Jr., written communication, July 16, 1979).

feet. The interval from 168 to 395 feet was cored. The drilling was completed on October 21, 1978. Logged and sampled on January 3, 1979 by R.F. Broadhead and R.C. Kepferle (fig. 17).

	Thickness (feet)	
	Unit	Cumulative
6. Not cored	168	168

Devonian (incomplete):
Chagrin Shale (incomplete, 227 ft+):

5. Shale, medium-dark-gray (N4), 70 percent, and light-gray (N7) siltstone, 30 percent. Shale is silty and pyritic in beds, 0.03 to 0.8 ft thick. Most siltstones are partial Tcd cycles. Lower contacts of siltstones are abrupt and either planar, marked by flutes, or load casts projecting into the underlying shale. In a few siltstones this load casting has proceeded far enough to form ball-and-pillow structures. Upper contacts of siltstones are abrupt and either rippled or planar except for the few siltstones that have gradational upper contacts, Td Bouma units. Siltstones are micaceous and are in beds 0.05 to 0.9 ft thick	12	180
4. Shale, medium-dark-gray (N4), 65 percent, and light-gray (N7) siltstone, 30 percent, and reddish-gray sideritic siltstone, 5 percent. Shale is silty and pyritic in beds 0.1 to 0.4 ft thick. Siltstone beds, including sideritic beds, are 0.03 to 0.1 ft thick, are micaceous, and, as in unit 5, are composed of stacked Bouma units; Tbc and Tcd partial cycles are the most prevalent	5	185
3. Shale, medium-dark-gray (N4), 70 percent, and light-gray (N7) siltstone, 30 percent, thinly interbedded. Shale is silty and pyritic in beds 0.05 to 0.8 ft thick and contains structures similar to those in the siltstones of unit 5 except that Bouma Tcd partial cycles are the most prevalent	35	220

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
2. Shale, medium-dark-gray (N4), 60 percent, and light-gray (N) siltstone, 40 percent. As in unit 3, shale is pyritic and silty but contains some thick laminae of medium-gray (N5) and dark-gray (N3) shale. Shale beds are commonly 0.2 to 0.4 ft thick but are as thick as 1.8 ft. Siltstones are composed of partial Bouma cycles (Tcd cycles being the most common) and otherwise are the same as those of unit 5. Most siltstones are 0.05 to 0.2 ft thick but a few are as thick as 0.8 ft. Thin siltstone beds at 277 and 281 ft are sideritic. The gradational zone to unit 1 below is about 20 ft thick	114	334
1. Shale, 80 percent, thinly interbedded with siltstone, 20 percent. Shale is pyritic and silty, consists of thin to medium beds of dark-gray (N3), medium-dark-gray (N4), and medium-gray (N5) shale, the lighter shades are more abundant in the lower 30 feet. Shale contains some flattened horizontal tubular burrows to 5 mm in width. Siltstones are as in unit 5, except that most beds are separate Tc or Td Bouma units less than 0.1 ft thick. A 1.0-ft-thick siltstone bed contains load casts, has been greatly contorted by soft sediment deformation, and contains small contorted pods of dark-gray shale	61	395

Hell Hole section, Lake County, Ohio

Locality 14, fig. 1)

The Chagrin Shale is exposed in a roadcut of Leroy Center Road in Hell Hole along Paine Creek, Leroy Township, Thompson quadrangle, Lake

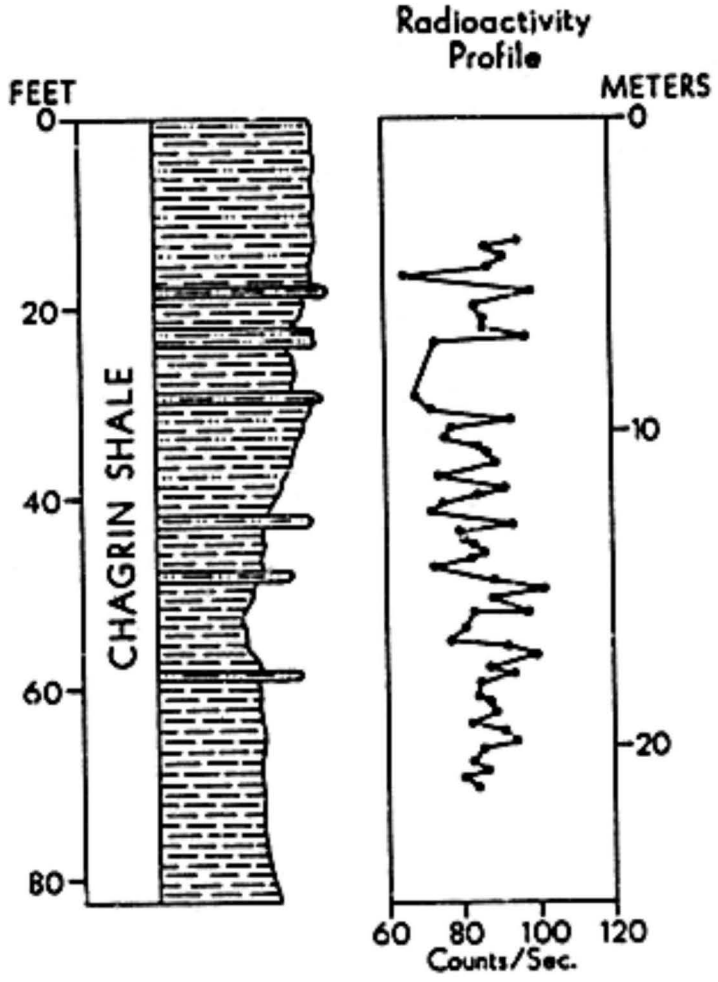

Figure 18. Lithologic and radioactivity profiles of the Hall Hole section (locality 14, fig. 1).

