

STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

LIMA PUBLIC LIBRARY
REFERENCE DEPT.

Report of Investigations No. 113

**CHEMICAL COMPOSITION, STRATIGRAPHY, AND
DEPOSITIONAL ENVIRONMENTS OF THE BLACK RIVER GROUP
(MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO**

by

David A. Stith

Columbus
1979



SCIENTIFIC AND TECHNICAL STAFF
OF THE
DIVISION OF GEOLOGICAL SURVEY

ADMINISTRATION

Horace R. Collins, MS, *State Geologist and Division Chief*
Richard A. Struble, PhD, *Geologist and Assistant Chief*

William J. Buschman, Jr., BS, *Administrative Geologist*
Barbara J. Adams, *Office Manager*

REGIONAL GEOLOGY

Robert G. Van Horn, MS, *Geologist and Section Head*
Richard W. Carlton, PhD, *Geologist*
Douglas L. Crowell, MS, *Geologist*
Richard M. DeLong, MS, *Geologist*
Michael C. Hansen, MS, *Geologist*
David A. Hodges, MS, *Geologist*
Dennis N. Hull, MS, *Geologist*
Michele L. Risser, BA, *Geologist*
Clark L. Scheerens, MS, *Geologist*
Joel D. Vormelker, MS, *Geologist*
Vanessa Tolliver, BS, *Laboratory Technician*

GEOCHEMISTRY LABORATORY

David A. Stith, MS, *Geologist and Section Head*
George Botoman, MS, *Geologist*
Norman F. Knapp, PhD, *Chemist*
Steven F. Kullman, BS, *Laboratory Technician*

LAKE ERIE

Charles H. Carter, PhD, *Geologist and Section Head*
Jonathan A. Fuller, MS, *Geologist*
Donald E. Guy, Jr., BA, *Geologist*
Carl L. Hopfinger, MS, *Geology Technician*
Dale L. Liebenthal, *Research Vessel Operator*
Marlene S. Longer, *Typist*

SUBSURFACE GEOLOGY

Frank L. Majchszak, MS, *Geologist and Section Head*
J. Scott Dailey, BA, *Geologist*
John D. Gray, MS, *Geologist*
Floyd M. Honeycutt, MS, *Geologist*
Richard H. Kingsbury, Jr., MS, *Geologist*
Michael T. Abele, AAS, *Geology Technician*
Martin L. Bretz, BA, *Geology Technician*
John C. Hadley, BGS, *Geology Technician*
Nina Hawranick, BS, *Environmental Technician*
David A. Nicklaus, BS, *Geology Technician*
Jerry M. Parks, BS, *Geology Technician*
James Wooten, *Geology Technician*
Garry E. Yates, *Environmental Technician*
Angelena M. Bailey, *Secretary*
Brenda L. Rinderle, *Office Machine Operator*

TECHNICAL PUBLICATIONS

Cartography
Philip J. Celnar, BFA, *Cartography Supervisor*
James A. Brown, *Cartographer*
Leonard M. Guckenheimer, BA, *Cartographer*
Victor J. Saylor, BA, *Cartographer*
Robert L. Stewart, *Cartographer*
Photocopy Composition
Jean M. Leshner, *Printing Technician*
Technical Editing
Merrienne Hackathorn, MS, *Geologist/Editor*
Sue Ellen Shear, BA, *Geologist/Editor*

PUBLIC SERVICE

Madge R. Fitak, BS, *Geologist and Supervisor*
Michael S. Temple, BS, *Geologist*
Inalee E. Johnson, *Public Inquiries Assistant*
Beverly A. Leffler, *Public Inquiries Assistant*
Rose Lehman, *Technical Typist*
Billie Wilder, *Clerical Specialist*

STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief

Report of Investigations No. 113

**CHEMICAL COMPOSITION, STRATIGRAPHY, AND
DEPOSITIONAL ENVIRONMENTS OF THE BLACK RIVER GROUP
(MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO**

by

David A. Stith

Columbus
1979



CONTENTS

	Page
Abstract	1
Introduction	1
Purpose and scope	1
Geologic setting	1
Acknowledgments	1
Previous investigations	1
Procedure	4
Stratigraphic study	4
X-ray analysis	4
Chemical analysis	6
Stratigraphy	6
General statement	6
Lower third of the Black River Group	6
Middle third of the Black River Group	9
Upper third of the Black River Group	9
Lithology and depositional environments	9
Supratidal facies	11
Laminated dolomite	11
Interlaminated micrite and dolomite	11
Micrite interbedded with dolomite	11
Laminated micrite	11
Laminated argillaceous limestone	11
Environment	11
Intertidal facies	11
Micrite	11
Limestone with vertical and U-shaped burrows	11
Ostracod biomicrite	11
Environment	14
Subtidal facies	14
Limestone with horizontal burrows	14
Limestone with dolomite interbeds	14
Micrite with <i>Tetradium</i> fragments	14
Biopelsparite	14
Argillaceous biomicrite and biopelsparite	14
Environment	14
Facies distribution	14
Chemical results	14
Summary	15
References cited	16
Appendix A—Summary of well data	18
Appendix B—Chemical and X-ray analysis data	20
Appendix C—Chemical analysis averages for high-carbonate zones	25
Appendix D—Descriptions of Adams County and Brown County cores	26

FIGURES

1. Study area and well locations	2
2. Comparison of gamma ray-neutron logs of basal Black River Group-Knox Dolomite section of Calvert (1962), Carpenter (1965), and this study ..	3
3. Thickness of Carntown unit	5
4. Thickness of rock between marker bed <i>a</i> and top of the Carntown unit	7
5. Elevation of top of the Carntown unit	8
6. Elevation of marker bed <i>a</i>	10
7. Polished sections of supratidal facies	12
8. Polished sections of intertidal and subtidal facies	13

CONTENTS

TABLES

	Page
1. X-ray settings	4
2. Depth to top of Carntown unit in Ohio wells	9
3. Character of marker beds, upper part of the Black River Group	9
4. Gamma-ray neutron logs showing apparent very low dolomite rock in the Carntown unit	15

PLATES

1. Geophysical-log cross section of the Black River Group from Union County, Indiana, to Fayette County, Ohio In pocket
2. Geophysical-log and core cross section of the Black River Group from Boone County, Kentucky, to Adams County, Ohio In pocket
3. Environmental interpretations of Adams County and Brown County cores . . In pocket

CHEMICAL COMPOSITION, STRATIGRAPHY, AND DEPOSITIONAL ENVIRONMENTS OF THE BLACK RIVER GROUP (MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO

by

David A. Stith

ABSTRACT

The chemical composition and stratigraphy of the Black River Group in southwestern Ohio were studied. Chemical analyses were done on two cores of the Black River in Adams and Brown Counties, Ohio. These studies show that substantial reserves of high-carbonate rock (96 to 98+ percent CaCO_3 plus MgCO_3) are present in the Black River at depths of less than 800 feet, in proximity to Cincinnati and the Ohio River.

