STATE OF OHIO
Richard F. Celeste, Governor
DEPARTMENT OF NATURAL RESOURCES
Joseph J. Sommer, Director
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Report of Investigations No. 132

SUPPLEMENTAL CORE INVESTIGATIONS FOR HIGH-CALCIUM LIMESTONES IN WESTERN OHIO AND DISCUSSION OF NATURAL GAS AND STRATIGRAPHIC RELATIONSHIPS IN THE MIDDLE TO UPPER ORDOVICIAN ROCKS OF SOUTHWESTERN OHIO

by

David A. Stith

Columbus
1986

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CONTENTS

FIGURES

TABLES

PLATES

SUPPLEMENTAL CORE INVESTIGATIONS FOR HIGH-CALCIUM LIMESTONES IN WESTERN OHIO AND DISCUSSION OF NATURAL GAS AND STRATIGRAPHIC RELATIONSHIPS IN THE MIDDLE TO UPPER ORDOVICIAN ROCKS OF SOUTHWESTERN OHIO

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ABSTRACT

Four core holes, one in northwestern Ohio and three in southwestern Ohio, were drilled in a continuing evaluation of the high-purity limestone resources of Ohio. The northwestern Ohio core shows high-calcium limestone (>95 percent $CaCO_3$) in the lithographic facies of the Dundee Limestone (Devonian) in Defiance County. This facies of the Dundee was deposited in a peritidal, possibly arid environment.

One southwestern Ohio core from Clermont County has almost 38 feet of high-calcium stone in the lower part of the Black River Group (Middle Ordovician). The high-calcium stone is included in a total of 59 feet of high-carbonate limestone (>95 percent $CaCO_3$ plus $MgCO_3$). A southwestern Ohio core from Butler County has 68 feet of high-carbonate limestone. Depositional environments of the Black River Group in Butler and Clermont Counties were shallow and tidally influenced in part, similar to those in Adams and Brown Counties and in central Kentucky. Bentonitic marker beds in the upper part of the Black River show evidence both of multiple ash falls and of bottom mixing. The Lexington Limestone and the Point Pleasant Tongue of the Clays Ferry Formation are present in southern Clermont County and are equivalent to the Trenton Limestone in northwestern Ohio. Natural gas was encountered in drilling all three holes in southwestern Ohio.

INTRODUCTION

PREVIOUS WORK

High-calcium (>95% $CaCO_3$) and high-carbonate (>95% $CaCO_3$ plus $MgCO_3$) limestone deposits are rather scarce in Ohio. Two earlier reports of the Ohio Department of Natural Resources, Division of Geological Survey investigated the occurrence of high-calcium limestone in northwestern Ohio (Stith, 1972) and high-carbonate limestone in southwestern Ohio (Stith, 1979).

The first of these studies looked at the Middle Devonian Dundee Limestone. The Dundee is underlain by the Detroit River Group and overlain by the Silica Formation of the Traverse Group (Janssens, 1970). The upper part of the Dundee is fine- to coarse-grained, fossiliferous limestone. The lower Dundee is sandy, fine to medium grained, and dolomitic. Throughout much of northwestern Ohio the basal portion of the upper Dundee is lithographic limestone. Analysis of quarry samples and drill cuttings showed this facies to contain high-calcium limestone throughout its surface and subsurface occurrence (Stith, 1972). Because most of the samples came from well cuttings, both the composition of the rock and the thickness of the high-calcium zone in the subsurface were somewhat uncertain.

The second study investigated limestone in the Middle Ordovician Black River Group. In southwestern Ohio the Black River generally overlies the porous, argillaceous, dolomitic Wells Creek Formation. In some places it directly overlies the Knox Dolomite on erosional remnants on the Knox unconformity. The Black River is overlain by the fine- to coarse-grained Trenton Limestone or Lexington Limestone. The Black River consists of micritic and pelletal limestone with a minor number of dolomitic beds. There are eight bentonitic and argillaceous marker beds in the upper and middle portions of the Black River. The lower Black River consists of the lower argillaceous unit, the Carntown unit, and the upper argillaceous unit (Stith, 1979). Chemical analysis of samples from two cores showed substantial thicknesses of high-carbonate limestone in several zones of the Black River. Although no high-calcium rock was found, it is mined in Kentucky just across the Ohio River from Moscow, Clermont County, Ohio. Geophysical logs used in the stratigraphic portion of the study indicated the possible presence of high-calcium limestone in the Carntown unit in Butler, Clermont, and Miami Counties, Ohio (Stith, 1979).

CORING PROGRAMS

Two core-drilling programs were developed to further investigate the chemical quality of the Dundee Limestone and the Black River Group. Three NQ diameter (1⁷/₈ inches) cores were planned in Defiance, Fulton, and Williams Counties (fig. 1) to check both the purity and the subsurface thickness of the lithographic limestone facies of the Dundee. The Defiance County site was cored to the top of the Detroit River Group (sample 20-2083, core no. 2538). Drilling at the other two sites was cancelled because of technical difficulties.

Three holes through the Black River Group were planned for southwestern Ohio, two in Clermont County and one in Butler County (fig. 1, table 1). One hole in southeastern Clermont County (Franklin Township) was sited near the crest of the Cincinnati Arch (Stith, 1981). The other Clermont County hole (Pierce Township) and the Butler County hole were sited near oil wells whose geophysical logs indicated very low dolomite rock in the Carntown unit of the Black River (Stith, 1979). Coring was stopped in southeastern Clermont County in the upper part of the Black River because of natural gas pressure that could not be controlled by methods available to the Division of Geological Survey rig. The other two sites were cored to the top of the Knox Dolomite.

Limestone sections in all the cores were split vertically

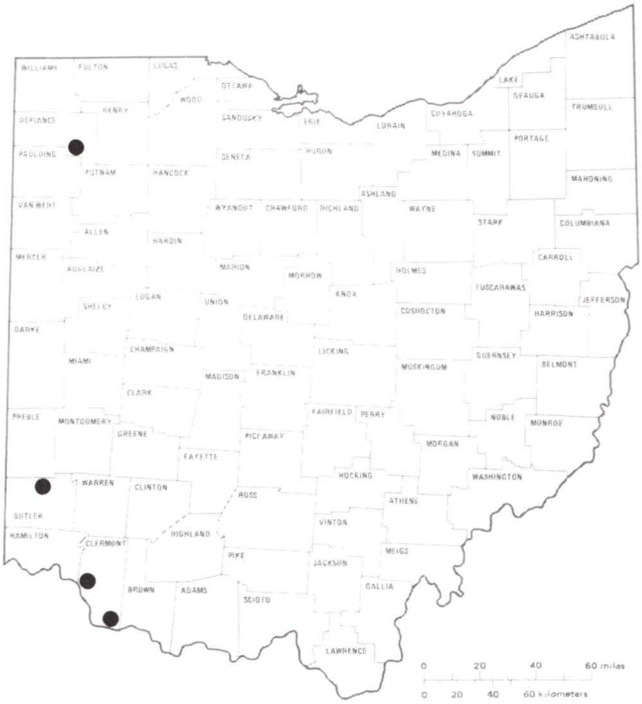


FIGURE 1.—Core locations.

with a hydraulic splitter. Limestone/shale sections of the cores were measured to the nearest 0.01 foot for construction of shale-percentage logs (Sweet and others, 1974). Detailed core descriptions were made of the entire core. Samples for chemical analysis consisted of a continuous ¼-core split of each sampled interval. The upper Dundee Limestone was sampled in the Defiance County core except for the top 2 feet, which was gradational with the overlying Silica Formation. The Carntown unit of the Black River Group was sampled in the Pierce Township, Clermont County, core and in the Butler County core. Chemical analyses were done by a combination of atomic absorption, emission, and titration methods. Chemical analysis results are listed in Appendix A and condensed core descriptions are listed in Appendix B. Complete detailed core descriptions are on open file at the Division of Geological Survey.

ACKNOWLEDGMENTS

The author expresses his appreciation to the landowners of the coring sites for allowing the Division of Geological Survey to drill on their property. Chemical analyses were done by Dr. Norman F. Knapp of the Survey's Geochemistry Laboratory. Thanks also go to Lawrence H. Wickstrom, of the Survey's Subsurface Geology Section, for many lengthy discussions on the problems of regional correlations of the Trenton Limestone. Core drilling was done by Michael J. Mitchell and John L. Sullivan of the Survey's Regional Geology Section.

TABLE 1.—*Limestone sample and core-file numbers, Black River Group*

County	Township	Limestone sample no.[1]	Core file no.
Butler	Wayne	09-2082	2537
Clermont	Franklin	13-2081	2535
Clermont	Pierce	13-2080	2536

[1]Ohio Division of Geological Survey field sample numbers. The first two digits of each sample designation refer to the county where the sample was collected. The final four digits are the actual sample number used throughout the report.

DUNDEE LIMESTONE RESULTS

The core recovered in Defiance County shows 15 feet of fossiliferous upper Dundee, 22 feet of lithographic upper Dundee, and 14 feet of slightly sandy, dolomitic lower Dundee (Appendix B). Chemical analyses (Appendix A) show most of the upper Dundee is fairly pure limestone, somewhat dolomitic in part. The lithographic facies, from 76.88 to 98.92 feet, is indeed very pure—insoluble oxides total about 1.2 percent and $MgCO_3$ is less than 1 percent.

The lithographic facies is micritic, pelletal, and generally laminated. Round to planar, sparry-calcite-filled birdseyes along with the generally laminated condition and suggestions of flat-pebble conglomerate, vertical burrows, and evaporite-crystal casts indicate deposition in a shallow, intertidal to supratidal, possibly arid environment.

BLACK RIVER GROUP RESULTS

CHEMISTRY

The overall purity of the Carntown unit of the Black River Group in the Butler and Clermont County cores (Appendix A) is the same as was found earlier in Adams and Brown Counties (Stith, 1979). Insoluble oxides total 1.6 percent for sample 2080 (Pierce Township, Clermont County), and 1.9 percent for sample 2082 (Wayne Township, Butler County). The Carntown does contain a mineable thickness of high-calcium limestone in Pierce Township, Clermont County. Rock in the interval from 641.25 to 678.88 feet of sample 2080 averages 95.3 percent $CaCO_3$, 2.6 percent $MgCO_3$, and 1.85 percent insoluble oxides. High-calcium stone is present in Wayne Township, Butler County, but is in thin (2.6-10 feet) zones not of mineable thickness. Total thickness of the high-carbonate Carntown unit is 59 feet in Clermont County sample 2080 and 68 feet in Butler County sample 2082.

STRATIGRAPHY AND DEPOSITIONAL ENVIRONMENTS

The two complete cores and one partial core of the Black River Group in this study show the Black River to be essentially the same in Butler and Clermont Counties as it is in Adams, Brown, and Highland Counties (Stith, 1979). The upper third of the Black River is interbedded micritic and pelletal limestone and fine-grained dolomite with six argillaceous and bentonitic marker beds (α, β, γ, Δ, a, b) (fig. 2). The middle third is burrow-mottled micritic and pelletal limestone with two dark-colored shaly marker beds (I, II). The lower third of the Black River is very pure micritic and pelletal limestone overlain by limestone and dolomite similar to marker beds I and II and underlain by interbedded argillaceous micrite and dolomite.