County, Ohio (Ohio Coordinate System: North zone, 2,378,000 ft E, 738,100 ft N) (fig. 18). Base of section is 200 ft east of the intersection of Paine Creek and Leroy Center Road. Top of section is covered by vegetation. Measured with hand level and tape by R.F. Broadhead on June 16, 1978.

	Thickness (feet)	
Devonian (incomplete):		
Chagrin Shale (incomplete 82.5 ft+):	Unit	Cumulative
21. Shale, medium-gray (N5), 70 percent, and medium-gray (N5) siltstone, 30 percent. Shale is in beds 0.3 to 2 ft thick, and siltstone is in beds 0.1 to 0.5 ft thick. Contacts between beds are sharp and planar. Basal shale bed has abrupt and planar lower contact	17.9	17.9
20. Siltstone, medium-light-gray (N6), containing platy partings 1 cm thick and internal very thin, plane-parallel laminae. Abrupt lower contact	0.4	18.3
19. Shale, medium-gray (N5), clayey, containing platy partings 3 to 6 mm thick. The sharp basal contact is planar. A 0.1-ft-thick sideritic layer 2.9 ft above base of unit contains molds of tubular horizontal burrows a few millimeters in diameter on its sole	3.2	21.5
18. Siltstone, light-olive-gray (5Y6/1), contains faint, internal, wavy, parallel laminae (Bouma unit Tc) and some tubular and branching burrows a few millimeters in diameter which are mostly horizontal, but locally are subvertical; abundant brachiopod molds; abrupt lower contact	0.6	22.1
17. Shale, medium-gray (N5), silty, and plastic when wet and weathered; partings are 2 to 5 mm thick; abrupt and planar lower contact	0.1	22.2
16. Siltstone, medium-light-gray (N6), argillaceous, internally homogeneous (Ta); basal contact is sharp and slightly undulose	0.1	22.3

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
15. Shale, medium-gray (N5), silty. When wet and weathered, it is plastic and parts in plates 2 to 5 mm thick. Abrupt and planar lower contact	0.1	22.4
14. Shale, grayish-black (N2), silty; upon weathering, parts into plates 2 to 6 mm thick. Sharp, planar lower contact	0.2	22.6
13. Shale, medium-dark-gray (N4), 90 percent, and medium-gray (N5) siltstone, 10 percent. Shale is silty and occurs in beds 0.5 to 1.0 ft thick which weather to moderate-brown (5YR4/4) tabular to platy partings 2 to 6 mm thick. Siltstones are internally homogeneous beds 0.1 to 0.3 ft thick and have abundant tubular, branching, horizontal burrows a few millimeters in diameter on their soles. Contacts between beds are abrupt	5.7	28.3
12. Siltstone, in a single medium-light-gray (N6) bed, 90 percent of which is internally homogeneous (Ta) except for sparse horizontal, tubular, branching burrows both internally and on the sole. Ten percent of this bed has wavy and plane-parallel laminae (Tb) as well as low-angle, small-scale cross-laminae having tangential lower and truncated upper contacts (Tc); brachiopods are common and usually convex-up	1.2	29.5
11. Siltstone, medium-gray (N5), 70 percent, and silty, medium-dark-gray (N4) shale, 30 percent. Siltstones have abundant brachiopod molds and tubular, branching, horizontal burrows within beds, which are 0.1 to 0.3 ft thick. Shale weathers moderate brown (5YR4/4) and typically has platy partings 2 to 6 mm thick	1.8	31.3
10. Shale, medium-dar-gray (N4), silty, 90 percent, and medium-gray (N5) internally homogeneous (Ta) siltstone, 10 percent. Shale beds are 0.5 to 1.0 ft		

evonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
thick, have tabular to platy partings, 2 to 6 mm thick and weather moderate brown (5YR4/4). Siltstone beds are 0.1 to 0.3 ft thick and have many branching tubular burrows a few millimeters in diameter on their soles	6.3	37.6
9. Shale, medium-gray (N5), silty; weathers moderate-brown (5YR4/4), parts into plates 2 to 6 mm thick. Lower contact abrupt and planar	4.3	41.9
8. Siltstone, light-olive-gray (5Y6/1), single bed is internally homogeneous (Ta) except for branching, tubular burrows a few millimeters in diameter in the lower 0.1 ft and on sole. Sharp, planar lower contact	0.7	42.6
7. Shale, medium-gray (N5), silty; weathers to moderate-yellowish-brown (10YR5/4) plates 1 to 5 mm thick; contains rare brachiopod molds in upright position and contains many silt-filled tubular burrows, which extend 0.1 ft vertically downward from the base of unit 8 and there branch into a poorly defined horizontal network. Abrupt lower contact	0.3	42.9
6. Siltstone, medium-gray (N5), homogeneous (Ta), weathers moderate brown (5YR4/4) and light brown (5YR5/6); abundant, branching tubular, horizontal burrows a few millimeters in diameter on sole; lower contact is burrowed and abrupt	0.2	43.1
5. Shale, medium-gray (N5); weathers to grayish-red (10Y4/2) plates 2 to 6 mm thick; clayey; contains sparse brachiopod molds. Silt-filled, tubular burrows extend 0.1 ft vertically downward from the base of unit 6 and there branch into horizontal networks. Sharp basal contact.	4.2	47.3
4. Siltstone, medium-light-gray (N6); weathers pale yellowish orange (10YR8/6) and moderate brown (5YR4/4); dense. Horizontal to		