Stratigraphic studies show that the Black River Group has eight marker beds in its middle and upper portions and three distinct lithologic units in its lower portion; these marker beds and units are present throughout southwestern Ohio. The Black River Group correlates well with the High Bridge Group of Kentucky. Depositional environments of the Black River are very similar to those of the High Bridge and to present-day tidal flats in the Bahamas.

INTRODUCTION

PURPOSE AND SCOPE

Surface deposits of high-purity carbonate rock are scarce in southwestern Ohio. Although mining is generally more expensive than quarrying, the lack of surface deposits requires the consideration of possible subsurface sources. The most likely subsurface source of carbonate rock in southwestern Ohio is the Black River Group (Middle Ordovician). The Black River correlative, the High Bridge Group, is quarried in central Kentucky and is mined near Carntown and Maysville, Kentucky, along the Ohio River.

This report presents the results of an investigation of the stratigraphy of the Black River Group in southwestern Ohio and of a chemical study of Black River high-carbonate zones. Forty-one geophysical logs and three cores from Ohio were examined along with several logs from adjacent parts of Indiana and Kentucky (fig. 1; Appendix A). The interpretation of the geophysical logs was done in conjunction with examination of drill cuttings from most of the wells and with a detailed lithologic study of the three cores. Mineralogy was determined by X-ray diffraction studies (Appendix B) on cores from Adams and Brown Counties, Ohio. Detailed chemical analyses (Appendixes B, C) were done on probable high-carbonate zones indicated by the X-ray study of the two cores. Rock with greater than 95 percent CaCO_3 is termed high calcium, and rock with greater than 95 percent total carbonates, CaCO_3 plus MgCO_3 , is termed high carbonate.

GEOLOGIC SETTING

The Black River Group in Ohio is overlain by the Trenton Limestone and underlain by the Wells Creek Formation. In Indiana the correlative units, in ascending

order, are the Chazyan, the Black River Limestone, and the Trenton Limestone (pl. 1) (L. E. Becker, written commun., 1976). In Kentucky the correlative of the Black River is the High Bridge Group, overlain by the Lexington Limestone and underlain by the Wells Creek Dolomite. The High Bridge Group is composed of, in ascending order, the Camp Nelson Limestone, the Oregon Formation, and the Tyrone Limestone (pl. 2) (Dever, 1974).

Because this study began as a chemical study of the Black River Group and is restricted to southwestern Ohio, formal subdivision of the group is not proposed. On an informal basis the Black River has three distinct units in the lower portion and eight distinctive marker beds that extend across the entire study area (pls. 1, 2). These units are, in ascending order, the lower argillaceous unit, the Carntown unit, the upper argillaceous unit, and marker beds II, I, b, a, Δ , γ , β , and α .

ACKNOWLEDGMENTS

The author would like to express his appreciation for discussions of the Black River Group and its correlatives to L. E. Becker of the Indiana Geological Survey, G. R. Dever, Jr., of the Kentucky Geological Survey, W. C. Sweet of the Department of Geology and Mineralogy, Ohio State University, and Max Warner formerly of MCQ Industries, Inc., Columbus, Ohio. Sulfur and phosphorus analyses were done by the author. Major and minor element chemical analyses were done in part by the author and in part by E. Lorraine Thomas.

PREVIOUS INVESTIGATIONS

Calvert (1962) gives an extensive review of the development of sub-Trenton terminology in Ohio. He correlates the