Current Ohio terminology for the Middle Ordovician and the lower part of the Upper Ordovician is shown in figure 2 along with the correlative Kentucky terminology. The

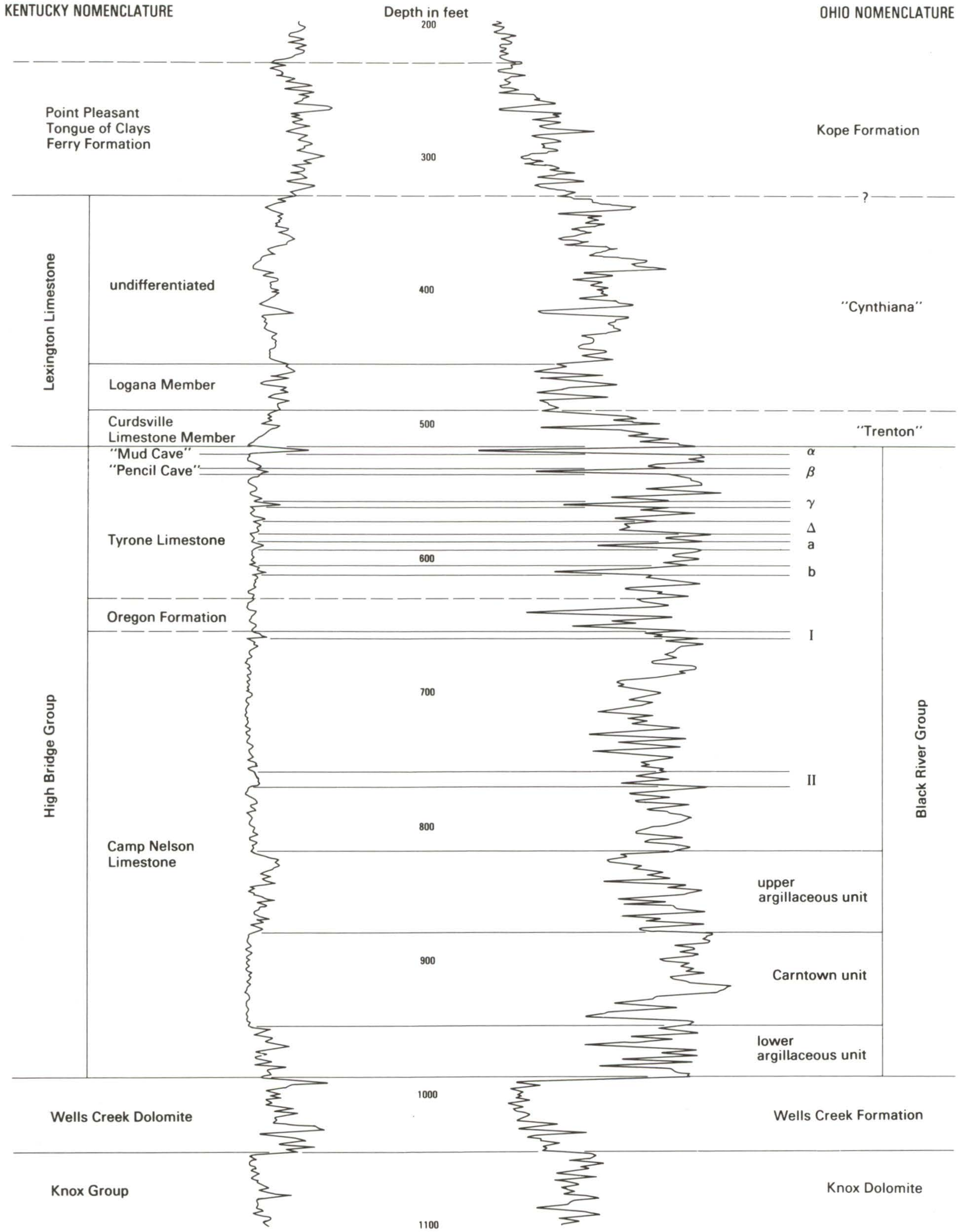


FIGURE 2.—Gamma ray-neutron log of Harold Wilson No. 1 well in Campbell County, Kentucky, and Middle to Upper Ordovician stratigraphic nomenclature in Ohio and Kentucky.

correlative of the Black River Group in Kentucky, the High Bridge Group, is composed of, in ascending order, the Camp Nelson Limestone, the Oregon Formation, and the Tyrone Limestone. Two K-bentonites, the "Mud Cave" and the "Pencil Cave," are found in the upper part of the Tyrone. The High Bridge Group is overlain by the Lexington Limestone. The lowermost two members of the Lexington are the Curdsville Limestone Member and the Logana Member. The name Cynthiana Formation has been abandoned in Kentucky and most of the rocks formerly assigned to this unit are now considered to be the upper part of the Lexington Limestone (Black and others, 1965). Because the name is abandoned in Kentucky and the "Cynthiana" has not been formally described in the subsurface of southwestern Ohio, "Cynthiana" is considered a local drillers' term and is so used in this report. The Trenton Limestone has been described in northwestern Ohio but is also considered a drillers' term in southwestern Ohio.

Most of the upper six marker beds in the Black River Group are K-bentonites or mixtures of K-bentonite and argillaceous or bentonitic limestone (Stith, 1979; and table 2, this study). The uppermost marker bed in the Black River, α, is the equivalent of the "Mud Cave" K-bentonite in Kentucky, and marker bed β is the equivalent of the "Pencil Cave" K-bentonite (Huff, 1983).

The previous Division of Geological Survey study of the Black River Group (Stith, 1979) noted that some of the K-bentonite marker beds appear to represent packets of multiple ash falls, based on the gamma ray-neutron logs of many of the wells. The possibility of multiple events, or, alternatively, of splits due to bottom mixing, has also been noted by Cressman and Noger (1976) and Huff (1983). Descriptions of the three cores in this study (sample nos. 2080, 2081, and 2082) and comparison with adjacent geophysical logs seem to support both circumstances. The bulk of the cases of multiple-bed appearance seems to be groupings of argillaceous or shaly limestones with a K-bentonite bed. It would take a detailed mineralogical investigation to determine if these argillaceous beds are composed of terrigenous clay or contain microscopic constituents of the K-bentonites. There are some cases, however, that are obvious by macroscopic examination.

Marker bed β in all three cores appears to be a case of multiple falls. It consists of two distinct K-bentonite layers separated by 1.4 to 2.6 feet of micrite with *Tetradium* fragments (table 2). The micrite has no visible evidence of ash such as biotite or heavy mineral grains as determined on split core with a binocular microscope.

The detailed core description of sample 2080 shows marker bed γ consists of 0.56 foot of K-bentonite overlain by 5.3 feet of argillaceous micrite and pelsparite with green shale partings. In sample 2081, marker bed γ is 0.3 foot thick (table 2) and overlain by 0.5 foot of pelmicrite and 0.6 foot of shaly micrite. A bed-by-bed correlation of the interval between marker beds β and b in samples 2080 and 2081 shows the γ K-bentonite in sample 2081 to be at the level of the upper, shalier part of the argillaceous beds in sample 2080. The γ K-bentonite in sample 2080 corresponds to several chert layers about 5 feet below the γ K-bentonite in sample 2081.

Bottom mixing as noted by Huff (1983) is also seen in the cores; marker bed b in sample 2080 is a good example. The 0.5 foot of limestone between the two K-bentonite layers has abundant heavy mineral grains and some biotite flakes.

TABLE 2.—*Description of marker beds in upper part of Black River Group*

Marker bed	Sample no. 2082		Sample no. 2080		Sample no. 2081	
	Thickness (ft)	Lithology	Thickness (ft)	Lithology	Thickness (ft)	Lithology
α	0.22	K-bentonite	1.83	K-bentonite		not present
	4.69	laminated micrite				
	0.05	K-bentonite				
β	0.54	K-bentonite	0.88	K-bentonite	0.64	K-bentonite interbedded with shaly, bentonitic(?) limestone
	2.55	micrite, *Tetradium* fragments	1.43	micrite, *Tetradium* fragments	2.00	micrite, *Tetradium* fragments
	0.26	K-bentonite	0.13	K-bentonite	0.59	K-bentonite interlaminated with micrite
γ	5.89	argillaceous, dolomitic micrite	1.00	micrite, pelsparite, dolomite, and shale	0.65	laminated, shaly micrite
	0.10	K-bentonite	1.58	laminated, argillaceous micrite	0.50	laminated pelmicrite
			2.75	argillaceous micrite and pelsparite	0.25	pelmicrite, dolomite, and bentonitic shale
			0.56	K-bentonite	0.08	K-bentonite
Δ	15.07	argillaceous micrite, biomicrite, and dolomite; burrowed	12.38	argillaceous micrite, biomicrite, and dolomite; burrowed	12.67	argillaceous micrite and shaly dolomite; burrowed
a	0.27	shaly limestone	1.23	laminated, argillaceous micrite	3.29	micrite, dolomite, and pelsparite; argillaceous
	0.04	K-bentonite?	2.89	laminated, dolomitic micrite	2.96	micrite and dolomite, laminated
	0.70	pelsparite and micrite	1.19	laminated micrite	0.06	shale and limestone, bentonitic
	0.04	K-bentonite?	0.27	shale and mudstone		
b	0.69	K-bentonite	0.50	K-bentonite, calcareous streaks	0.76	laminated pelsparite/claystone
			0.54	bentonitic limestone	0.06	K-bentonite
			0.20	K-bentonite		

In the area of outcrop of Middle Ordovician rocks in central Kentucky the Tyrone Limestone is disconformably overlain by the Curdsville Limestone Member of the Lexington Limestone. The "Mud Cave" K-bentonite is present locally at the contact in part of the outcrop area (Cressman, 1973). The widespread absence of the "Mud Cave" in central Kentucky is attributed, in part, to pre-Curdsville erosion (Cressman, 1973). In southwestern Ohio absence of marker bed α ("Mud Cave") is not so simply explained. The α K-bentonite is recognizable in most cores and geophysical logs in the study area. In most of the available cores and core descriptions (10 in Ohio and two in Kentucky) there are from 0.1 to 6.5 feet of micritic limestone between marker bed α and the overlying "Trenton" (Curdsville Limestone Member of the Lexington Limestone). In the one core with no visible indication of the α K-bentonite (sample 2081, Franklin Township, Clermont County) the interval from the β K-bentonite to the top of the Black River Group is greater than the α/β interval in surrounding cores (fig. 3).

The core in Pierce Township, Clermont County (sample 2080), is only 2.85 miles from a well (Calloway No. 1, permit 5) with a gamma ray-neutron log (fig. 4). The α K-bentonite in the core is one of the thickest (1.8 feet) noted in cores and core descriptions in the study area. However, there is no obvious K-bentonite log signature at the α position on the gamma ray-neutron log for the permit 5 well. There are two small shale markers between the β marker and the log signature of a local K-bentonite in the Curdsville Member of the Lexington Limestone. The core and the gamma ray-neutron log show a nearly perfect bed-by-bed correlation for about 190 feet from a porous zone above the Logana Member of the Lexington Limestone to the b marker bed.

Figure 4 graphically illustrates this situation with four labelled horizons (A, B, C, D). The entire section shown in figure 4 is 3 feet shorter in the core than in the permit 5 log. Most of this shortage, 2.2 feet, occurs in the 20+ feet of core containing the α K-bentonite (interval B-C), even though the core has 1.8 feet of α K-bentonite apparently not present at the permit 5 well site. Bed-by-bed correlations from above (horizons A to B) and from below (horizons C to D) place the α bed in the core between the positions of the two small shale markers in the gamma ray-neutron log. This placement would seem to indicate bottom dispersal and dilution of the ash fall into two separate beds with some intervening carbonate deposition at the well-log site.

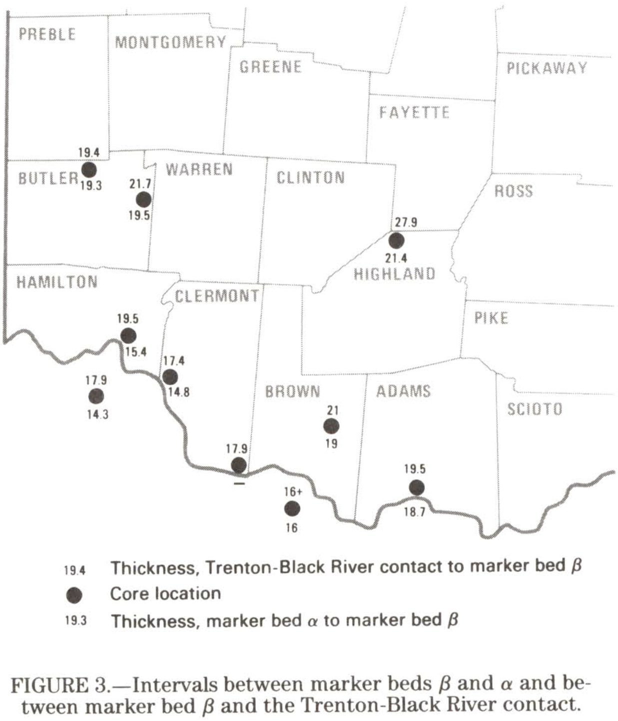
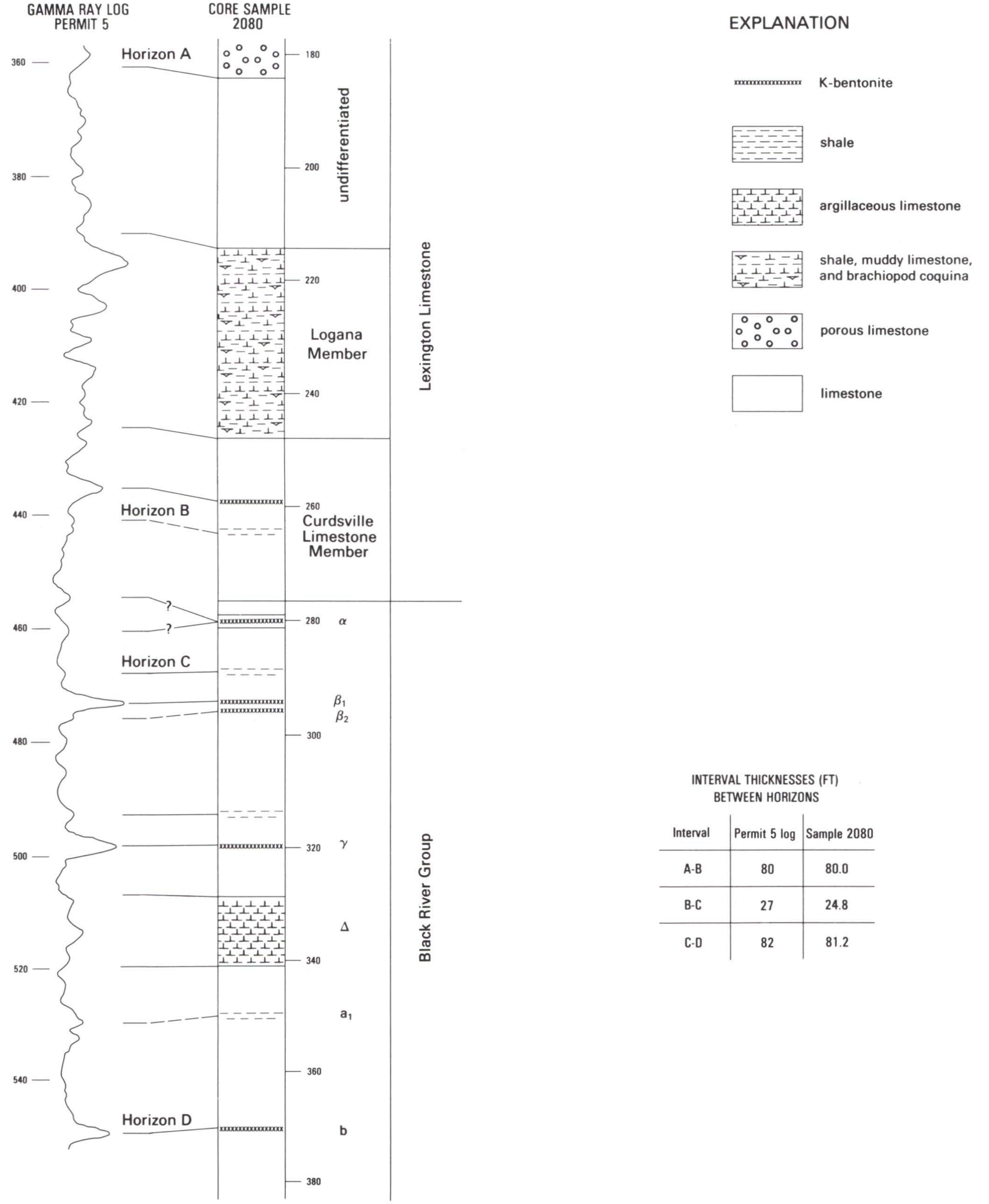