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
subvertical, branching, tubular burrows a few millimeters in diameter are common both inside the bed and on its sole. Abrupt basal contact	0.6	47.9
3. Shale, medium-gray (N5), weathers dark yellowish orange (10YR6/6). Platy partings are 4 to 10 mm thick. Common medium-dark-gray (N4), ovoid dolomitic concretions 0.1 ft thick and 0.5 ft long are elongated parallel to bedding. Shale partings are subparallel to the edges of the concretions. Lower contact is abrupt	10.1	58.0
2. Siltstone, light-gray (N7); weathers grayish brown (5YR3/2). Horizontal to subvertical tubular burrows a few millimeters in diameter common within and on the sole of the bed. The lower contact is abrupt in most places, but is locally gradational. Gradational zones contain some silt-filled burrows	0.7	58.7
1. Shale, medium-gray (N5); weathers pale brown (5YR5/2) and grayish red (5YR4/2). Partings are 3 to 15 mm thick, platy to tabular. Sparse horizontal silt-filled tubular burrows a few millimeters in diameter are internal to bedding. Sparse pyritic nodules 1 to 3 cm thick and 5 to 10 cm long are silty. Base of unit 1 not exposed	23.8	82.5

Grand River section, Ashtabula County, Ohio

(Locality 15, fig. 1)

The Chagrin Shale is exposed in a cliff on the west bank of the Grand River about 2700 feet west of the bridge of Ohio Highway 534 in Harpersfield Township, Geneva quadrangle, Ashtabula County, Ohio (Ohio Coordinate System: North Zone, 2,423,200 ft E, 7,646,000 ft N) (fig. 19). Base of section is on the river bank and its top is covered with colluvium at the top of the cliff. Measured with hand level and tape by R.F. Broadhead on June 6, 1978.

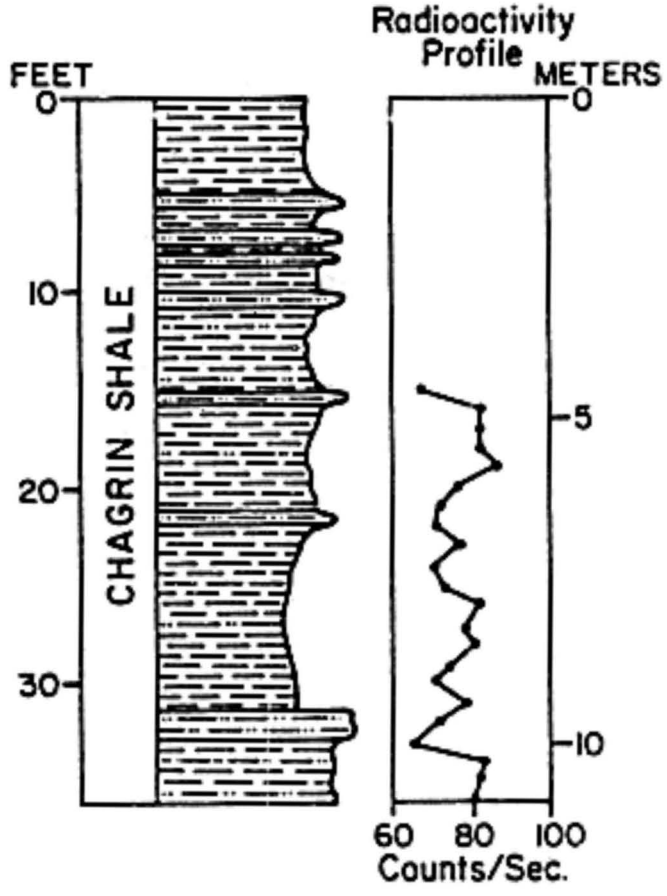

Figure 19. Lithologic and radioactivity profiles of the Grand River section (locality 15, fig. 1).

Siltstone and shale beds in the section are laterally continuous and uniform, unless otherwise noted in the unit descriptions.

Devonian (incomplete): Chagrin Shale (incomplete, 36.1 ft+):	Thickness (feet) Unit	Cumulative
15. Shale, medium-gray (N5). Sharp, planar basal contact. Top is covered with colluvium and is heavily vegetated	5.0	5.0
14. Siltstone, medium-gray (N5); basal contact is abrupt and planar	0.5	5.5
13. Shale, medium-gray (N5); lower contact is sharp and planar	1.5	7.0
12. Siltstone, medium-gray (N5); basal contact is sharp and planar	0.7	7.7
11. Shale, medium-gray (N5); basal contact is abrupt and planar	0.2	7.9
10. Siltstone, medium-gray (N5); abrupt, planar lower contact	0.7	8.6
9. Shale, medium-gray (N5); abrupt, planar lower contact	1.5	10.1
8. Siltstone, very-light-gray (N7); base is sharp and planar	0.7	10.8
7. Shale, medium-gray (N5), 70 percent, and thin beds of medium-gray (N5) siltstone, 30 percent. Siltstone beds are less than 0.1 ft thick	4.2	15.0
6. Siltstone, medium-gray (N5), internally homogeneous. Sole has some horizontal, branching tubular burrows a few millimeters in diameter. Lower contact is abrupt and planar	0.6	15.6
5. Shale, medium-gray (N5), 90 percent, interbedded with medium-gray (N5) siltstone, 10 percent. Siltstone beds are less than 0.05 ft thick, and are load-casted into underlying shale. Contacts with shales are sharp and generally planar	5.6	21.2