BLACK RIVER GROUP (MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO

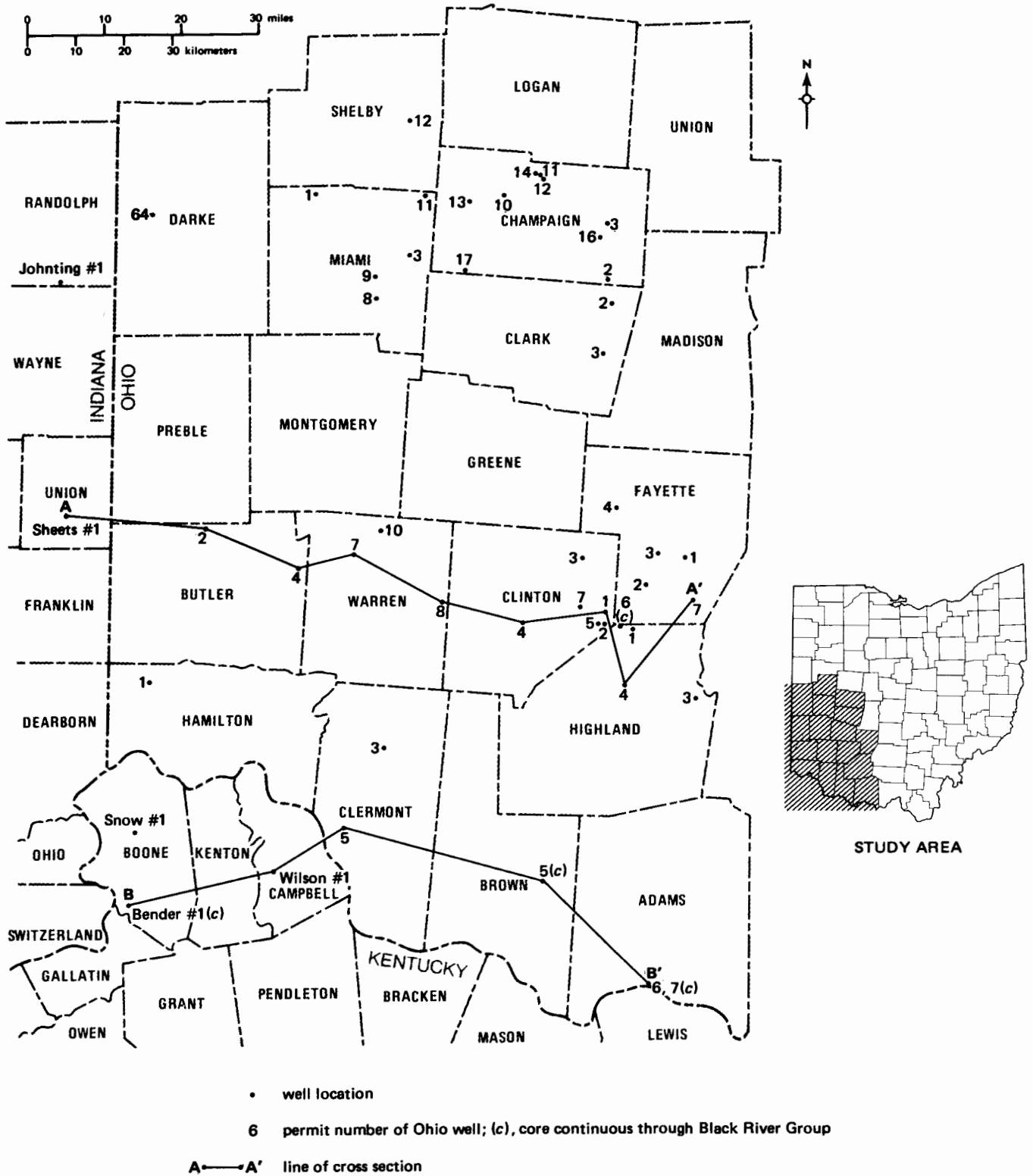


FIGURE 1.—Study area and well locations. Lines of cross sections in plate 1 (A-A') and plate 2 (B-B') also shown.

Calvert (1962, pl. 1)

Carpenter (1965, fig. 2)

This study

Union Twp., Fayette Co., Ohio
P. 1
Kewanee Hopkins #1

Boone Co., Kentucky
Cincinnati Gas and Electric Co.
Bender #1

location not given

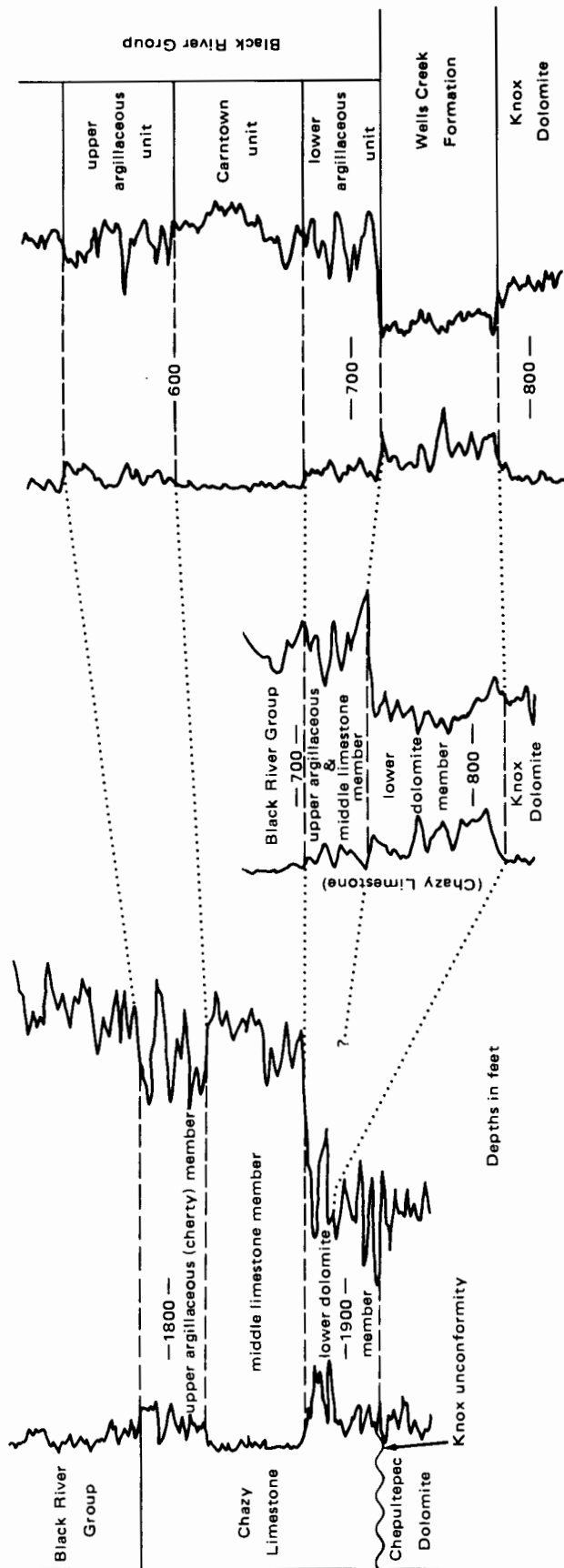


FIGURE 2.—Comparison of gamma ray-neutron logs of basal Black River Group-Knox Dolomite section of Calvert (1962), Carpenter (1965), and this study.

sub-Trenton rocks of Ohio with the outcrop in western Virginia by means of geophysical logs and commercial sample descriptions. Unfortunately, the one gamma ray-neutron log he illustrates from southwestern Ohio is from a well, the Kewanee Hopkins #1, drilled on a high point of the Knox unconformity. All the stratigraphic section normally present from the basal Black River Group to the Knox Dolomite is absent in this well. Use of Calvert's log as a type illustration gives an erroneous picture of the stratigraphy between the Carntown unit as defined in this study (fig. 2) and the Knox in southwestern Ohio and adjacent Indiana and Kentucky. The problem is further compounded by Calvert's use of Virginia outcrop lithologies for text descriptions of Chazy Limestone members and by his incorrect location of the top of the Knox in the Kewanee Hopkins #1 well. No chert was found in the upper argillaceous unit, and the top of the Knox Dolomite is at 1,893 feet on the gamma ray-neutron log of the Kewanee Hopkins #1, not at 1,920 feet as Calvert indicates (fig. 2).

Huff (1963) studied the mineralogy of the Middle Ordovician bentonites in southwestern Ohio and north-central Kentucky but made no stratigraphic correlations.