FIGURE 3.—Intervals between marker beds β and α and between marker bed β and the Trenton-Black River contact.

The generally smooth and simple isopach and structure maps shown in Stith (1979, figs. 3, 4, 5, and 6) are artifacts of the lack of detailed drilling information in southwestern Ohio. The more complex structural and thickness trends in the Champaign/Miami County and Clinton/Fayette County areas probably exist over most of southwestern Ohio. A comparison (table 3) of two of the cores in this study and one of the older cores with geophysical logs from nearby wells shows the definite effect of the relief of the Knox unconformity on the various units of the Black River Group and the Wells Creek Formation. Thinning over highs on the Knox surface apparently can affect the Wells Creek (Adams County), the Wells Creek and the lower part of the Black River (Butler County), or virtually the entire Black River Group (Clermont County).

The cores in this study (samples 2080, 2081, and 2082) show that the widespread tidal flats that developed during deposition of the Black River Group in central Kentucky (Cressman and Noger, 1976) and in Adams, Brown, and Highland Counties, Ohio (Stith, 1979), extended into Butler and Clermont Counties, Ohio. Most of the supratidal and intertidal lithologies illustrated in the earlier Division of Geological Survey study (Stith, 1979) also are found in these cores, as indicated by the presence of laminated micrite, interlaminated micrite and dolomite, sheet cracks, mudcracks, birdseyes, and vertical burrows. Supratidal and intertidal environments are postulated to have existed mainly during deposition of the upper third of the Black River (above marker bed I), and at times during deposition of the upper argillaceous unit, the Carntown unit, and the lower argillaceous unit. Most of the middle third of the Black River is subtidal burrow-mottled limestone. The tidal facies appear to decrease in aggregate thickness to the northeast in the upper Black River and to the north in the Black River Group as a whole, as shown in figure 5.

The Oregon Formation in central Kentucky has been described as mainly supratidal and intertidal (Cressman and Noger, 1976) or intertidal (Horrell 1981). The earlier Division of Geological Survey study (Stith, 1979) indicated a largely supratidal/intertidal environment for the dolomitic beds just above marker bed I correlative to the Oregon. The existence of the Oregon also has been attributed to secondary dolomitization related to development of the Lexington Dome (Freeman, 1953). Thickness of the Oregon correlative gradually decreases to the northwest in Ohio from 42 feet in Adams County to 3 feet in Butler County. Indications of tidal-flat environments in the Oregon correlative are vertical burrows, faint laminations, birdseyes, interlaminated micrite and dolomite, sheet cracks, and mudcracks. However, the Oregon correlative in Ohio is largely dolomitic limestone with a minor amount of limy dolomite. Much of the Oregon correlative is micrite with "floating" dolomite rhombs. This rock shows extensive relict texture such as biopelsparite, biomicrite, intrasparite, and horizontal burrows, indicating some secondary dolomitization of subtidal facies did occur.



INTERVAL THICKNESSES (FT) BETWEEN HORIZONS

Interval	Permit 5 log	Sample 2080
A-B	80	80.0
B-C	27	24.8
C-D	82	81.2

FIGURE 4.—Absence of α K-bentonite illustrated by comparison of core sample 2080 and gamma ray-neutron log of Calloway No. 1, permit no. 5 well in Pierce Township, Clermont County, Ohio. Depths in feet.

TABLE 3.—*Effect of Knox topography on thickness of Wells Creek Formation and various units in Black River Group*

County Core sample no. Geophysical-log[1] well-permit no.	Distance between core and well	Thickness (feet)					Elevation (feet below sea level) of Knox Dolomite
		β to upper argillaceous unit	Upper argillaceous unit	Carntown unit	Lower argillaceous unit	Wells Creek Fm.	
Adams							
S-2405	150 feet	315	65	62	41	64	-891
P-6 (GRN)		318	63	63	42	55	-883
Clermont							
13-2080	2.85 miles	291	56	60	35	26	-282
P-5 (GRN)		302	54	72	34	44	-299[2]
Butler							
09-2082	0.85 mile	276	49	68	28	37	-480
P-2 (LL/GRN)		279	52	70	28	45	-495

[1]GRN = gamma ray-neutron log; LL = laterolog.
[2]Elevation of Knox Dolomite is -330 feet if elevation of well site is near topo pick of plotted location.

NATURAL GAS IN SOUTHWESTERN OHIO

Natural gas has been reported from southwestern Ohio for over a century (Orton, 1888; Harper, 1939; Ohio Division of Geological Survey open-file records) but generally not in commercial quantities. A review of well records for Brown, Butler, Clermont, Hamilton, and Warren Counties on open file at the Division of Geological Survey shows roughly half of the wells on record reported one or more shows of gas. Many of the gas reports are listed as "show," "small gas flow," "some gas," or just "gas." About 40 percent of the records with gas notations show comments about heating buildings for 1 to 50 years or about strong gas pressure. Five of these wells are listed as "75 MCF," "300,000 cu. ft.," "½ million," "1,000 MCF Nat," and "2,000,000 cu. ft." Most of the wells reporting natural gas were drilled in the late 1880's; another group was drilled in the early 1920's. Where depths are listed or inferred, most of the gas reports are shallow (less than 600 feet deep). Where reported or inferred, the producing horizon was mainly in the Upper Ordovician; some wells were in the "Utica" or in the "Cynthiana."

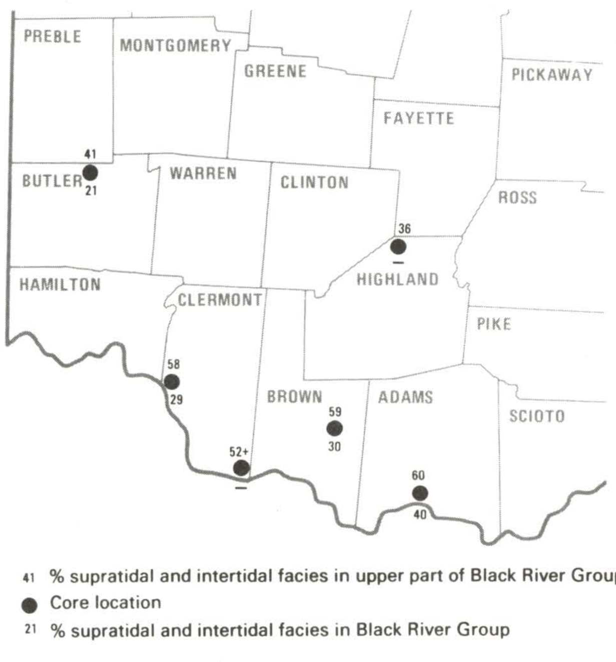


FIGURE 5.—Percentage of tidal facies in Black River Group.

Natural gas was encountered during the drilling of all three cores in southwestern Ohio. Two sites had low-pressure shows as in the majority of the historical reports; the third site was probably similar to those reports showing local heating supplies years after drilling. The hole in Pierce Township, Clermont County (sample 2080), recorded several minor instances of gas bubbles in the drilling water and slight flowing water at 260 to 270 feet in the Curdsville Limestone Member of the Lexington Limestone, and at 430 to 450 feet in the upper part of the middle of the Black River Group. The hole in Wayne Township, Butler County (sample 2082), had fairly constant gas shows down to 550 feet (middle of the Kope Formation). Most shows were slight gas bubbles to gas flows lasting 5 to 10 minutes, then subsiding. Rarely the gas would blow for 30 minutes to 2 days. In addition, a minor number of gas bubbles occurred in water in the top of the drilling rod around 750 and 790 feet in the middle to lower "Utica," at 895 to 935 feet in the Logana and Curdsville Members of the Lexington Limestone, and at 1015 to 1045 feet between marker beds a and b in the Black River Group.

Natural gas encountered in the hole in Franklin Township, Clermont County (sample 2081), was in strong contrast to that found in the other two core holes. Fairly high pressure gas flowed for hours at 180 to 190 feet in the Logana and at about 290 feet in marker bed Δ. After bentonitic drilling mud was pumped down the hole, the second flow died out or was sealed off. Drilling continued to 350 feet, about 4 feet into the Oregon correlative, where there was a very strong gas flow. No pressure or flow measurements were made of the gas, but the gas and water plume blew about 60 feet in the air for several days. At the same time a problem with the engine shut down the core rig for a month. When the engine was repaired and the Division of Geological Survey was able to retrieve the rod and start to cement the hole, the pressure was still sufficient to blow water 2½ to 3 feet above the top of the rod about every 20 seconds.

STRATIGRAPHIC RELATIONSHIPS IN THE MIDDLE TO UPPER ORDOVICIAN ROCKS IN SOUTHWESTERN OHIO

The core holes in southwestern Ohio were drilled to investigate the possibility of high-calcium limestone in the Black River Group. Because the cores are continuous (or nearly continuous) to total depth, they also include rocks spanning the Middle-Upper Ordovician boundary and provide indications of work that still needs to be done on this part of the geologic section in Ohio.

In Ohio the Black River Group is overlain by the Trenton Limestone. The closest outcrop area of these rocks is in central Kentucky, where the Black River equivalent, the High Bridge Group, is overlain by the Lexington Limestone. Historically the rocks between the High Bridge and the Upper Ordovician were divided into the Lexington Limestone and the overlying Cynthiana Formation. Beginning in the 1960's, extensive work in Kentucky has revised the Lexington to include all of the bioclastic limestone between the High Bridge and the interbedded shale/limestone of the Upper Ordovician (Black and others, 1965). As much as 100 feet of the upper part of the Lexington and equivalent rocks is now considered to be Late Ordovician in age. A review of the stratigraphy, conodont biostratigraphy, and age relationships of these rocks in Kentucky and the Cincinnati vicinity can be found in Black and others (1965), Bergström and Sweet (1966), Sweet and Bergström (1971), Cressman (1973), Sweet and others (1974), and Sweet (1979).

What was once called the Cynthiana Formation is now considered to be a complex facies mosaic in the upper part of the Lexington Limestone in central Kentucky. To the north toward the Ohio River the upper part of the revised Lexington intertongues with and, in part, grades into the Point Pleasant Tongue of the Clays Ferry Formation (Cressman, 1973). The Point Pleasant has been retained in the current classification because it has historical precedent (Orton, 1873). Traditional subsurface terminology in Ohio, however, has used "Trenton" and "Cynthiana" for the limestone and interbedded limestone and shale between the Black River Group and the Upper Ordovician shales (fig. 2). A series of cross sections (pls. 1, 2, 3) has been prepared relating the Middle to Upper Ordovician rocks in the cores from this study to the subsurface stratigraphy of southwestern and central Ohio and Kentucky.

In southern Clermont County, the shallow subsurface rocks correlate with the Lexington Limestone of Kentucky (fig. 2; pl. 1). The Lexington in samples 2080 and 2081 consists of, in ascending order, the Curdsville Limestone Member, the Logana Member, and approximately 130 feet of undifferentiated Lexington. Overlying the Lexington and cropping out along some of the valley bottoms is 100 to 110 feet of the Point Pleasant Tongue of the Clays Ferry Formation (Kohut and Weiss, 1981). The Point Pleasant, which is equivalent to the upper part of the Lexington in central Kentucky, is gradationally overlain by the Upper Ordovician Kope Formation. The Kope and Point Pleasant intertongue in part (Osborne and others, 1973).