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
4. Siltstone, medium-gray (N5), intensely bioturbated; most burrows are sub-horizontal and tubular, a few millimeters in diameter. The basal contact is sharp and planar, burrowed and load-casted, and marked by small grove casts and flutes	0.7	21.9
3. Shale, medium-gray (N5), 95 percent, and medium-gray (N5) siltstone, 5 percent. The shale contains about 10 percent thin silt laminae. Siltstone beds are less than 0.1 ft thick and are laterally continuous but pinch and swell. Lower contact is abrupt and planar	9.4	31.3
2. Siltstone, medium-gray (N5), laterally continuous and uniform. Parts into layers 0.05 to 1.0 ft thick. Plane-parallel and ripple laminations have been strongly contorted by burrowing. Some small wood fragments are present. The base is sharp and planar	1.6	32.9
1. Shale, medium-dark-gray (N4) and silty, 60 percent, interlaminated with light-gray (N7) siltstone, 40 percent. Most siltstone beds have a nodular appearance and only about 10 percent are laterally continuous for more than 5 feet. Base of unit 1 is in river bed and not exposed ...	3.2	36.1

Gerald No. 1 Drill Hole, Ashtabula County, Ohio

(Locality 16, fig. 1)

Gerald No. 1 drill hole was completed on March 17, 1949, by the International Salt Company. The hole is about 1.5 miles southwest of

the city of Ashtabula in Saybrook Township, Ashtabula South quadrangle, Ashtabula County, Ohio (Ohio Coordinate System: North zone 2,454,800 ft E, 796,800 ft N), at a surface elevation of 691 ft. Coring started at a depth of 51 feet in the Chagrin Shale and continued to a total depth of 2400 ft in Silurian rocks. Devonian shale logged by R. Carlton, R. Kepferle, and E. Rothman on February 21, 22, and 23, 1979 (fig. 20). Colors are from wet core.

		Thickness (feet)	
		Unit	Cumulative
18.	No core	51	51
Devonian (incomplete):			
Chagrin Shale (incomplete, 574 ft+):			
17.	Shale, olive-gray (5Y4/1) to olive-black (5Y2/1), 80 percent, siltstone, 20 percent, and minor sideritic layers. Siltstones are calcareous and have soft-sediment load structures. Sideritic layers are less than 0.1 ft thick. Top of Foerstia zone is at 250 ft	234	285
16.	Shale, dark-greenish-gray (5GY4/1), 70 percent, siltstone, 25 percent, olive-black (5Y2/1) shale, 5 percent, and a few sideritic layers. Siltstones are cross-laminated and contain rippled thick laminae to thin beds. Base of Foerstia zone is at 395 ft	130	415
15.	Shale, dark-greenish-gray (5GY4/1), 65 percent, siltstone, 25 percent, and olive-black (5Y2/1) shale, 10 percent. Siltstones are cross-laminated and contain rippled laminae and thin beds. Some are calcareous	210	625
Ohio Shale			
Lower part of Huron Member (443 ft):			
14.	Shale, olive-black (5Y2/1), faintly and thinly laminated	74	699
13.	Shale, olive-black (5Y2/1), 80 percent, dark-greenish-gray (5GY4/1) shale, 15 percent, and siltstone, 5 percent.		

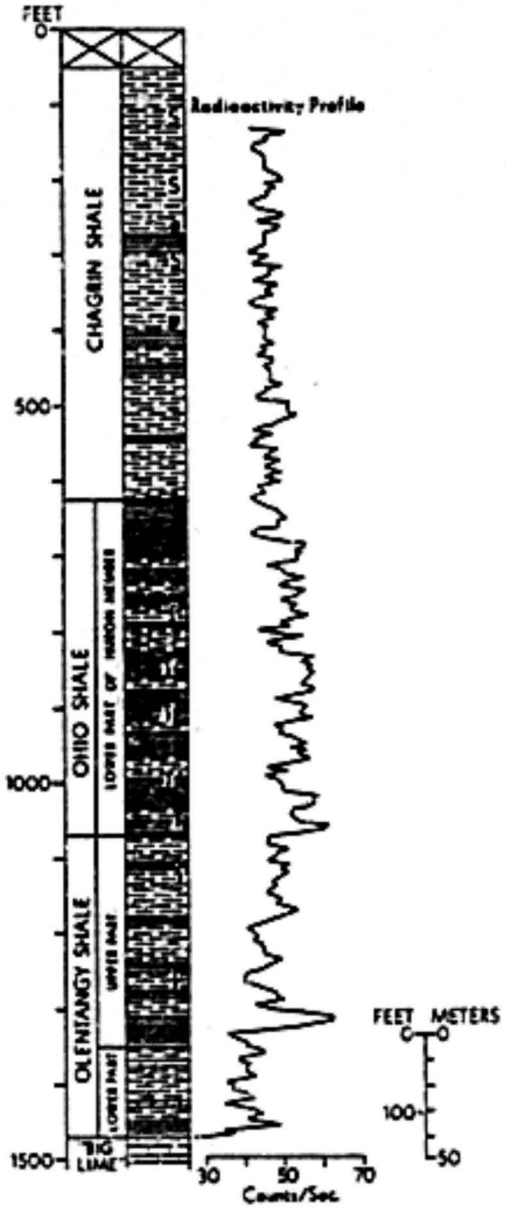

Figure 20. Lithologic and radioactivity profiles of the Geraid No. 1 drill hole of the International Salt Co. (locality 16, fig. 1).