Carpenter (1965) studied the lower dolomite member of the Chazy Limestone in northern Kentucky and adjacent Ohio and Indiana. He apparently misinterpreted Calvert's work because of the missing section in Calvert's illustration. Carpenter assigns the upper argillaceous and middle limestone members of the Chazy to the upper part of the section (lower argillaceous unit, this study) generally present in northern Kentucky and southwestern Ohio (fig. 2) but which is missing from Calvert's illustration. The lower dolomite member is assigned to the lower part of the section (Wells Creek Formation) normally found in this region (fig. 2). The units that Calvert assigned to the upper and middle Chazy are referred to as the Black River Group by Carpenter.

Levine (1971), in an article describing a new lime plant at the Carntown, Kentucky, mine, reports a typical chemical composition for the 34 feet of limestone being mined in the lower part of the Black River Group. This analysis shows a high-calcium limestone, 95.1 percent CaCO_3 and 3.8 percent MgCO_3 . The mine is in Calvert's middle Chazy Limestone (Max Warner, oral commun., 1972), the Carntown unit of this study.

Votaw (1972) studied the conodonts of the type Black River Group and correlative strata from New York to Iowa and from Ontario to Tennessee. He gives an extensive summary of the development of Black River terminology for the eastern midcontinent. There are discrepancies among Votaw's text, tables, and figures, and he ignores lithology in at least one core (Mason County, Kentucky). Nevertheless, his data for the Mason County core, which is near Brown County, Ohio, indicate that all the rock from the base of the Lexington Limestone down at least to the top of the Wells Creek Formation is Black Riveran in age (W. C. Sweet, oral commun., 1977).

Dever (1974) lists core descriptions and foot-by-foot chemical analyses of the portion of a core from basal Lexington Limestone to upper Knox Group from southwestern Boone County, Kentucky (fig. 1). He reports several zones of high-carbonate rock in this core, particularly in the lower part of the Camp Nelson Limestone.

Cressman and Noger (1976) studied in detail the surface exposures of the High Bridge Group in central Kentucky.

Their study shows that the Tyrone, Oregon, and uppermost Camp Nelson Formations were deposited in extensive tidal-flat environments similar to present-day Bahamas and Florida Bay environments.

PROCEDURE

STRATIGRAPHIC STUDY

The stratigraphic study of the Black River Group involved two phases: (1) a detailed investigation of the lithology of the Black River in three cores in Adams (S-2405), Brown (S-2507), and Highland (S-2499) Counties, Ohio, and (2) correlation of certain beds and units by use of drill cuttings and geophysical logs, primarily gamma ray-neutron logs. All oil wells within the study area with available geophysical logs were used (fig. 1). The core study (Appendix D) was done on split core and 10 polished sections with a binocular microscope. Approximately 25 thin sections were studied with a petrographic microscope.

X-RAY ANALYSIS

Samples of the Black River Group were taken every foot in the Adams County and Brown County cores. These samples were crushed, pulverized to -80 mesh, and combined into 5-foot composites. Samples for X-ray diffraction analysis were taken from the composites. Approximately 0.45 g of sample was mixed with sufficient reagent-grade CaF_2 as an internal standard to produce a mixture of 75 percent sample and 25 percent standard. The mixture was ground for 10 minutes in a SPEX mill and then made into a powder pack following a modification of the method described by McCreery (1949). The powder was backfilled into a standard aluminum holder placed on a glass slide and was tamped with the edge of a spatula; the excess was then scraped off with a razor blade. A glass slide was taped over the back of the holder with no further pressure applied to the powder. Quantitative analyses were made using a Norelco DCP control panel and diffractometer. The data-accumulation technique used was the discrete preset time mode (total counts accumulated while scanning across the mineral diffraction peak). The count-accumulation time was determined for each peak based on peak width and goniometer scanning speed. Table 1 gives the X-ray settings used. Background-corrected mineral-to-fluorite intensity

TABLE 1.—X-ray settings

Mineral	$d\text{\AA}$	{hkl}	Degrees 2θ , start	Counting time (sec.)
Background			25.00	30
Quartz	3.343	{101}	26.30	30
Fluorite	3.153	{111}	27.55	75
Calcite	3.035	{211} ({10·4})	28.80	72
Dolomite	2.89	{211} ({10·4})	30.20	78
Background			32.00	30
Goniometer speed	1° 2 θ /min		Pulse-height analyzer	Integral, 285
Radiation	Cu, K α		Time constant	0.5 sec.
Filter	Ni		Receiving slit	.006 inch
Power	35 kv, 20 ma			