Numerous limestone beds and carbonate zones in the Lexington/Point Pleasant equivalents, including the Curdsville and Logana Members, can be traced to the north and northeast (pls. 2 and 3). As most of these zones thin to the northeast, both in individual carbonate-bed thickness and by wedging out of certain limestone beds, the distinction between the Lexington, the Point Pleasant, and the lower Kope becomes more difficult. The Curdsville Member, on the other hand, thickens to the northeast and the Logana Member maintains a fairly constant thickness, rising with the top of the Curdsville. There is a considerable amount of intertonguing between the Logana and the overlying and underlying beds.

Between Highland County and Delaware County the limestone bed marking the Kope-Point Pleasant contact in Clermont County becomes virtually indistinguishable (pls. 1 and 3). The only part of the section calcareous enough to be called limestone is the correlative of the Curdsville Member (pl. 3). Because the top of the "Cynthiana" has not been defined in the subsurface in Ohio, various workers have picked the top at various limestone beds from the lowermost Kope to the upper part of the Lexington, as shown on plate 2. Preliminary correlations by the author, by Wickstrom and Gray (in preparation), and by L. H. Wickstrom and others (Division of Geological Survey work in progress) between the Trenton Limestone of northwestern Ohio and the Lexington/Point Pleasant equivalents in central and southwestern Ohio indicate that the basal member of the Lexington, the Curdsville, is equivalent to the basal facies of the Trenton in northwestern Ohio. Also, the higher beds in the Lexington/Point Pleasant which wedge out to the north are equivalent facies of the rapidly thickening upper Trenton facies which overlies the basal Curdsville equivalent in northwestern Ohio.

The carbonate zones also thin to the northwest and lie closer to the top of the Black River Group. However, the Point Pleasant and much of the Lexington equivalents interfinger with and are eventually replaced by brown and black carbonaceous shales and siltstones in northern Butler County (pl. 2). These rocks are the "Utica" of local drillers. The Curdsville and Logana Members of the Lexington are still recognizable in Butler County. The Kope/Point Pleasant contact in Clermont County correlates with the top of the "Utica" in Wayne Township, Butler County (pl. 2). Bergström and Sweet (1966) determined the top of the "Lexington equivalents" by conodont biostratigraphy in a core from near Middletown, in Lemon Township, Butler County. This horizon is in the lower part of the Kope Formation at Middletown and correlates with the top of interbedded gray and brown shales in the lower Kope in core sample 2082, Wayne Township, Butler County (pl. 2).

Unlike the complex facies changes and intertonguing of the upper Lexington Limestone in central Kentucky, the equivalent rocks in southwestern Ohio are interbedded limestone and shale beds traceable over considerable distances (pls. 2 and 3). Several studies (Stout, 1941; Freeman, 1953; Rooney, 1966) have implied or postulated the equivalence of the "Cynthiana"-"Point Pleasant" rocks to the upper Trenton in northwestern Ohio. The cores from this study and other recent work at the Division of Geological Survey (Wickstrom and Gray, in preparation; L. H. Wickstrom and others, work in progress) support this contention. In addition, there is a trend or trough of dark-colored shales with very low carbonate content extending from Preble County to the northeast. This trend, which has been noted previously (Rooney, 1966; Cressman, 1973), is parallel to the slope edge of the Trenton platform of northwestern Ohio as mapped by Wickstrom and Gray (in preparation). Preliminary work in Indiana indicates a zone of very thin or no Trenton entering Ohio along this trend (Brian Keith, written communication). The main problems still needing work are: (1) whether or not the lower portion of the Trenton exists across the trough in west-central Ohio; (2) the relationship of the dark shales of the "Utica" to a facies framework of the Trenton-Lexington-Point Pleasant; and (3) formal definition of a packet of limestone and shale equivalent to the Trenton and Lexington Limestones.

SUMMARY

This study has confirmed the presence of high-calcium stone in the Dundee Limestone in the subsurface of northwestern Ohio, as indicated previously (Stith, 1972). The lithographic facies of the Dundee is 22 feet thick in Defiance Township, Defiance County. Composition of the stone is about 97.5 percent $CaCO_3$, with less than 1 percent each of SiO_2 and $MgCO_3$. The depositional environment of the unit is interpreted to be peritidal, possibly arid.

In southwestern Ohio, the Black River Group in Butler and Clermont Counties is essentially the same as it is in Adams and Brown Counties (Stith, 1979). The Carntown unit of the Black River has 68 feet of high-carbonate stone in Butler County and 59 feet in Clermont County. The Carntown averages less than 2 percent insoluble oxides. One Clermont County core has over 37 feet of high-calcium stone in the Carntown unit. This high-calcium section has 1.85 percent insoluble oxides and 2.6 percent $MgCO_3$.

Close examination of the K-bentonite marker beds in the three Black River Group cores and adjacent geophysical logs supports the occurrence both of multiple ash falls and of bottom mixing in the deposition of these beds. The Knox unconformity and the thickness and structural trends of the Black River Group are probably more complex than previously shown.

Depositional environments of the upper third of the Black River Group were generally tidally influenced. The middle third of the Black River is mainly subtidal burrowed micrite. The lower third is a mixture of subtidal and peritidal facies. The overall thickness of tidal facies in the Black River decreases to the north. The dolomitic beds correlative to the Oregon Formation thin drastically to the northwest. Moreover, some of the rock in these beds shows relict subtidal texture, indicating secondary dolomitization.

Natural gas was encountered in drilling all three cores in southwestern Ohio. Most of these shows of gas were in the Upper Ordovician rocks in the shallow subsurface. Gas at two of the sites was low pressure as in most of the historical records of gas shows in the area. The hole in Franklin Township, Clermont County, encountered very strong gas pressure in marker bed Δ and in the Oregon correlative in the Black River Group.

The lower part of the Lexington Limestone is present in southern Clermont County. The overlying Point Pleasant Tongue of the Clays Ferry Formation intertongues with the upper part of the Lexington to the south. The Lexington and Point Pleasant in Clermont County are probably in facies relationship with the carbonaceous rocks of the "Utica" in southwestern Ohio, with the interbedded limestone and shale of the "Cynthiana" and "Trenton" in central Ohio, and with the Trenton Limestone in northwestern Ohio. Additional work needs to be done to develop a formal nomenclature relating these four facies of the Middle to Upper Ordovician rocks in western Ohio to replace the abandoned Cynthiana Formation terminology.

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APPENDIX A.—CHEMICAL ANALYSIS DATA

TABLE A1.—*Results of chemical analysis of Dundee Limestone, limestone sample no. 20-2083, Defiance Township, Defiance County*

Sample no.	Depth (ft)	$CaCO_3$ %	$MgCO_3$ %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	K_2O %	Na_2O %	SrO %	MnO %	TiO_2 ppm	S %	P ppm	Ba ppm
a	63.58-64.88	91.9	6.59	1.71	0.33	0.25	0.17	0.097	0.024	0.052	170	0.18	130	16
b	64.88-66.38	84.2	13.1	2.25	0.22	0.14	0.13	0.066	0.017	0.056	98	0.087	120	12
c	66.38-69.38	79.4	15.9	4.02	0.41	0.27	0.19	0.050	0.015	0.059	270	0.16	210	14
d	69.38-71.79	94.8	3.46	1.34	0.12	0.077	0.033	0.038	0.019	0.029	48	0.066	70	-
e	71.79-74.17	97.5	1.10	0.48	0.13	0.059	0.010	0.024	0.019	0.026	53	0.050	48	16
f	74.17-76.88	87.9	2.99	7.44	0.47	0.18	0.20	0.013	0.034	0.016	240	0.16	130	16
g	76.88-78.04	99.3	0.54	0.53	0.15	0.17	0.044	0.008	0.027	0.016	100	0.15	58	7
h	78.04-79.75	98.7	0.48	0.40	0.098	0.093	0.044	0.006	0.024	0.014	73	0.078	50	-
i	79.75-82.00	97.8	0.45	0.60	0.12	0.13	0.054	0.006	0.021	0.012	77	0.098	48	-
j	82.00-83.42	98.3	0.52	0.78	0.28	0.093	0.089	0.008	0.020	0.010	120	0.086	35	-
k	83.42-84.88	97.9	0.76	0.45	0.14	0.14	0.059	0.010	0.018	0.010	42	0.15	20	-
l	84.88-86.25	96.1	0.83	1.51	0.33	0.14	0.098	0.008	0.020	0.014	180	0.13	34	-
m	86.25-87.67	95.6	0.80	1.98	0.47	0.17	0.18	0.010	0.021	0.014	230	0.14	53	12
n	87.67-89.88	97.6	0.63	0.57	0.14	0.11	0.029	0.005	0.020	0.009	32	0.11	21	6
o	89.88-90.83	96.3	2.42	1.00	0.33	0.17	0.10	0.005	0.018	0.010	180	0.11	32	2
p	90.83-93.00	97.6	0.53	0.56	0.14	0.067	0.012	0.007	0.016	0.010	87	0.028	12	10
q	93.00-95.08	97.9	0.37	0.23	0.077	0.026	ND[1]	0.004	0.011	0.009	25	0.018	16	-
r	95.08-97.17	97.1	0.70	0.83	0.20	0.10	0.041	0.011	0.019	0.011	85	0.098	22	-
s	97.17-98.92	95.1	3.05	1.46	0.096	0.060	0.018	0.010	0.018	0.013	18	0.040	14	12
g-s[2]	76.88-98.92	97.4	0.86	0.79	0.18	0.11	0.052	0.007	0.019	0.011	87	0.089	30	-

[1]ND, no data.
[2]Weighted average.

TABLE A2.—*Results of chemical analysis of Carntown unit, Black River Group, limestone sample no. 13-2080, Pierce Township, Clermont County*

Sample no.	Depth (ft)	$CaCO_3$ %	$MgCO_3$ %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	K_2O %	Na_2O %	SrO %	MnO ppm	TiO_2 ppm	S %	P ppm	Ba ppm	V ppm
1	638.96-641.25	85.0	5.60	4.96	1.81	0.47	0.73	0.039	0.037	65	660	0.15	50	45	20
2	641.25-643.25	96.4	1.44	0.98	0.38	0.12	0.16	0.010	0.028	28	87	0.031	20	4	38
3	643.25-645.81	96.2	1.70	1.69	0.71	0.20	0.36	0.016	0.041	37	250	0.092	30	6	22
4	645.81-647.42	96.6	1.43	0.88	0.40	0.11	0.15	0.012	0.042	26	93	0.046	26	16	21
5	647.42-650.42	94.7	2.44	1.58	0.58	0.17	0.34	0.014	0.029	26	220	0.078	30	10	37
6	650.42-652.54	97.3	1.46	0.65	0.16	0.076	0.073	0.016	0.025	30	72	0.029	14	6	12
7	652.54-655.08	96.7	1.58	0.89	0.29	0.093	0.14	0.013	0.037	23	58	0.056	20	8	15
8	655.08-658.75	92.9	5.33	0.89	0.32	0.14	0.16	0.018	0.036	36	120	0.082	21	9	12
9	658.75-660.79	92.1	3.63	1.82	0.71	0.20	0.33	0.019	0.035	40	280	0.12	40	22	14
10	660.79-662.79	96.2	1.55	1.11	0.40	0.085	0.18	0.014	0.026	28	86	0.042	22	6	11
11	662.79-664.25	93.8	3.54	1.15	0.43	0.13	0.22	0.014	0.024	34	160	0.072	25	11	14
12	664.25-666.25	97.0	1.82	0.46	0.20	0.059	0.091	0.015	0.021	35	64	0.072	9	7	15
13	666.25-667.98	95.1	2.26	1.10	0.43	0.11	0.20	0.016	0.023	30	160	0.096	22	13	13
14	667.98-670.56	96.7	2.13	0.60	0.16	0.062	0.075	0.009	0.016	36	60	0.062	16	60	14
15	670.56-673.31	91.4	5.17	1.43	0.59	0.17	0.26	0.018	0.020	34	230	0.13	26	15	14
16	673.31-675.58	96.3	2.13	0.98	0.31	0.12	0.17	0.004	0.020	37	140	0.10	24	13	16
17	675.58-678.88	96.4	1.90	1.00	0.28	0.088	0.14	0.011	0.033	30	110	0.077	27	9	13
18	678.88-680.92	93.8	3.74	1.29	0.27	0.11	0.12	0.015	0.029	34	110	0.093	19	10	13
19	680.92-682.75	89.5	10.4	0.61	0.22	0.14	0.10	0.020	0.029	46	110	0.065	20	14	15
20	682.75-685.75	84.1	14.6	0.48	0.16	0.15	0.080	0.026	0.025	51	73	0.069	16	7	17
21	685.75-688.75	81.6	16.9	0.64	0.22	0.19	0.11	0.028	0.022	48	96	0.057	18	9	16
22	688.75-691.75	80.6	17.6	0.83	0.28	0.22	0.14	0.027	0.022	54	120	0.069	23	10	16
23	691.75-694.75	76.9	21.6	0.42	0.15	0.19	0.067	0.042	0.021	56	64	0.069	18	8	16
24	694.75-697.92	76.8	21.5	0.69	0.17	0.22	0.080	0.047	0.022	59	72	0.065	28	8	17
25	697.92-699.54	84.8	13.5	0.42	0.16	0.21	0.080	0.029	0.026	50	73	0.069	16	8	17
26	699.54-700.52	93.5	3.39	1.41	0.59	0.22	0.30	0.024	0.040	38	190	0.22	14	19	18
27	700.52-701.46	87.2	3.40	5.20	1.56	0.54	0.48	0.045	0.042	81	600	0.12	14	28	17
28	701.46-702.21	79.8	6.45	7.46	2.59	0.70	1.22	0.057	0.033	98	910	0.31	50	67	22
2-17[1]	641.25-678.88	95.3	2.59	1.08	0.40	0.12	0.19	0.014	0.029	32	140	0.076	23	14	18
18-26[1]	678.88-700.52	83.0	15.3	0.70	0.22	0.18	0.11	0.030	0.025	50	93	0.076	20	9	16
2-26[1]	641.25-700.52	90.8	7.25	0.94	0.33	0.14	0.16	0.020	0.027	39	120	0.076	22	12	17

[1]Weighted average.