Devonian--continued:	Thickness (feet)	
Ohio Shale--continued:		
Lower part of Huron Member--continued:	Unit	Cumulative
Siltstones are laminae and decrease in abundance downward	61	760
12. Shale, dark-greenish-gray (5GY4/1) to olive-black (5Y2/1), 75 percent, and brownish-black (5YR2/1) shale, 25 percent. Unit contains burrows 4.0 mm to 20.0 mm in diameter	74	834
11. Shale, brownish-black (5YR2/1), 95 percent, and dark-greenish-gray (5GY4/1) to olive-black (5Y2/1) shale, 5 percent. Greenish-gray shales are in laminae and thin beds and contain small pyritized burrows	139	973
10. Shale, brownish-black (5YR2/1), 50 percent, and dark-greenish-gray (5GY4/1) shale, 50 percent. Greenish-gray shale contains burrows	36	1009
9. Shale, brownish-black (5YR2/1), 95 percent, and 5 percent olive-black (5Y2/1) shale. Olive-black shale contains pyritized burrows	59	1068
Olentangy Shale (396 ft):		
Upper part (256 ft, includes equivalents of Java and West Falls Formations, as differentiated below):		
Equivalent of Java Formation (112 ft):		
8. Shale, grayish-olive-green (5GY3/2), 90 percent, and brownish-black (5YR2/1) shale, 10 percent. Grayish-green shale contains pyritized burrows and irregular calcareous pods as much as 1 cm in diameter. Grayish-green shale is locally calcareous	110	1178
7. Shale, brownish-black (5YR2/1). Basal marker of Pipe Creek Shale Member	2	1180
Equivalent of Angola Shale Member (98 ft):		
6. Shale, dark-greenish-gray (5GY4/1), 95 percent, olive-black (5Y2/1) and brownish-black (5YR2/1) shale, 5 percent. Greenish-gray shale contains burrows and irregular calcareous pods as much as 1 cm in diameter	98	1278

Devonian--continued:	Thickness (feet)	
Olentangy Shale--continued:		
Upper part--continued:	Unit	Cumulative
Equivalent of Rhinestreet Shale Member (46 ft):		
5. Shale, dark-greenish-gray (5GY4/1), 90 percent; olive-black and brownish-black (5YR2/1) shale, 10 percent. Contains burrows in upper 10 feet	31	1309
4. Shale, brownish-black (5YR2/1), containing Lingula and conodonts	15	1324
Lower part (140 ft, includes equivalents of Mahantango Formation and Marcellus Shale, as differentiated below):		
Equivalent of Mahantango Formation (120 ft):		
3. Shale, olive-black (5Y2/1), calcareous, and a few thin limestones less than 0.1 ft thick from 1362 ft to 1420 ft	120	1444
Equivalent of Marcellus Shale (20 ft):		
*2. Shale, brownish-black (5YR2/1), pyritic ...	20	1464
"Big Lime" (incomplete, 15 ft+):		
1. Limestone	15+	1479+

*USGS collection 10112-SD at base of unit contains rhynchonelloid brachiopods, probably Cupularostrum, and other fossils including Orbiculoidea, Eostrophalosia, and Styliolina of pre-Centerfield age (J. T. Dutro, Jr., written communication, July 16, 1979).

Gulf Park section, Ashtabula County, Ohio

(Locality 17, fig. 1)

Chagrin Shale is exposed along an incised meander of Ashtabula River and in a roadcut on Ohio Route 84 in Gulf Park on the southeast side of the City of Ashtabula, Ashtabula Township, Ashtabula South quadrangle, Ashtabula County, Ohio (Ohio Coordinate System: North

zone, 2,474,100 ft E, 802,200 ft N) (fig. 21). Base of section is exposed on the west bank of the Ashtabula River just north of the Route-84 bridge; top of section is in the roadcut, overgrown with grass and trees. Measured with hand level and tape by R.F. Broadhead on June 4, 1978.

		Thickness (feet)	
Devonian (incomplete):			
Chagrin Shale (incomplete, 86.4 ft+):		Unit	Cumulative
12	Siltstone, medium-gray (N5), weathers grayish red (5R4/2). Sharp, planar lower contact. Burrowed, disrupting parallel laminae and small-scale, low-angle, cross-laminae having tangential lower and either tangential or truncated upper contacts	0.9	0.9
11.	Shale, light-olive-gray (5Y6/1), silty, and less than 5 percent thick laminae of gray siltstone. When weathered, shale is grayish red (10R4/2) and splits to platy to tabular partings 2 to 6 cm thick	11.8	12.7
10.	Siltstone, olive-gray (5Y4/1); weathers grayish red (10R4/2); abrupt, planar bedding contacts; sole-marked basal contact. Plane-parallel laminated and bioturbated	0.3	13.0
9.	Shale, light-olive-gray (5Y6/1), 80 percent thin beds and thick interlaminae of siltstone, 20 percent, have abrupt and planar to slightly undulose bedding contacts with the shales. Sharp, planar lower contact	5.5	18.5
8.	Shale, light-olive-gray (5Y6/1)	8.3	26 8
7.	Siltstone, light-olive-gray (5Y6/1); weathers grayish red (10R4/2), contains small-scale cross-laminae (tc) and is locally bioturbated. Lower contact is abrupt and planar	0.7	27.5
6.	Shale, light-olive-gray (5Y6/1); weathers grayish red (5R4/2); silty, containing less than 5 percent very thin silty laminae as thick as 2 cm, which		