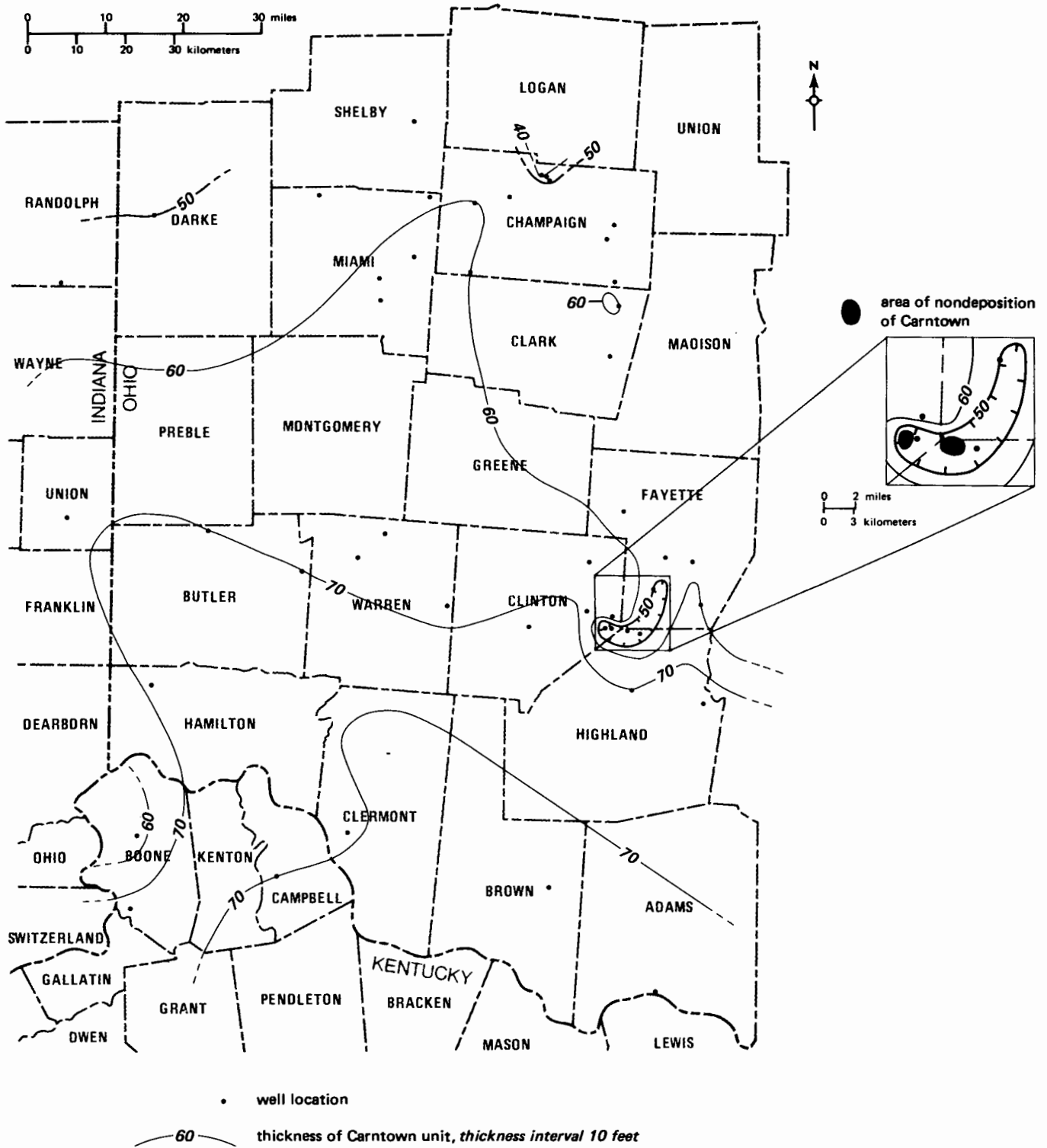


FIGURE 3.—Thickness of Carntown unit.

ratios I_Q/I_F , I_C/I_F , and I_D/I_F were computed and percentages of quartz, calcite, and dolomite in the sample were determined from standard-mixture curves.

Samples of some well cuttings from a well in Greene County (S-290) and a short core in Fayette County (S-751) were analyzed in a similar manner.

CHEMICAL ANALYSIS

Chemical analyses were done on zones indicated as high carbonate by the X-ray study of the Adams County and Brown County cores. Samples were taken from the core-composite powders. Calcium, magnesium, aluminum, iron, potassium, sodium, strontium, and manganese were determined by atomic absorption spectrophotometry (AAS) using a 0.2-g sample and a combined HF, HClO₄ dissolution technique. Silicon was determined by AAS using a 0.2-g sample and a NaOH flux technique. A limestone standard sample was analyzed as a control check with most batches of major element determinations. Sulfur was determined by a modified LECO method with semi-automatic titration using a 0.10-g sample. Phosphorus analyses were done by a modification of the ammonium molybdate/potassium antimonyl tartrate complexing method (U.S. Environmental Protection Agency, 1971) using a 0.5-g sample.

STRATIGRAPHY

GENERAL STATEMENT

The Black River Group in Ohio is not exposed at the surface. It is shallowest in extreme southwestern Ohio on the crest of the Cincinnati Arch. The Black River is 400 to 500 feet of micritic and pelletal limestone with some dolomitic and argillaceous zones. It is overlain by the Trenton Limestone, a fine- to coarse-grained bioclastic limestone. In most places the Black River is underlain by the Wells Creek Formation, a porous very argillaceous tan to light-gray dolomite with some intercalated green shale. In some places in the study area the Wells Creek-lower Black River section is thin or absent because of highs on the Knox unconformity (figs. 2, 3).

In Indiana the micritic limestone of Middle Ordovician age is termed the Black River Limestone. It is overlain by the Trenton Limestone as in Ohio, with the contact being drawn at the change from micritic to coarse-grained limestone. The rocks underlying the Black River are termed Chazyan in Indiana (pl. 1) (L. E. Becker, written commun., 1976), and include all or part of the lower argillaceous unit (this study) and the Wells Creek Formation of Ohio and northern Kentucky.

The 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 (pl. 2). The Tyrone is overlain by the Lexington Limestone; the contact is placed at a lithologic change similar to the change in Ohio. The basal Camp Nelson is not exposed in central Kentucky, but in the subsurface of northern Kentucky the Camp Nelson-Wells Creek contact is the same as the Black River-Wells Creek contact in southwestern Ohio (pl. 2).

The lower third of the Black River Group in Ohio is a

mixture of micritic, burrowed, and argillaceous limestones that can be divided into three units, upper and lower argillaceous limestones and pure limestone in the middle. The middle third of the Black River is predominantly micritic limestone with dolomite-filled burrows. This is the typical Camp Nelson lithology of the central Kentucky outcrop area. There are two marker beds in the middle third. The upper third of the Black River is a mixture of micritic-limestone types that, in general, correlates with the Tyrone Limestone and the Oregon Formation of Kentucky. Six marker beds are found in the upper third. Present at or near the base of the upper third are dolomite beds that are the equivalent of the Oregon.

LOWER THIRD OF THE BLACK RIVER GROUP

The lowermost unit of the Black River Group, here termed the lower argillaceous unit (pl. 2), is made up of interbedded micrite, fine-grained dolomite, argillaceous micrite, and shaly greenish limestone. All are laminated in part. This unit is assigned to the Black River rather than to the underlying Wells Creek Formation primarily on the basis of lithology. Most of the limestone found in this unit in the Adams County and Brown County cores is essentially the same—micritic, pelletal, fossiliferous, laminated, and argillaceous in large part—as that in marker beds I and II and in the upper argillaceous unit.

The lower argillaceous unit of the Black River Group and the Wells Creek Formation are the units most affected by relief on the Knox unconformity. In three wells (Champaign County, P-14; Clinton County, P-5; Highland County, core) this section is absent because of highs that extend into the position of overlying units. In approximately 10 other wells the entire lower argillaceous unit-Wells Creek section is replaced by 10 to 50 feet of argillaceous dolomitic limestone that is difficult to assign to either unit. There are no known cores from wells with this particular lithology and sample recovery was too poor in the 10 wells to assign an exact unit to the section.