APPENDIX A.—CHEMICAL ANALYSIS DATA—Continued

TABLE A3.—*Results of chemical analysis of Carntown unit, Black River Group, limestone sample no. 09-2082, Wayne Township, Butler County*

Sample no.	Depth (ft)	$CaCO_3$ %	$MgCO_3$ %	SiO_2 %	Al_2O_3 %	Fe_2O_3 %	K_2O %	Na_2O %	SrO %	MnO ppm	TiO_2 ppm	S %	P ppm	Ba ppm	V ppm
1	1277.29-1280.42	81.7	5.85	6.78	2.30	0.57	1.25	0.052	0.034	110	690	0.25	-	40	22
2	1280.42-1282.12	75.5	6.46	10.8	3.66	0.87	1.70	0.077	0.034	130	1100	0.40	-	78	25
3	1282.12-1284.75	96.7	1.56	0.98	0.26	0.14	0.13	0.013	0.028	47	98	0.10	21	7	14
4	1284.75-1287.33	94.6	3.06	1.09	0.30	0.15	0.16	0.016	0.033	56	110	0.076	14	10	15
5	1287.33-1288.83	89.8	4.96	2.95	0.84	0.36	0.46	0.026	0.031	68	390	0.18	26	25	17
6	1288.83-1291.42	95.3	3.19	0.74	0.22	0.13	0.11	0.020	0.038	43	71	0.074	10	7	13
7	1291.42-1293.58	86.6	9.91	2.46	0.71	0.29	0.40	0.026	0.030	74	280	0.11	22	17	17
8	1293.58-1296.50	94.0	4.72	0.86	0.23	0.15	0.12	0.020	0.034	53	94	0.062	12	6	14
9	1296.50-1299.42	91.3	6.03	1.37	0.43	0.19	0.20	0.025	0.035	56	170	0.076	10	12	17
10	1299.42-1302.38	95.8	2.02	0.95	0.27	0.083	0.12	0.014	0.022	40	98	0.054	10	8	15
11	1302.38-1305.17	94.8	1.80	1.38	0.48	0.10	0.24	0.020	0.034	40	150	0.062	12	17	17
12	1305.17-1306.62	95.5	2.04	1.02	0.36	0.086	0.16	0.016	0.025	33	130	0.061	20	10	16
13	1306.62-1309.33	93.9	3.63	0.86	0.22	0.11	0.10	0.021	0.037	50	87	0.044	17	8	14
14	1309.33-1311.38	88.8	8.15	1.56	0.47	0.20	0.20	0.025	0.034	64	220	0.097	24	13	12
15	1311.38-1313.12	84.4	11.9	1.89	0.70	0.28	0.30	0.029	0.034	82	330	0.098	29	16	13
16	1313.12-1314.98	84.1	11.6	2.41	1.00	0.25	0.43	0.031	0.032	68	290	0.11	28	18	14
17	1314.98-1318.17	92.1	6.61	0.62	0.19	0.15	0.095	0.023	0.038	56	72	0.052	16	66	11
18	1318.17-1320.52	82.8	14.5	1.46	0.42	0.28	0.19	0.030	0.026	78	180	0.080	24	14	12
19	1320.52-1322.75	93.6	4.51	0.74	0.32	0.11	0.13	0.024	0.036	48	95	0.044	12	10	16
20	1322.75-1325.00	92.7	5.27	0.77	0.22	0.12	0.089	0.023	0.041	60	110	0.022	17	14	12
21	1325.00-1326.21	90.4	7.99	0.74	0.24	0.12	0.12	0.021	0.036	55	110	0.024	17	10	14
22	1326.21-1327.50	88.5	10.8	0.66	0.20	0.13	0.10	0.027	0.039	53	84	0.034	17	8	12
23	1327.50-1328.88	81.9	16.8	0.84	0.23	0.20	0.10	0.034	0.035	77	130	0.064	24	13	13
24	1328.88-1331.38	85.6	13.4	0.56	0.15	0.14	0.061	0.036	0.034	68	73	0.040	17	7	11
25	1331.38-1333.79	83.0	15.7	0.91	0.24	0.21	0.11	0.032	0.040	88	150	0.052	20	14	11
26	1333.79-1336.21	82.8	15.3	1.19	0.35	0.24	0.17	0.028	0.036	82	190	0.068	25	20	12
27	1336.21-1338.08	84.2	14.8	0.17	0.11	0.16	0.044	0.032	0.036	78	68	0.031	14	7	11
28	1338.08-1340.00	84.0	15.0	0.32	0.10	0.15	0.038	0.045	0.038	72	62	0.024	14	6	11
29	1340.00-1342.46	80.2	18.7	0.42	0.13	0.18	0.056	0.040	0.037	80	77	0.022	14	8	10
30	1342.46-1343.25	75.5	21.2	2.06	0.64	0.33	0.32	0.039	0.032	97	360	0.10	32	28	14
31	1343.25-1346.75	90.7	7.91	0.62	0.20	0.12	0.088	0.031	0.036	50	65	0.040	18	7	14
32	1346.75-1350.42	91.4	3.07	2.58	0.98	0.21	0.51	0.034	0.042	66	350	0.14	45	19	18
33	1350.42-1352.71	84.5	4.20	6.08	1.79	0.55	1.18	0.044	0.039	130	520	0.27	66	40	22
3-32[1]	1282.12-1350.42	89.6	8.11	1.15	0.37	0.17	0.18	0.026	0.034	61	150	0.068	19	14	14

[1]Weighted average.

APPENDIX B.—CONDENSED CORE DESCRIPTIONS

Defiance County — Core file no. 2538
Defiance Township — Sample no. 20-2083
Ayersville 7½-minute quadrangle — Elevation (topo) 680 feet

Depth (ft)

0 16.8 Alluvium, rotary drilled

OHIO (ANTRIM) SHALE

16.8 25.8 Mudstone, dark-brown, pyritic

TENMILE CREEK DOLOMITE

25.8 44.1 Dolomite, gray, dense to very fine grained; porous and vuggy in part; chert nodules up to 0.42 foot thick; becoming limy and argillaceous in bottom foot

SILICA FORMATION

44.1 53.6 Limestone, medium- to dark-gray, fine-grained to very fine grained, sparsely to very fossiliferous, very argillaceous, grading to limy mudstone in bottom half

53.6 61.5 Mudstone, dark-gray, fossiliferous; laminated in upper 2 feet; becoming lighter gray and calcareous in lower 3 feet and very argillaceous limestone in basal few inches. Gradational with unit below

DUNDEE LIMESTONE

61.5 74.2 Limestone, gray to brownish-gray, fine- to medium-grained, becoming slightly coarse grained in bottom 5 feet; fossiliferous, bioclastic in part; sparse to numerous euhedral dolomite grains; argillaceous in upper 2 feet

74.2 76.9 Limestone, brown; micritic in part, very fine grained in part; 0.12-foot-thick chert nodules at 74.8 feet and 75.7 feet

76.9 98.9 Limestone, brownish-gray, gray, and brown; micrite, pelletal in part; sparse pelsparite; sparse to numerous small round and planar birdseyes in part; very faint to faint laminations in large part; sparse suggestions of flat-pebble conglomerate, vertical burrows, evaporite casts, and spindle-shaped crystals; biopelsparite and biopelmicrite in bottom 1.75 feet with corals and oncolites in basal 0.5 foot

98.9 113.0 Dolomite, brown, minor amount tan, brownish gray, and gray; very fine grained to fine grained; very sparse sand grains; porous; laminated in large part; 0.42- and 0.25-foot-thick chert nodules at 106 feet and 109 feet; sparse dolomitic limestone and lithographic limestone; entire unit shows sparse suggestions of recrystallization and relict conglomeratic texture

DETROIT RIVER GROUP

113.0 128.0 Dolomite, gray, microcrystalline; brecciated in part; laminated in part; very fine vugular porosity

TD 128.0 feet

Clermont County — Core file no. 2535
Franklin Township — Sample no. 13-2081
Felicity 7½-minute quadrangle — Elevation (topo) 495 feet

Depth (ft)

0 19.8 Alluvium

POINT PLEASANT TONGUE OF CLAYS FERRY FORMATION

19.8 31.4 Limestone, gray, argillaceous. Claystone, soft. Mudstone, hard, calcareous

LEXINGTON LIMESTONE UNDIFFERENTIATED

31.4 79.8 Limestone, gray, fine- to coarse-grained, irregular-bedded, bioclastic, crossbedded in part; moderate number black shale partings

79.8 96.0 Limestone, gray, medium- to coarse-grained, calcarenitic

96.0 127.7 Limestone, gray, fine- to coarse-grained. Limestone, gray, very fine grained, argillaceous. Shale, dark-gray to black, irregular- to flat-bedded

127.7 163.2 Limestone, gray, fine-grained to very coarse grained, fossiliferous, irregular-bedded; moderate number dark-gray shale partings

LOGANA MEMBER OF LEXINGTON LIMESTONE

163.2 182.1 Shale, black to dark-gray. Limestone, gray, coarse-grained, bioclastic. Limestone, dark-gray, very fine grained, argillaceous, flat- to irregular-bedded

182.1 204.6 Shale, black, shelly. Limestone, gray, fine- to coarse-grained, argillaceous in part, brachiopod coquina in part

CURDSVILLE LIMESTONE MEMBER OF LEXINGTON LIMESTONE

204.6 235.0 Limestone, gray, fine- to coarse-grained, bioclastic. 1.1 feet of soft gray shale with numerous biotite and heavy mineral grains at 213.5 feet. 0.1+ foot of chert at 216.0 feet, 216.6 feet, and 218.4 feet

BLACK RIVER GROUP

235.0 240.1 Limestone, brown, micritic, pelletal at top and base, sparse to moderate number desiccation features

240.1 248.0 Limestone, brown and gray, micritic and pelletal, generally fossiliferous, bioturbated

248.0 253.0 Limestone, gray and brown, greenish in part, pelletal and micritic, argillaceous in part, sparse desiccation features in middle of unit

253.0 258.2 Limestone, gray; micrite; *Tetradium* fragments, chert. 0.6 foot of greenish-gray bentonitic shale at 253.0 feet and 255.6 feet. Marker bed β

258.2 279.3 Limestone, brown and gray, micritic, pelletal in part, dolomitic in part; sparse to numerous desiccation features. 0.3 foot of K-bentonite and argillaceous limestone at 272.9 feet. Marker bed γ. 0.04 to 0.08 foot of chert at 277.1 to 278.8 feet

279.3 286.6 Limestone, gray; micrite, biopelsparite; horizontal burrows

286.6 296.5 Limestone, gray, dark-gray, and greenish-gray; biomicrite and micrite; dolomitic in part, argillaceous, *Tetradium* fragments, horizontal burrows in part; sparse to minor number shale partings. Top of marker bed Δ

296.5 299.2 Limestone, gray and dark-gray; micrite, pelsparite; desiccation features; partings and interbeds of gray and greenish-gray argillaceous, dolomitic limestone. Base of marker bed Δ

299.2	312.5	Limestone, gray and brown; micrite; pelletal in part, dolomitic in part, desiccation features and dolomite laminations. 3.3-foot argillaceous zone at 306.2 feet. Marker bed a_1. 0.01 foot of bentonitic, shaly limestone at 312.4 feet. Marker bed a_2
312.5	327.4	Limestone, dolomitic, gray; interbedded and interlaminated pelletal and micritic limestones and dolomitic limestone; sparse to moderate number faint desiccation features. 0.8-foot argillaceous, shaly zone with bentonitic shale at 326.6 feet. Marker bed b
327.4	345.3	Limestone, dolomitic, gray and brown; interbedded micritic, pelletal, and dolomitic limestones; generally dolomitized, sparse desiccation features in part, sparse horizontal burrows in part
345.3	349.5	Limestone, dolomitic, brown and gray; highly dolomitized micritic limestone. Oregon Formation correlative