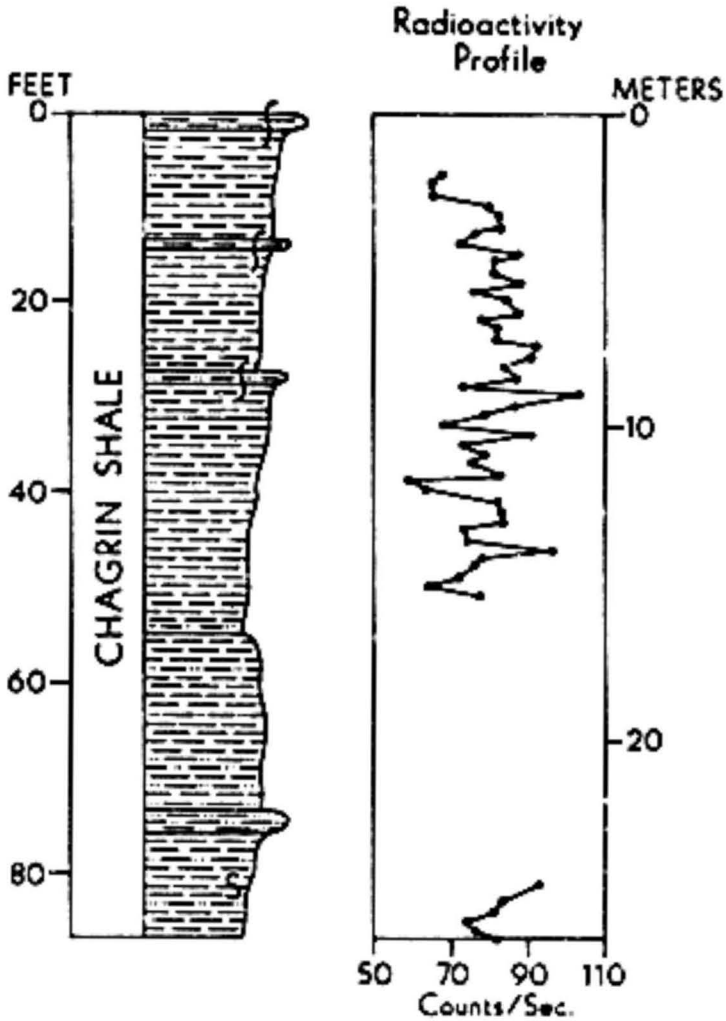

Figure 21. Columnar section and radioactivity profile of the Gulf Park section (locality 17, fig. 1).

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
consist of very thin (less than 1 mm thick) plane-parallel layers of alternating silt and shale. Contains small pyrite nodules. Gradational lower contact	1.9	29.4
5. Shale, interlamined light-olive-gray (5Y6/1) and olive-gray (5Y4/1), 95 percent, and light-olive-gray (5Y6/1) siltstone, 5 percent. Shale weathers grayish red (5R4/2) and moderate olive brown (5Y4/4), and contains many thin silt laminae. Siltstone beds are 0.5 to 2 cm thick, laterally continuous and uniform, and plane-parallel (Tb) laminated; contacts with shale are sharp and planar or slightly undulose. Siltstone beds are thicker and more numerous in the uppermost 3 ft. Sharp, planar lower contact	8.8	38.2
4. Shale, interlaminated light-olive-gray (5Y6/1) and olive-gray (5Y4/1). Contains stringers of white silt laminae. Basal contact is sharp	15.9	54.1
3. Siltstone, light-olive-gray (5Y6/1), 60 percent, and medium-gray (N5) shale, 40 percent. Beds are 2 to 10 cm thick and laterally continuous. Lower contact is gradational	18.6	72.7
2. Siltstone, light-olive-gray (5Y6/1), 90 percent, and thin intercalations of olive-gray (5Y4/1) shale which weather moderate brown (5YR4/4). Siltstones are more abundant toward the middle of the unit. Siltstones are laterally continuous and uniform. Most are thinner than 0.05 ft but some beds are as thick as 0.2 ft. They are plane-parallel (Tb) or cross-laminated (Tc) and have abrupt planar lower contacts and abrupt planar or rippled upper contacts. Unit contains both horizontal, tubular burrows and vertical escape structures. Lower contact is gradational	2.3	75.0