Overlying the lower argillaceous unit is the Carntown unit (pl. 2), a thick section of very pure limestone and dolomitic limestone. The unit normally ranges from 50 to 74 feet in thickness (fig. 3). In a few localities the Carntown is thin or absent because of nondeposition resulting from 100 to 150 feet of relief developed on the Knox unconformity. The top of the Carntown unit is 320 to 400 feet below the top of the Black River Group (fig. 4) and is generally less than 2,000 feet below the surface (table 2) in the study area. Structure contours on the top of this unit show a broad, gentle downward slope to the northeast with some irregularities in Champaign, Miami, Clinton, and Fayette Counties (fig. 5). There is an abrupt change in steepness and direction of slope from northeast to east along the edge of the Cincinnati Arch in Adams and Highland Counties.

The uppermost unit in the lower third of the Black River Group is the upper argillaceous unit, which consists of micritic and pelletal limestone with a moderate amount of dolomite. The limestone and dolomite are dark colored and argillaceous in part with partings and interbeds of dark-gray to black shale and shaly limestone. No chert was found in this unit. Argillaceous and shaly material is concentrated mainly in the upper quarter and to a lesser extent in the lower half of the upper argillaceous unit (pls. 1, 2).

BLACK RIVER GROUP (MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO

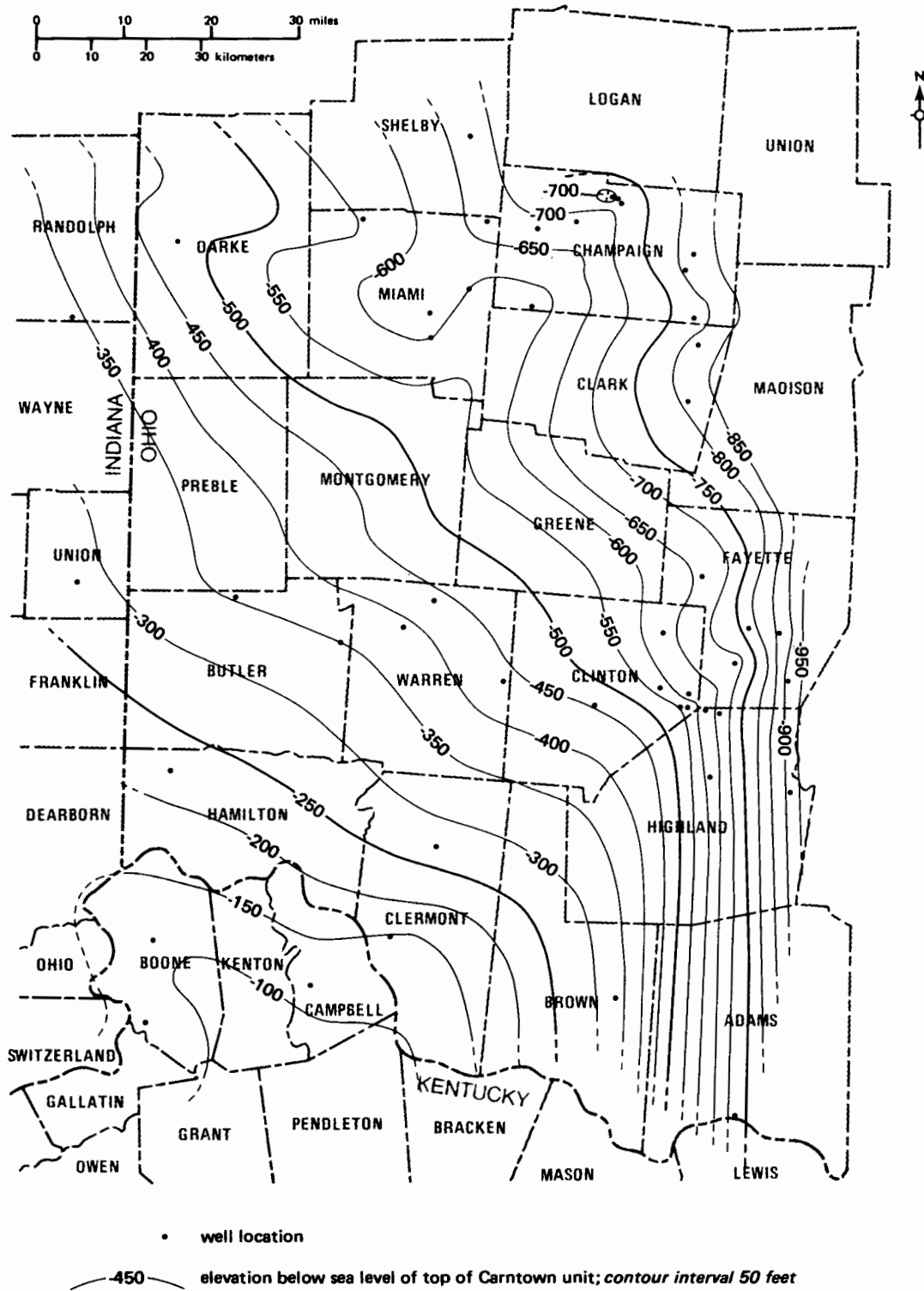


FIGURE 5.—Elevation of top of the Carntown unit.

TABLE 2.—Depth to top of Carntown unit in Ohio wells

County	Permit no.	Depth (ft) to Carntown	County	Permit no.	Depth (ft) to Carntown
Adams	6	1250		5	x ¹
	7	1256		7	1656
Brown	5	1310	Darke	64	1562
Butler	2	1342	Fayette	1	1820
	4	1017		2	1700
Champaign	2	2042		3	1767
	3	2037		4	1700
	10	1820		7	1910
	11	1783	Hamilton	1	1041
	12	1784	Highland	1	1706
	13	1810		3	1800
	14	1774		4	1750
	16	2040		6	x
	17	1748	Miami	1	1547
Clark	2	2070		3	1635
	3	1974		8	1401
Clermont	3	1090		9	1468
	5	830		11	1804
Clinton	1	1743	Shelby	12	1727
	2	1645	Warren	7	1320
	3	1685		8	1387
	4	1522		10	1494

¹x, Carntown absent because of nondeposition.