TD 349.5 feet

Clermont County — Core file no. 2536
Pierce Township — Sample no. 13-2080
Withamsville 7½-minute quadrangle — Elevation (topo) 480 feet

Depth (ft)		
0	21.0	Alluvium

POINT PLEASANT TONGUE OF CLAYS FERRY FORMATION

21.0	33.4	Limestone (70%), gray, medium- to coarse-grained, bioclastic. Mudstone, greenish-gray, soft. Mudstone, gray, hard
33.4	66.0	Mudstone (55%), gray, calcareous. Limestone, gray, very fine grained to medium-grained, argillaceous, fossiliferous in part
66.0	75.6	Limestone (60%), gray, fine- to coarse-grained, bioclastic. Mudstone, gray, hard; calcareous fragments and streaks
75.6	79.9	Breccia, wispy to rounded nodules of fine-grained limestone (35%) in gray mudstone matrix

LEXINGTON LIMESTONE UNDIFFERENTIATED

79.9	81.1	Limestone, gray, medium-grained
81.1	148.3	Limestone (75%), gray, medium- to coarse-grained, fossiliferous in part, crinoidal in part, brecciated in part; irregularly interbedded with soft, calcareous, dark-gray to black mudstone
148.3	184.3	Limestone (70%), gray, very fine grained to medium-grained, argillaceous. Limestone, gray, medium- to coarse-grained, fossiliferous. Mudstone, gray and brown, shelly in part, irregular- to flat-bedded
184.3	194.3	Limestone (80%), gray, fine- to coarse-grained, fossiliferous in part; irregular to nodular bedded with brownish-gray mudstone and semi-waxy gray claystone
194.3	214.5	Limestone (75%), gray, fine- to coarse-grained; irregular bedded with soft gray and greenish-gray mudstone

LOGANA MEMBER OF LEXINGTON LIMESTONE

214.5	221.0	Limestone (50%), dark-gray, fine- to medium-grained, argillaceous, shelly in part; flat bedded with dark-gray mudstone
221.0	237.1	Limestone, gray, medium- to coarse-grained, fossiliferous. Limestone, dark-gray, fine- to medium-grained, argillaceous. Mudstone (5% to 65%), dark-gray; limestone and mudstone are brachiopod coquinas in large part
237.1	248.0	Mudstone (85%), dark-gray. Limestone, dark-gray, fine-grained, argillaceous; generally shelly; brachiopod coquina in part

CURDSVILLE LIMESTONE MEMBER OF LEXINGTON LIMESTONE

248.0	264.7	Limestone, gray, fine- to coarse-grained, brecciated in part, fossiliferous in part, irregular-bedded. 0.1 foot of bentonitic greenish-gray claystone at 252 feet, 258.5 feet, and 258.8 feet. 0.7 foot of gray shale at 264 feet
264.7	276.7	Limestone, gray and brown, fine- to coarse-grained, calcarenitic in part, bioclastic in part. 0.1 foot of chert at 274.7 feet

BLACK RIVER GROUP

276.7	282.2	Limestone, gray and brown, micritic, pelletal in part, sparry in part; bioturbated in part; generally silicified in bottom 1.1 feet. 1.8 feet of bentonitic greenish shale at 279.3 feet. Marker bed α
282.2	291.9	Limestone, gray, micritic and pelletal, fossiliferous, *Tetradium* fragments; sparse horizontal burrows; sparse irregular shaly partings
291.9	294.0	Limestone, gray; micrite; pelletal in part, laminated; sparse to moderate number desiccation features, vertical burrows
294.0	294.9	Shale, green, bentonitic. Marker bed β_1
294.9	296.5	Limestone, gray; micrite and biomicrite (*Tetradium* and gastropods); silicified in part. 0.1 foot of bentonitic green shale at base of unit. Marker bed β_2
296.5	319.1	Limestone, gray and brown; micrite, pelmicrite, pelsparite; in part dolomite laminations; sparse to moderate number desiccation features and vertical burrows; numerous argillaceous partings and zones from 313.8 feet to 316.3 feet; pelletal and fossiliferous (*Tetradium*) in basal 0.2 foot
319.1	319.6	Shale, green, bentonitic. Marker bed γ
319.6	328.6	Limestone, gray and brown, micritic and pelletal, fossiliferous in part; silicified in small part; sparse to numerous horizontal burrows
328.6	341.0	Limestone, gray, brown, and greenish-gray; micrite and biomicrite; pelletal in part, argillaceous; sparse to numerous horizontal burrows. Marker bed Δ
341.0	355.3	Limestone, gray; micrite; pelletal in part, dolomitic in part; sparse to numerous desiccation features; sparse to minor number vertical burrows. 1.2-foot argillaceous zone at 349.7 feet. Marker bed a_1. 0.3 foot of shale and mudstone at 355.0 feet. Marker bed a_2
355.3	370.9	Limestone, dolomitic, gray; interbedded and interlaminated micritic and pelletal limestones and dolomitic limestone; relict intrasparite and pelsparite texture; sparse to moderate number laminations and desiccation features and sparse vertical burrows. 1.2 feet of shaly, bentonitic, greenish mudstone and limestone at 369.6 feet. Marker bed b
370.9	379.0	Limestone, gray, micritic, pelletal in part, dolomitic in part; sparse to minor number faint desiccation features; sparse to numerous vertical burrows in part
379.0	387.8	Limestone, gray, brown, and white; micrite and biomicrite; pelletal in part, calcarenitic in small part
387.8	406.0	Limestone and dolomite, gray and brown; dolomitic micrite and limy dolomite, interlaminated in part; fossiliferous in large part; relict intraclastic and pelletal texture in small part; relict desiccation features in small part. Oregon Formation correlative
406.0	408.3	Limestone, gray; micrite and pelmicrite; limy dolomite interbeds
408.3	418.4	Limestone, brown, gray, and dark-gray, greenish in part; micrite, biomicrite, and limy dolomite; argillaceous; sparse to numerous horizontal burrows. Marker bed I

418.4	434.9	Limestone, gray and brown; micrite and biomicrite; *Tetradium* and bryozoans; becoming pelletal and bioturbated in lower part
434.9	493.6	Limestone, gray and brown, pelletal, micritic, and dolomitic; chalky in part; moderate number to numerous horizontal burrows
493.6	519.5	Limestone, gray and brown; pelsparite, pelmicrite, micrite, and various combinations of bio-, pel-, and intra- sparites and micrites; mainly pelsparite and dolomitic relict pelsparite in upper third, becoming micritic and pelletal limestones interbedded with bioturbated, poorly washed sparites and micrites; horizontal burrows in mixed-lithology zones
519.5	539.7	Limestone, brown and light- to dark-gray; biomicrite, pelmicrite, and micrite interbedded with minor amount various combinations of bio-, pel-, and intra- sparites and micrites; generally argillaceous below 522.5 feet; minor number irregular interbeds of dolomitic limestone; minor number algal-coated grains in part; bioturbated in part. 0.1 foot of carbonaceous shale at 420.5 feet. Marker bed II
539.7	585.0	Limestone, brown and gray; micrite, biomicrite, and pelmicrite interbedded with various combinations of pel-, bio-, and intra- sparites; sparse to numerous horizontal burrows in part. Nodular interbedded biomicrite and bentonitic claystone from 551.3 feet to 551.6 feet. Chalky in part and generally dolomitic from 562 feet to 580 feet
585.0	601.6	Limestone and dolomite, medium- to dark-gray and brown, argillaceous to shaly; biomicrite, micrite, and very fine grained dolomitic limestone. Top of upper argillaceous unit
601.6	619.1	Limestone, gray and brownish-gray; micrite and biomicrite interbedded with various combinations of bio-, intra-, and pel- micrites and sparites; bioturbated and burrowed in part; sparse to numerous irregular to stylolitic partings and interbeds of very fine grained dolomitic limestone, argillaceous in part, shaly in part
619.1	630.4	Limestone, light- to dark-gray and brown, greenish in part; micrite and minor amount various combinations of bio-, intra-, and pel- sparites and micrites; laminations, mudcracks, and other desiccation features, decreasing toward base; sparse to numerous irregular partings and interbeds of argillaceous, shaly, dolomitic limestone, particularly in upper 2 feet
630.4	636.6	Limestone, dolomitic, light- to dark-gray and brownish-gray; biomicrite, micrite, biopelsparite, pelsparite; intraclastic in part, argillaceous in part, dolomitic in part; bioturbated and burrowed; moderate number argillaceous, dolomitic limestone partings
636.6	640.9	Limestone, light- to dark-gray and greenish-gray; intrasparite and pelsparite grading to micrite grading to ostracod biomicrite; *Tetradium* biomicrite in lower quarter of unit; argillaceous in part, dolomitic in part; desiccation features in upper half grading to sparse U-shaped burrows in ostracod biomicrite; moderate number interbeds of argillaceous and shaly dolomitic limestone. Base of upper argillaceous unit
640.9	651.8	Limestone, gray and brown; micrite; pelletal, intraclastic, and sparry in part; faint to definite laminations and desiccation features, interlaminated dolomite and micrite in small part, sparse vertical burrows in small part; sparse fossiliferous layers. 0.04-foot bed of argillaceous dolomite at 641.2 feet. Top of Carntown unit
651.8	659.1	Limestone, gray and brown; micrite and biomicrite; pelletal in part, sparry in part; *Tetradium* fragments; horizontal burrows in lower part; laminations and sheet cracks in basal 0.2 foot
659.1	678.9	Limestone, gray and brown; micrite, minor amount pelsparite, pelmicrite, laminated dolomite, and interlaminated micrite and dolomite; very faint to definite laminations in large part; minor number sheet cracks and round and irregular birdseyes; sparse mudcracks and vertical burrows
678.9	700.5	Limestone, dolomitic, brown; pelmicrite and biopelmicrite; sparse to moderate amount biopelsparite, pelsparite, micrite, and biomicrite; moderate number irregular interbeds and horizontal burrows of dolomitic limestone; burrowed, generally dolomitic to chalky pelmicrite and biopelmicrite from 682.8 feet to 697.9 feet. Base of Carntown unit
700.5	704.8	Limestone and dolomite, gray, brown, and greenish-gray; 0.9 foot of biopelsparite, becoming biomicrite; argillaceous, burrowed. 0.5 foot of desiccated intrasparite. 0.3 foot of argillaceous laminated dolomite and interlaminated dolomite and micrite. 2.5 feet of faintly laminated micrite, with intraclastic clumps and desiccation features. Top of lower argillaceous unit
704.8	730.2	Dolomite and limestone, mottled gray, green, and brown; very fine grained limy dolomite; minor amount micrite and various combinations of intra-, pel-, and bio- micrites and sparites; argillaceous to very argillaceous; micrite blebs and stringers and relict pelletal and intraclastic texture in limy dolomite; sparsely sandy in part; mottled variously as laminations, burrowing, or brecciation. Limestone and dolomite, mottled gray, green, and brown; micrite, limy dolomite, and various combinations of intra-, pel-, and bio- sparites and micrites; slightly argillaceous; limestone generally dolomitic; sparse to numerous desiccation features in limestone and dolomite; relict fossiliferous, intraclastic, and pelletal texture in limy dolomite; sparsely sandy in part; mottled with vague horizontal aspect
730.2	736.1	Limestone and dolomite, olive-gray; interbedded and interlaminated micrite and very fine grained dolomite; generally laminated; argillaceous in part; mudcracks in part; sparse sand grains in part. Base of lower argillaceous unit

WELLS CREEK FORMATION

736.1	739.0	Dolomite, brown and gray, very fine grained, argillaceous, porous, and soft
739.0	762.0	Dolomite (60+%), gray, very fine grained to medium-grained, argillaceous in part; slightly sandy in large part; faintly laminated in small part. Dolomite (25%), tan, brown, and gray, micrograined to fine-grained; slightly argillaceous in small part; laminated, wavy to contorted bedding; brecciated in part, porous and chalky where contorted. Dolomite (10+%), greenish-gray, micrograined to very fine grained; very argillaceous, sandy in part. Unit sandy and conglomeratic in basal 0.3 foot