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
1. Shale, olive-gray (5Y4/1), 70 percent, intercalated with medium-light-gray (N6) siltstone, 20 percent, and medium-light-gray (N6) sideritic fine-grained, slightly fossiliferous carbonate beds, 10 percent. Shale is silty, weathers moderate brown (5YR4/4) in beds 0.2 ft to 0.7 ft thick. Siltstone layers are less than 0.1 ft thick and most are laterally continuous and uniform and contain either small-scale low-angle cross-laminae (Tc) or plane-parallel laminae (Tb) with dark-shale interlaminae. Contacts with shales are abrupt and planar, very slightly undulose, or rippled. Sideritic carbonate beds are 0.05 to 0.1 ft thick, and many are laterally continuous and uniform although some pinch out. A few of the sideritic carbonate lenses are in the form of starved ripples less than 1 ft wide. Some have surficial black manganese stains. In the lower 5 ft, very light gray cone-in-cone limestone lenses are present along the upper and lower surfaces of two sideritic beds; these are 0.1 to 0.2 ft thick and 2 to 6 ft wide. Lower contact of unit 1 is not exposed	11.4	86.4

Hadlock Road section, Ashtabula County, Ohio

(Locality 18, fig. 1)

Chagrin Shale is exposed in a roadcut on Hadlock Road 100 yards south of its junction with Creamer Road about 2 miles southwest of Kingsville in Ashtabula Township, North Kingsville quadrangle, Ashtabula County, Ohio (Ohio Coordinate System: North zone, 2,486,460 ft E, 809,600 ft N) (fig. 22). Top of section is heavily overgrown with grass and trees. Measured with hand level and tape by R.F. Broadhead on June 7, 1978.

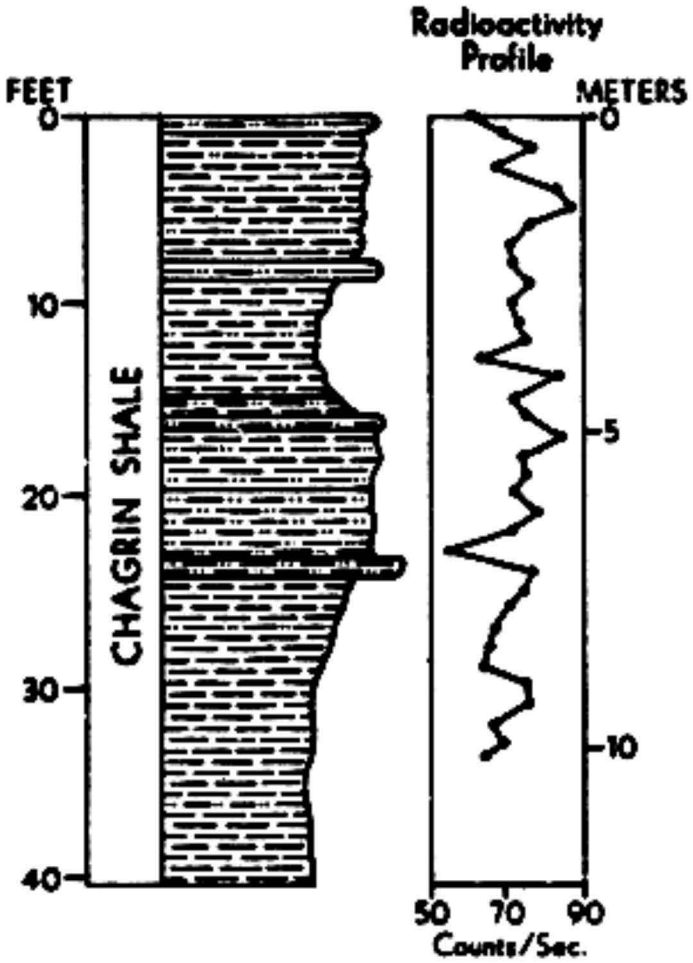

Figure 22. Lithologic and radioactivity profiles of the Hadlock Road section (locality 18, fig. 1).

Devonian (incomplete): Chagrin Shale (incomplete, 40.8 ft+):	Thickness (feet) Unit	Cumulative
10. Siltstone, medium-gray (N5), argillaceous, 95 percent, and thin lighter gray non-clayey silt laminae, 5 percent; slightly mottled. Sharp, planar lower contact	1.0	1.0
9. Shale, medium-light-gray (N6), 70 percent, and medium-light-gray (N6) siltstone, 30 percent. Shale is micaceous, extremely silty, hard and brittle, and contains as much as 30 percent silt in thin laminae. Shale beds are laterally continuous and 0.05 to 0.3 ft thick. Siltstone is micaceous in laterally continuous and uniform beds 0.05 to 0.2 ft thick, which contain superimposed sets of small-scale, low-angle, concave-upward cross-laminae (Tc). Lower contact is abrupt and planar but in some places is erosional and scoured	6.8	7.8
8. Siltstone, medium-gray (N5), laterally continuous and uniform, argillaceous, containing wavy parallel laminae, which in most places have been mottled by bioturbation. Basal contact is planar and abrupt	0.9	8.7
7. Shale, medium-gray (N5), 80 percent, and medium-light-gray (N6) siltstone, 20 percent, in beds 0.1 to 0.2 ft thick. Shale is very silty and micaceous; beds are laterally continuous and uniform. Siltstones are laterally uniform and continuous, micaceous, very pyritic, and plane-parallel (Tb) laminated. Laminae are alternating darker and lighter gray. Bases of siltstone beds are sharp and planar and contain some molds of crawling and resting traces on underlying shales	6.2	14.9
6. Siltstone, medium-gray (N5), laterally continuous, mottled by calcareous burrow fills and shaley wisps, and traces of original plane-parallel (Tb) laminae. Poorly exposed	0.9	15.8