MIDDLE THIRD OF THE BLACK RIVER GROUP

The two marker beds in the middle third of the Black River Group are about 95 to 120 feet apart; marker bed II is in the lower part of the section, and marker bed I is at the top of the section (pls. 1, 2). Almost all the middle third is burrow-mottled micritic and pelletal limestone. The burrows are dolomitized, and the matrix limestone is dolomitized in part. Marker bed II is 10 to 20 feet of burrowed micritic and pelletal limestone. It is dark colored and argillaceous in large part, with some carbonaceous shale and shaly limestone. Marker bed I is 5 to 10 feet of interbedded argillaceous dark-colored micritic limestone and fine-grained dolomite, with sparse to moderate amounts of carbonaceous shale and shaly limestone.

UPPER THIRD OF THE BLACK RIVER GROUP

The upper third of the Black River Group is composed of interbedded micritic and pelletal limestone and fine-grained dolomite. The rocks are argillaceous in part and laminated in part. Argillaceous material is concentrated mainly above marker bed b. The six marker beds in this section are listed in table 3 and shown on plates 1 and 2. Marker bed b is recognizable in about three-quarters of the logs and cores, and marker bed a is recognizable in about half the logs and cores. Marker beds b and a are not always distinct bentonites. In the three cores, these beds are generally mixtures of thin bentonitic shale and thin argillaceous or bentonitic limestone. Marker bed Δ is the thickest, 7 to 15 feet, of the upper six marker beds and is the only nonbentonitic one. This thick shaly to argillaceous limestone is recognizable in all but one of the logs and cores in this study and has a somewhat multifold character. In most of the wells, the middle part of marker bed Δ is highly argillaceous and grades into slightly less argillaceous beds above and(or) below. The three uppermost marker beds are

all bentonites that are probably zones of multiple ash falls and reworkings rather than three distinct continuous beds. A number of thin less distinct bentonites are shown on plates 1 and 2 and in the core descriptions. Marker beds γ and β are recognizable in all the logs and cores, and marker bed α is well developed in three-quarters of the logs and cores (pls. 1, 2). Marker bed γ is a distinct bentonite in the Highland County core, but is a thin bentonitic shale or limestone overlain by about 2 feet of argillaceous limestone in the Adams County and Brown County cores. Marker beds β and α are thick (6 inches to 1½ feet) bentonites in all three cores.

The change from micritic limestone of the Black River Group to fossiliferous medium- to coarse-grained limestone of the Trenton Limestone occurs 1 to 7 feet above marker bed α in all three cores. Examination of sample cuttings and shorter cores from the other wells indicates that marker bed α in effect marks the Black River-Trenton contact throughout the study area. Structure contours on marker bed α (fig. 6) show the same general structure as the top of the Carntown unit (fig. 5).

LITHOLOGY AND DEPOSITIONAL ENVIRONMENTS

Recently, numerous papers on tidal sediments in general (Ginsburg, 1975; Shinn, 1968; Shinn and others, 1969) and a few papers on tidal environments in the Black River Group (Cressman and Noger, 1976; Mukherji, 1969; Walker, 1973) have been published. Detailed examination of the three cores in this study indicates that extensive supratidal and intertidal environments are represented in the Black River carbonates in southwestern Ohio. The Black River is analogous to Middle Ordovician rocks in central Kentucky and to recent sediments in the Bahamas.

The cores in Adams, Brown, and Highland Counties are nominal 2-inch cores ($\approx 1\frac{3}{8}$ inch core diameter) drilled for mineral exploration. Certain features, such as channels, bedding continuity, and mudcracks, cannot be determined accurately because of the small core diameter. Because the cores are fresh rock, certain other features such as laminations and burrows do not show up as well as on weathered rock.

Lithologic terminology is basically that used by Folk (1959) with the exception of micrite. Micrite in this study is not strictly a thin-section-derived term describing individual grain size. Instead, micrite is used as a rock name for

TABLE 3.—Character of marker beds, upper part of Black River Group

Marker bed	Character
α	bentonite
β	bentonite
γ	bentonite commonly overlain by argillaceous limestone
Δ	thick very argillaceous limestone
a	mixed bentonitic shale and argillaceous limestone
b	bentonite and bentonitic limestone