KNOX DOLOMITE

762.0	789.4	Dolomite, gray, fine- to coarse-grained, crystalline; vuggy

TD 789.4 feet

Butler County
Wayne Township
West Elkton 7½-minute quadrangle

Core file no. 2537
Sample no. 09-2082
Elevation (topo) 935 feet

Depth (ft)		
0	12.0	Alluvium

UPPER ORDOVICIAN UNDIFFERENTIATED

12.0	215.0	Shale and limestone, drilled with rotary bit

215.0	224.2	Mudstone (80%), gray, calcareous, fossiliferous. Limestone (20%), gray, fine- to coarse-grained, fossiliferous, irregular- to nodular-bedded
224.2	255.4	Mudstone (60%), gray to dark-gray, calcareous. Limestone, gray, fossiliferous, medium-grained to very coarse grained, irregular- to nodular-bedded; interbedded with fine- to coarse-grained, flat- to nodular-bedded limestone
255.4	290.9	Mudstone (80%), dark-gray; hackly fracture; numerous calcareous streaks, nodules, and fossils. Limestone (20%), gray, fine- to coarse-grained, fossiliferous, flat- to nodular-bedded. Minor amount subfissile mudstone and flat-bedded limestone, particularly from 268.8 feet to 271.5 feet
290.9	315.9	Limestone (50%), gray, medium- to coarse-grained, very fossiliferous, irregular- to nodular-bedded. Mudstone (50%), dark-gray; hackly fracture. Upper half of unit 40% limestone, lower half 60%
315.9	322.2	Mudstone (80%), gray; hackly fracture to subfissile; calcareous and silty streaks. Limestone (20%), gray, very fine grained to fine-grained, silty, argillaceous; laminated in part; crossbedded in part; flat to irregular bedded

BELLEVUE LIMESTONE

322.2	326.1	Limestone (65%), nodular. Mudstone (35%) as in sample from 290.9 feet to 315.9 feet
326.1	330.0	Limestone (60%), gray, fine- to coarse-grained, phosphatic; laminated and crossbedded in part; wavy bedded. Mudstone, gray, subfissile; laminated and crossbedded in part
330.0	333.7	Limestone (80%), nodular. Mudstone (20%) as in sample from 290.9 feet to 315.9 feet

MIAMITOWN SHALE

333.7	362.8	Mudstone (75%), gray; hackly fracture to subfissile. Limestone, gray, very fine grained to coarse-grained, fossiliferous. Medium- to coarse-grained shelly limestone from 355.2 feet to 358.3 feet. Mudstone from 358.3 feet to base

FAIRVIEW FORMATION

362.8	400.4	Mudstone (60%), gray; hackly to blocky fracture; thin- to medium-bedded. Limestone, gray, fine- to coarse-grained, thin- to medium-bedded, irregular- to flat-bedded

KOPE FORMATION

400.4	449.7	Mudstone (80%), gray; hackly fracture to subfissile. Limestone, gray, medium- to coarse-grained, fossiliferous. Calcareous beds and streaks generally with sharp, flat base and diffuse top; decreasing carbonate content toward base
449.7	619.0	Mudstone, gray to dark-gray, hard; slightly hackly fracture, subfissile to slightly blocky; sparse calcareous and silty streaks; becoming brown toward base with decreasing calcareous streaks
619.0	682.8	Mudstone, dark-brownish-gray; slightly hackly to smooth fracture, subfissile; interbedded with moderate amount gray mudstone as above, brown color increasing toward base; gradational between units above and below

"UTICA"

682.8	755.5	Mudstone, dark-brownish-gray, smooth to slightly hackly fracture; faintly to definitely banded and laminated; calcareous, phosphatic; sparse to minor number calcareous streaks
755.5	832.5	Mudstone as above, becoming browner in lower part, fracture becoming smooth, fissile; minor number to numerous calcareous laminae

LEXINGTON LIMESTONE UNDIFFERENTIATED

832.5	873.1	Limestone (60%), dark-gray and dark-brownish-gray, becoming lighter toward base; very fine grained to very coarse grained, finer toward top, coarser toward base; argillaceous; fossiliferous; interbedded with brown and gray calcareous mudstone as above

LOGANA MEMBER OF LEXINGTON LIMESTONE

873.1	913.4	Limestone, brown and brownish-gray, very fine grained to medium-grained; argillaceous; barren in part, fossiliferous and coquinoid in part; flat to wavy bedded; interbedded with brownish-gray mudstone that is laminated in part, shelly in part

CURDSVILLE LIMESTONE MEMBER OF LEXINGTON LIMESTONE

913.4	930.2	Limestone, gray, medium-grained to very coarse grained; bioclastic; medium to thick bedded in part, nodular in part
930.2	937.0	Limestone, brownish-gray, very fine grained to medium-grained, flat to irregular-bedded; very fine grained matrix has pelletal aspect similar to underlying Black River Group

BLACK RIVER GROUP

937.0	948.0	Limestone, brown and gray, micritic and pelletal; faintly laminated in upper part; dolomitic in part; fossiliferous in part. 0.2 foot of bentonitic greenish-gray shale at 937.1 feet. Marker bed α. 0.1 foot of bentonitic gray and green claystone at 942.0 feet. 0.1 foot of bentonitic(?) green claystone at 947.9 feet
948.0	956.4	Limestone, brown and gray, micritic and pelletal; laminated in part; vertical burrows in part; argillaceous with sparry-calcite-filled "bubble-tracks" from 951.7 feet to 953 feet
956.4	956.9	Shale, green, bentonitic. Marker bed β_1
956.9	959.5	Limestone, gray, micritic; *Tetradium*
959.5	959.7	Shale, green, bentonitic. Marker bed β_2
959.7	973.8	Limestone, brown and gray, micritic, pelletal, dolomitic; generally laminated; vertical burrows in large part; desiccation features and dolomite laminations in part; argillaceous interbeds in basal 2.0 feet
973.8	1006.4	Limestone, gray and brown; micrite, biomicrite, biosparite; horizontal burrows in large part. Generally argillaceous from 976.4 feet to 982.4 feet; basal 0.1 foot is bentonitic claystone. Marker bed γ. Three argillaceous, shaly zones from 985.9 feet to 1001.0 feet. Marker bed Δ
1006.4	1022.6	Limestone, dolomitic, gray; micrite, pelsparite, intrasparite; sparse to moderate number desiccation features; dolomitic limestone and dolomite interbeds and laminae, particularly in lower half; flat-pebble conglomerate in part; mudcracked in part. Argillaceous, shaly limestone overlying bentonitic(?) greenish-brown claystone from 1014.2 feet to 1014.5 feet. Marker bed a
1022.6	1038.0	Limestone, gray and brown, micritic; fossiliferous and pelletal in part; argillaceous in part with vertical burrows and mudcracks. Bentonitic green shale from 1030.8 feet to 1031.5 feet. Marker bed b
1038.0	1076.9	Limestone, gray and brown, micritic, pelletal, fossiliferous; bioturbated in large part; sparse to numerous *Tetradium* fragments. Interbedded tan and gray dolomite, dolomitic micrite, and dolomitic micrite with relict desiccation features from 1067.8 feet to 1070.8 feet. Oregon Formation correlative

1076.9	1086.2	Limestone, light- to dark-gray and brown, greenish in part; micrite and biomicrite, pelletal in part; bioturbated in part, burrowed in part; argillaceous. Marker bed I
1086.2	1140.6	Limestone, brown and gray; micrite; pelletal in part; fossiliferous in part; sparse to numerous horizontal burrows; dolomitic in part
1140.6	1150.0	Limestone and dolomite, brown; micrite, calcarenite, pelsparite, and very fine grained dolomite; laminated in part, crossbedded in part; wavy to regular bedded, ribboned(?)
1150.0	1175.0	Limestone, brown and gray; interbedded micrite, pelsparite, and intrasparite; pelletal in part; fossiliferous in part; microdolomitic in part; sparse to numerous horizontal burrows
1175.0	1184.6	Limestone, gray and dark-gray; micrite, pelmicrite, and pelsparite; argillaceous; fossiliferous; bioturbated; minor number argillaceous, shaly partings. Marker bed II
1184.6	1215.4	Limestone, brown and gray; micrite and biomicrite; minor amount pelsparite, pelmicrite, intrasparite, and biointrasparite; sparse to numerous horizontal burrows and sparse to moderate number stylolitic to irregular interbeds of dolomitic limestone; some burrows pelsparite filled; some pelsparite and intrasparite laminated (crossbedded?). 0.2 foot of interbedded limestone and bentonitic(?) green claystone at 1199.3 feet
1215.4	1219.1	Limestone, gray, micritic, pelletal, intraclastic; fossiliferous in large part; jumbled *Tetradium* fragments and colonies at top grading to brecciated limestone at base
1219.1	1233.3	Limestone, gray; micrite; pelletal, fossiliferous, and intraclastic in part; bioturbated in part, burrowed in part, brecciated in part; moderate amount pelsparite in lower half, faintly laminated and crossbedded in part
1233.3	1246.7	Limestone, gray and brown, greenish in part; biomicrite and micrite; pelletal in part; bioturbated in part; minor amount recrystallized biomicrite or poorly washed biointrasparite. Sparse to numerous partings and interbeds of argillaceous, dolomitic limestone, dolomitic mudstone, and carbonaceous shale. Top of upper argillaceous unit
1246.7	1249.3	Limestone, brown and gray; micrite and biomicrite; *Tetradium* fragments; generally breccia appearing
1249.3	1253.8	Limestone, tan and gray; micrite and biomicrite; bioturbated
1253.8	1259.0	Limestone, gray; various combinations of micritic bio-, intra-, and pel- sparites; bioturbated in part; sparse to numerous faint laminations, geopetal structures, and sheet cracks; interbedded with fossiliferous, intraclastic micrite
1259.0	1264.2	Limestone, medium- to dark-brown and gray, greenish in part; micrite; sparse to numerous desiccation features; laminated in part; dolomitic in part; sparse to numerous shaly and argillaceous dolomitic limestone partings and interbeds. 0.2 foot of laminated brown dolomitic mudstone at 1259.3 feet
1264.2	1282.1	Limestone, light- to dark-gray and brown, greenish in part; micrite; moderate amount biomicrite, pelmicrite, pelsparite, intrasparite; generally argillaceous, dolomitic in part; bioturbated in part, horizontal burrows in part; sparse to numerous partings and interbeds of argillaceous, dolomitic limestone; micrite in part laminated, with sparse to numerous desiccation features. Base of upper argillaceous unit
1282.1	1285.7	Limestone, brown; biomicrite and micrite; minor amount pelmicrite; *Tetradium* fragments. Top of Carntown unit
1285.7	1299.4	Limestone, brown and gray; micrite, biomicrite, biointrasparite; sparse to numerous horizontal burrows and, in part, moderate number irregular interbeds of dolomitic limestone; sparse sparry-calcite-filled shrinkage cracks
1299.4	1302.4	Limestone, gray; micrite, laminated, with desiccation features, interbedded with fossiliferous micrite; sparse ostracods, sparse to numerous *Tetradium* fragments
1302.4	1309.3	Limestone, gray and brown; micrite; sparse intrapelsparite, pelmicrite, pelsparite, and interlaminated micrite and dolomite; laminated in part; sparse to numerous desiccation features
1309.3	1315.0	Limestone, light- to dark-brown and gray; micrite; sparse biopelmicrite, biopelsparite, and biointrasparite; in part replaced by and in part interbedded with dolomitic limestone
1315.0	1325.0	Limestone, brown and gray; micrite and pelmicrite; sparse biopelmicrite, biopelsparite, and biomicrite; moderate number to numerous horizontal burrows and minor number irregular interbeds of fine-grained dolomitic limestone
1325.0	1326.2	Limestone, brown and gray; micrite and biomicrite; sparse pelmicrite and intrasparite; regularly interbedded (ribboned); moderate number dolomitic limestone interbeds
1326.2	1343.2	Limestone, brown and gray; biomicrite, pelmicrite, and micrite; minor amount biopelsparite; sparse biopelmicrite; generally dolomitic; moderate number to numerous horizontal burrows and moderate number stylolitic to irregular interbeds of fine-grained dolomitic limestone
1343.2	1350.4	Limestone, light- to dark-brownish-gray; micrite and biomicrite; minor amount pelmicrite, biopelmicrite, and biopelsparite; pelletal material mainly in upper half; moderate number horizontal burrows and minor number irregular interbeds of fine-grained dolomitic limestone; dolomitic interbeds in lower half generally dark colored, very argillaceous. Base of Carntown unit
1350.4	1359.8	Limestone, gray and brown, greenish in part; micrite and very fine grained dolomitic limestone; minor amount intrasparite; argillaceous, dolomitic in part; mottled in part, laminated in part; desiccation features in large part; minor amount interbedded and interlaminated mudstone, particularly from 1352.7 feet to 1355.6 feet and 1358.1 feet to 1358.5 feet. Top of lower argillaceous unit
1359.8	1371.2	Dolomite and limestone, light- to dark-gray, brown, and green; interbedded limy dolomite and dolomitic limestone; very fine grained to fine-grained euhedral dolomite rhombs set in micrograined dolomitic matrix and in relict micritic, intraclastic, fossiliferous matrix; mottled in part, laminated in part; argillaceous; sparse relict desiccation features in part
1371.2	1373.2	Limestone, black and brown, micrograined to micritic, carbonaceous, argillaceous, dolomitic, laminated
1373.2	1377.7	Dolomite and limestone, light- to dark-brownish-gray, greenish in part; very fine grained limy dolomite and micrograined dolomitic limestone; argillaceous; laminated. Base of lower argillaceous unit

WELLS CREEK FORMATION

1377.7	1382.3	Dolomite, tan and gray, micrograined to very fine grained, argillaceous, porous, soft, laminated
1382.3	1392.2	Dolomite, light- to dark-gray and brown, greenish in part; micrograined to very fine grained; generally laminated, brecciated in part, mot-