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
5. Siltstone, medium-gray (N5), 95 percent, and very thin gray shale, 5 percent, in beds which pinch and swell and pinch out. Siltstone beds are less than 0.1 ft thick, are laterally continuous, and have sharp planar bases marked by molds of trails and resting traces on underlying shales; many are plane-parallel (Tb) laminated. Very dark shaley laminae alternate with very thin light silt laminae; laminations become finer and less shaley upward within a single bed. The upper parts of beds are mottled by burrows	0.8	16.6
4. Siltstone, light-olive-gray (5Y6/1), 50 percent, and medium-light-gray (N6) shale, 50 percent. Both the siltstone and shale beds are less than 0.1 ft thick and are laterally continuous and uniform. Siltstones are slightly calcareous, have sharp basal contacts, and contain mottled laminae and molds of brachiopods	3.2	19.8
3. Siltstone, medium-gray (N5), micaceous, in thin beds 0.05 to 0.1 ft thick, which contain lensoid parallel laminae (Tb-Tc) and are mottled	3.7	23.5
2. Siltstone, medium-light-gray (N6), in single bed which is mostly mottled but contains some plane-parallel laminae (Tb) and small-scale cross laminae (Tc); bed is laterally continuous with an abrupt and slightly undulatory base	0.8	24.3
1. Shale, light-gray (N7), clayey, 95 percent, and medium-gray (N5) siltstone, 5 percent, in laminae which are less than 0.05 ft thick, are laterally continuous and uniform, and increase in abundance upward. Base of unit 1 is not exposed	16.5	40.8

Conneaut Creek section, Ashtabula County, Ohio

(Locality 19, fig. 1)

Chagrin Shale is exposed on Ohio Route 84 and in cut of Conneaut Creek, 1/4 mile east of the city of Kingsville, Kingsville Township, North Kingsville quadrangle, Ashtabula County, Ohio (Ohio Coordinate System: North zone, 2,498,600 ft E, 815,200 ft N) (fig. 23). Base of section is in roadcut. Top of section is heavily vegetated. Measured with hand level and tape by R.F. Broadhead on June 5, 1978.

Devonian (incomplete): Chagrin Shale (incomplete, 25.3 ft+):	Thickness (feet) Unit	Cumulative
11. Shale, medium-gray (N5) to medium-dark-gray (N4); weathers moderate-yellowish-brown (10YR5/4) and is plastic when wet. The lower contact is abrupt and planar and has a few small undulations	15.0	15.0
10. Siltstone, medium-dark-gray (N4), calcareous; weathers light brown (5YR5/6). Single bed is laterally continuous but pinches and swells; contains some small-scale cross-laminae (Tc) having tangential lower and angular upper contacts and wavy-parallel laminae (Tb) which are disrupted by burrowing. Basal contact, sharp and slightly undulose but generally planar ..	0.5	15.5
9. Shale, medium-gray (N5), silty. Lower contact is abrupt and planar, slightly undulose locally	0.2	15.7
8. Siltstone, like that in unit 10	0.2	15.9
7. Shale, like that in unit 9	0.1	16.0
6. Siltstone like that in unit 10	0.5	16.5
5. Shale, light-gray (N7); weathers moderate olive brown (5Y4/4) and very dusky red (10R2/2); silty. Bed is laterally continuous and uniform	1.4	17.9
4. Siltstone, medium-light-gray (N6); weathers light brown (5YR6/4); laterally continuous and uniform. Faint laminae (Tb) are disrupted by burrows. Sharp planar lower contact	0.7	18.6

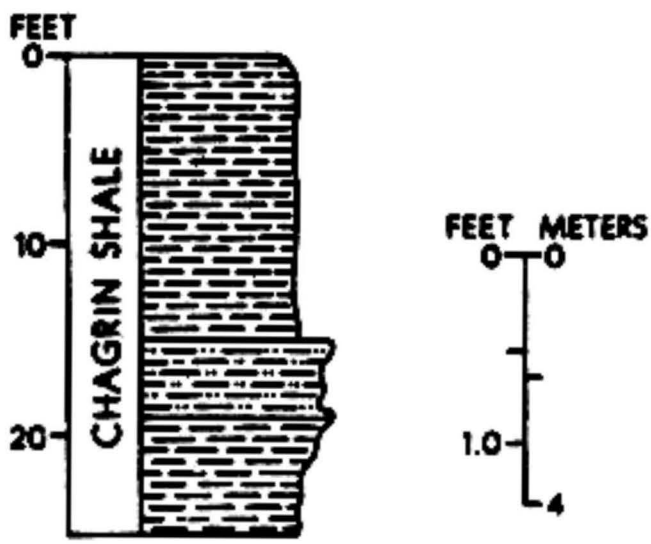

Figure 23. Lithologic profile of the Conneaut Creek section (locality 19, fig. 1).

Devonian--continued: Chagrin Shale--continued:	Thickness (feet) Unit	Cumulative
3. Shale, medium-light-gray (N6); weathers moderate yellowish brown (10YR5/4); laterally continuous and uniform. Basal contact is abrupt and planar	0.2	18.8
2. Siltstone, medium-light-gray (N6); weathers light brown (5YR6/4); in laterally continuous single bed which pinches and swells with a thickness range from less than 0.05 ft to 0.3 ft. Sharp lower contact	0.3	19.1
1. Shale, medium-light-gray (N6); weathers moderate yellowish brown (10YR5/4). Base not exposed	6.2	25.3

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