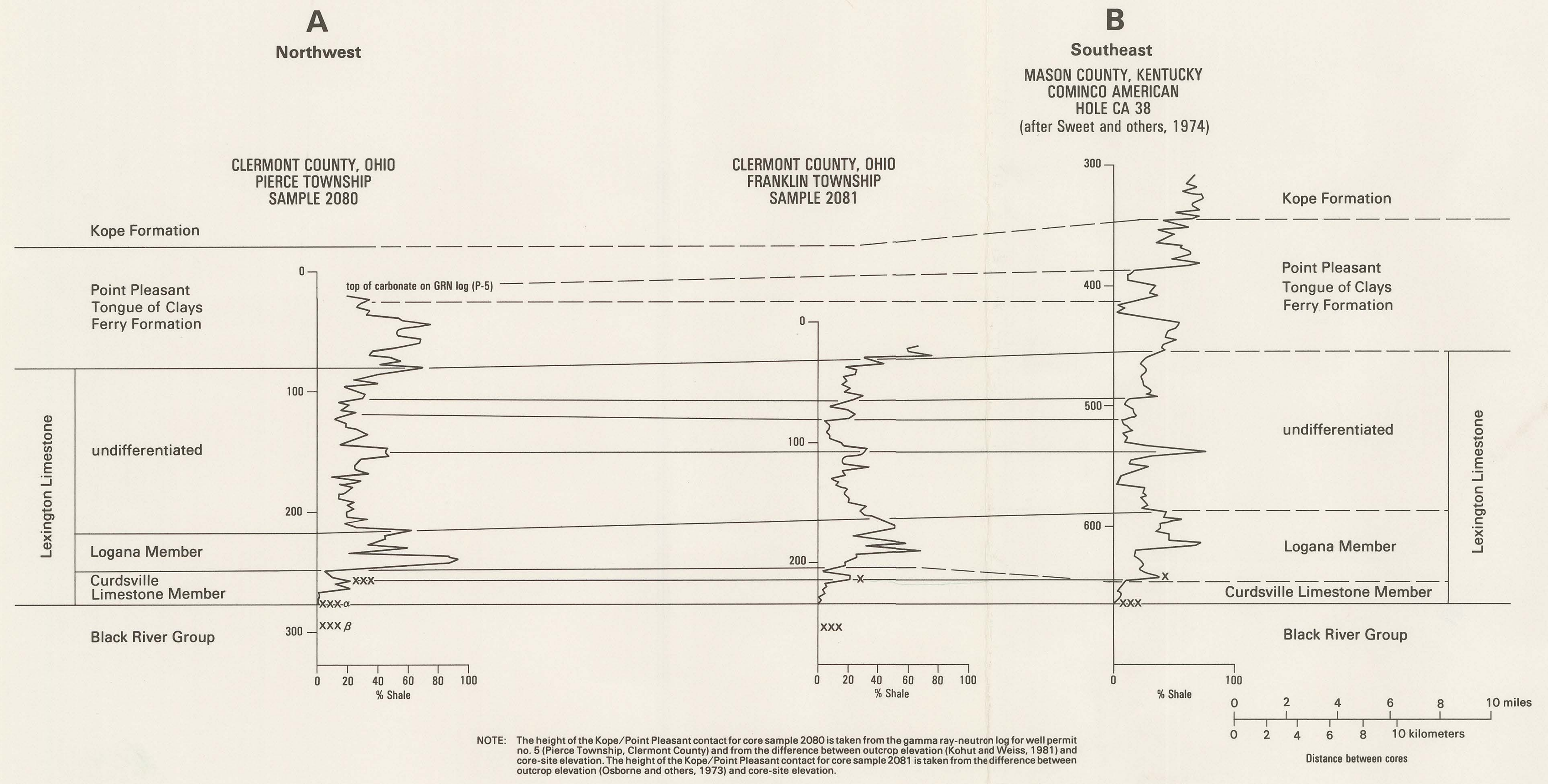
		tled in part; very argillaceous greenish dolomite (or dolomitic mudstone) from 1384.3 feet to 1384.7 feet and 1385.6 feet to 1387.3 feet
1392.2	1415.4	Dolomite, gray and green; very fine grained rhombs in micrograined matrix; generally mottled, sparsely laminated; sparse fine-grained quartz sand; grayish dolomite interbedded with minor amount very argillaceous greenish dolomite

KNOX DOLOMITE

1415.4	1423.9	Dolomite, gray, very fine grained, crystalline; minor laminations; pyritiferous
1423.9	1444.9	Dolomite, gray and brown, very fine grained to medium-grained, crystalline; banded and laminated, decreasing toward base; vuggy in part; moderate amount tripolitic chert from 1427.9 feet to 1437.9 feet
		TD 1444.9 feet

STATE OF OHIO
Richard F. Celeste, Governor
DEPARTMENT OF NATURAL RESOURCES
Joseph J. Sommer, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

DIVISION OF GEOLOGICAL SURVEY
REPORT OF INVESTIGATIONS NO. 132
PLATES 1, 2, AND 3

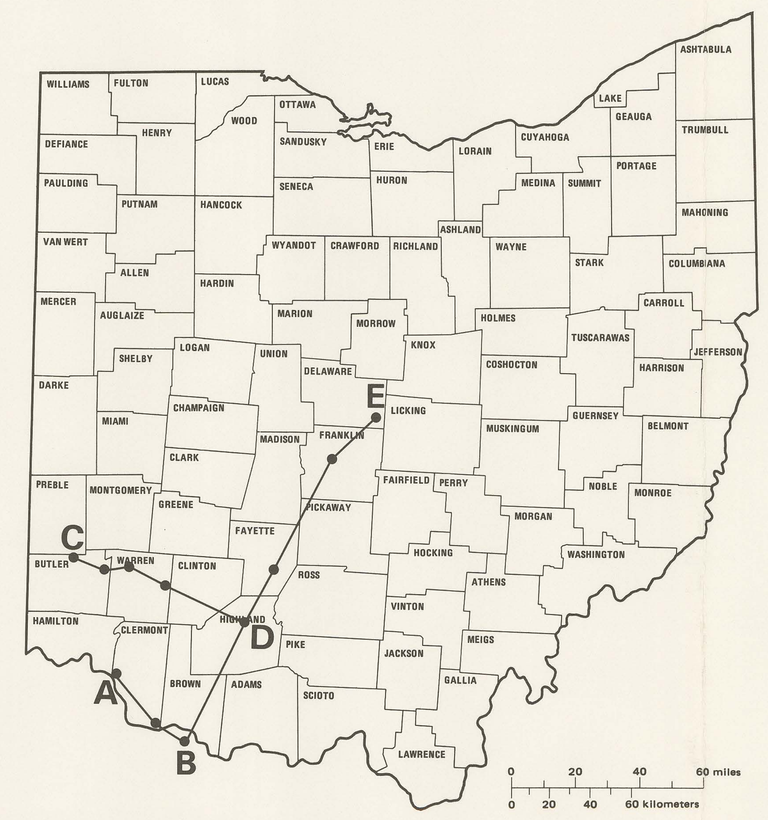


EXPLANATION

x, xxx = Bentonite

Vertical scale in feet
Datum is marker bed α

Gamma ray trace on left and neutron trace on right for all geophysical logs



Location of cross sections of Lexington Limestone and equivalents, southwestern Ohio.

PLATE 1.—SHALE-PERCENTAGE-LOG CROSS SECTION A-B OF THE LEXINGTON LIMESTONE AND EQUIVALENTS FROM CLERMONT COUNTY, OHIO, TO MASON COUNTY, KENTUCKY

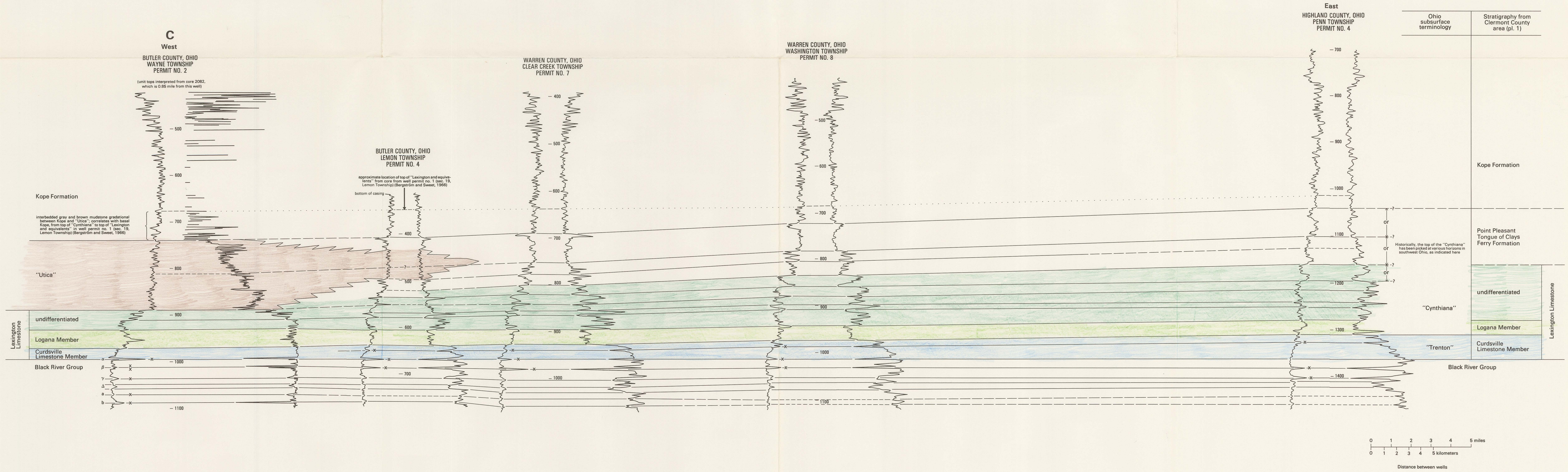


PLATE 2.—GEOPHYSICAL-LOG CROSS SECTION C-D OF THE LEXINGTON LIMESTONE AND EQUIVALENTS FROM BUTLER COUNTY, OHIO, TO HIGHLAND COUNTY, OHIO

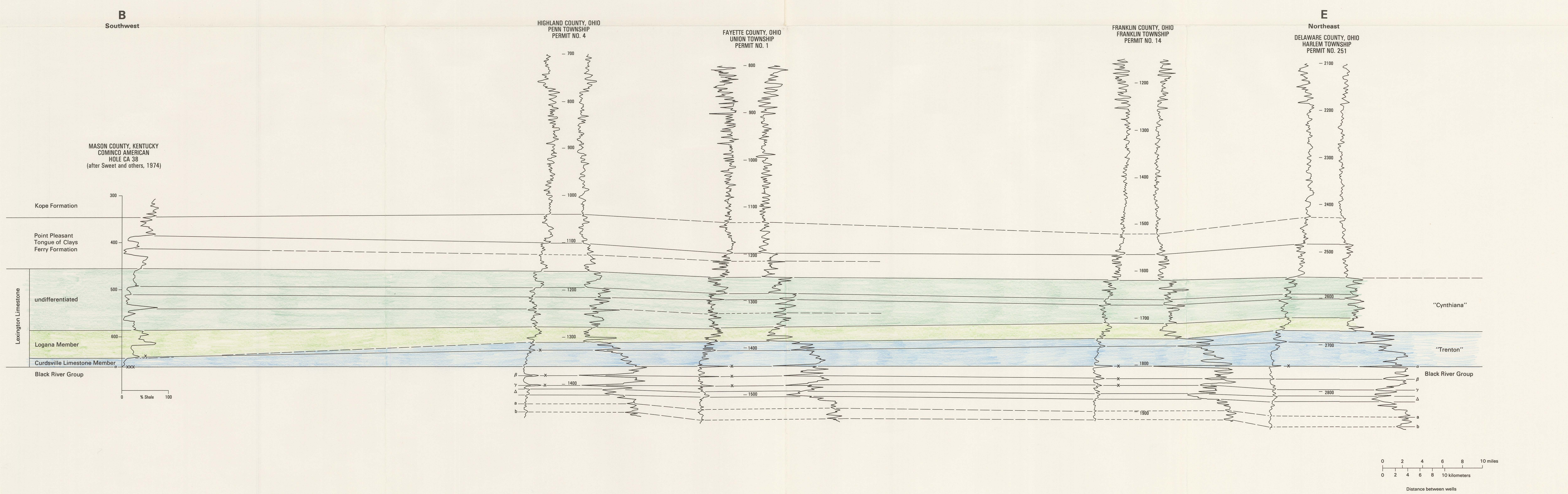


PLATE 3.—SHALE-PERCENTAGE-LOG AND GEOPHYSICAL-LOG CROSS SECTION OF THE LEXINGTON LIMESTONE AND EQUIVALENTS FROM MASON COUNTY, KENTUCKY, TO DELAWARE COUNTY, OHIO

CARTOGRAPHIC DRAFTING BY EDWARD V. KUEHNLE

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