BLACK RIVER GROUP (MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO

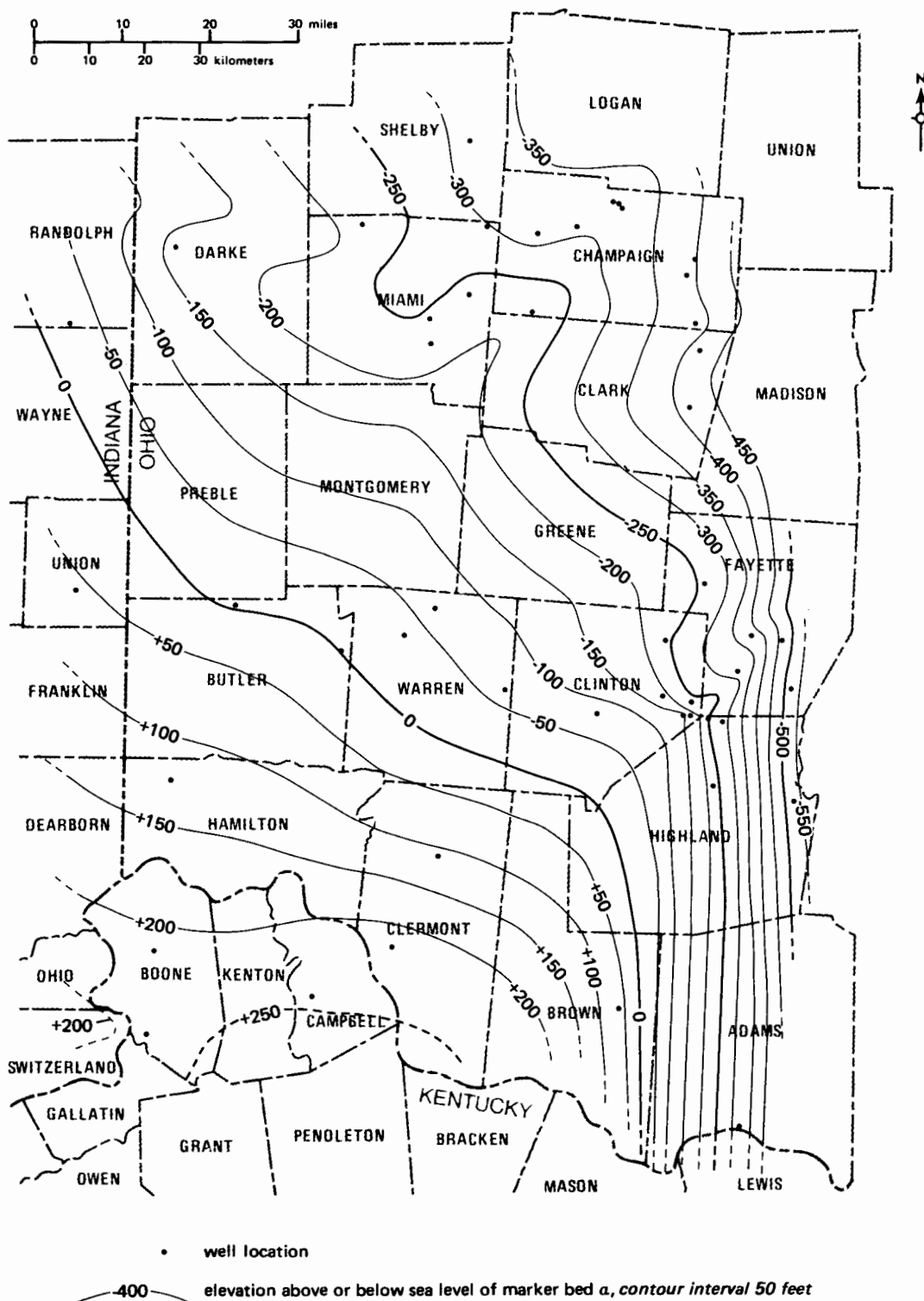


FIGURE 6.—Elevation of marker bed a.

lithographic limestone as determined by use of a binocular microscope. Some thin sections were made of core samples with lithologies that were difficult to determine by use of a binocular microscope. The thin sections were used to make determinations of very fine-grained pelletal rocks versus micritic rocks in the split core. The term pellet (pel-) in this study does not necessarily denote fecal pellets. There seems to be a complete size range of rounded structureless micrite particles from true microscopic pellets to millimeter-size intraclasts. The pellets are very different from the blocky to platy laminated intraclasts composed of micrite. Within any one bed there is generally a high degree of sorting and roundness of the pellets, regardless of size.

In this study the terms supratidal, intertidal, and subtidal do not have any reference to water levels or tides. The terms refer to zones that were covered by marine waters rarely, often, and almost always, respectively. Although the individual lithologies described below do occur separately, they are considered more as end members because there is a considerable amount of interbedding and gradation.

SUPRATIDAL FACIES

Laminated dolomite

The dolomite in the Black River Group is very fine- to fine-grained, 0.01 to 0.08 mm in diameter. Most of the dolomite has faint laminations caused by differences in color and grain size. There are sparse micrite laminations, and the dolomite is unfossiliferous.

Interlaminated micrite and dolomite

The laminations are less than a millimeter to several millimeters thick, straight to wavy, and nodular to discontinuous in part (fig. 7A). Some of the micrite laminations are partially dolomitized, and there are a few intrasparite and pelsparite laminations. The micrite shows desiccation features (planar and nonplanar birdseyes and mudcracks) in part.

Micrite interbedded with dolomite

This lithology is similar to the previous one, but on a larger scale (fig. 7B). Micrite layers are about a centimeter thick, are faintly laminated, and show desiccation features in part. The dolomite layers generally are less than $\frac{1}{2}$ as thick as the micrite layers and are laminated in part.

Laminated micrite

The micrite is faintly to distinctly laminated (fig. 7C). Most laminations are caused by color differences, but a few laminations are formed from single layers of pellets or of dolomite rhombs. There are some interbeds of pelsparite (fig. 7D) and intrasparite. Desiccation features are numerous, and the planar birdseyes commonly coalesce into sheet cracks. Vertical burrows are sparse; some are filled with pelsparite and some with sparry calcite. Fossils are limited to a few scattered ostracod valves. The micrite is dolomitized in part with a sparse to moderate number of scattered dolomite rhombs.

Laminated argillaceous limestone

These rocks are a mixture of micrite and fine-grained shaly limestone with a minor amount of pelsparite and intrasparite. They are very argillaceous and generally laminated. Some beds are dolomitic, and desiccation features are abundant. The color generally is darker than in the clean micrites and has a greenish cast.

Environment

The rocks in this study more closely resemble the recent supratidal sediments of the Bahamas than the sediments of Western Australia or the Persian Gulf (Ginsburg, 1975). Consequently, the laminations (Shinn and others, 1969), planar to nonplanar birdseye fabric (Shinn, 1968), and dolomite are considered indicative of supratidal deposition. No evidence of evaporites such as crystal molds or collapse breccia was found in any of the three cores, indicating the climate was more humid than arid. Some mudcracks are present, but their apparent absence in many samples is probably due to the small core diameter.

INTERTIDAL FACIES

Micrite

The micrite has most of the features of supratidal laminated micrite, but the features are much more subdued. Laminations are very faint to faint and sparse to moderate in number. Birdseyes are generally small and sparse to moderate in number. Some of the thicker nonlaminated beds have sparse to moderate numbers of sparry-calcite-filled vertical shrinkage cracks. A few mudcracks are present.

Limestone with vertical and U-shaped burrows

The rock is composed of micrite and pelsparite that is intraclastic in part. The burrows are sparse to numerous and mainly vertical; a few are U shaped (fig. 8A). The burrows are commonly filled with sparry calcite or pelsparite; a few are filled with fine-grained dolomite. The burrows range from 1 to 6 mm in diameter and may be as long as 6 cm. A few fossils, mainly ostracods and small fragments of the tabulate coral *Tetradium*, are found in the limestone. Any or all of the following features may be present in this rock: sparse to moderate number of faint laminations; sparse small birdseyes, mainly planar; thin dolomite interbeds or laminations; mudcracks; sparse to moderate number of sparry-calcite-filled vertical shrinkage cracks.

Ostracod biomicrite

The rock is an ostracod biomicrite with minor amounts of interbedded micrite, pelsparite, and fine-grained dolomite. There are a few vertical burrows; some are filled with sparry calcite and some with pelsparite. Faint laminations of color, grain size, or dolomite rhombs are present in a few beds. Some beds are pelsparite with a vaguely churned and bioturbated appearance. The rock is generally very light tan or gray.

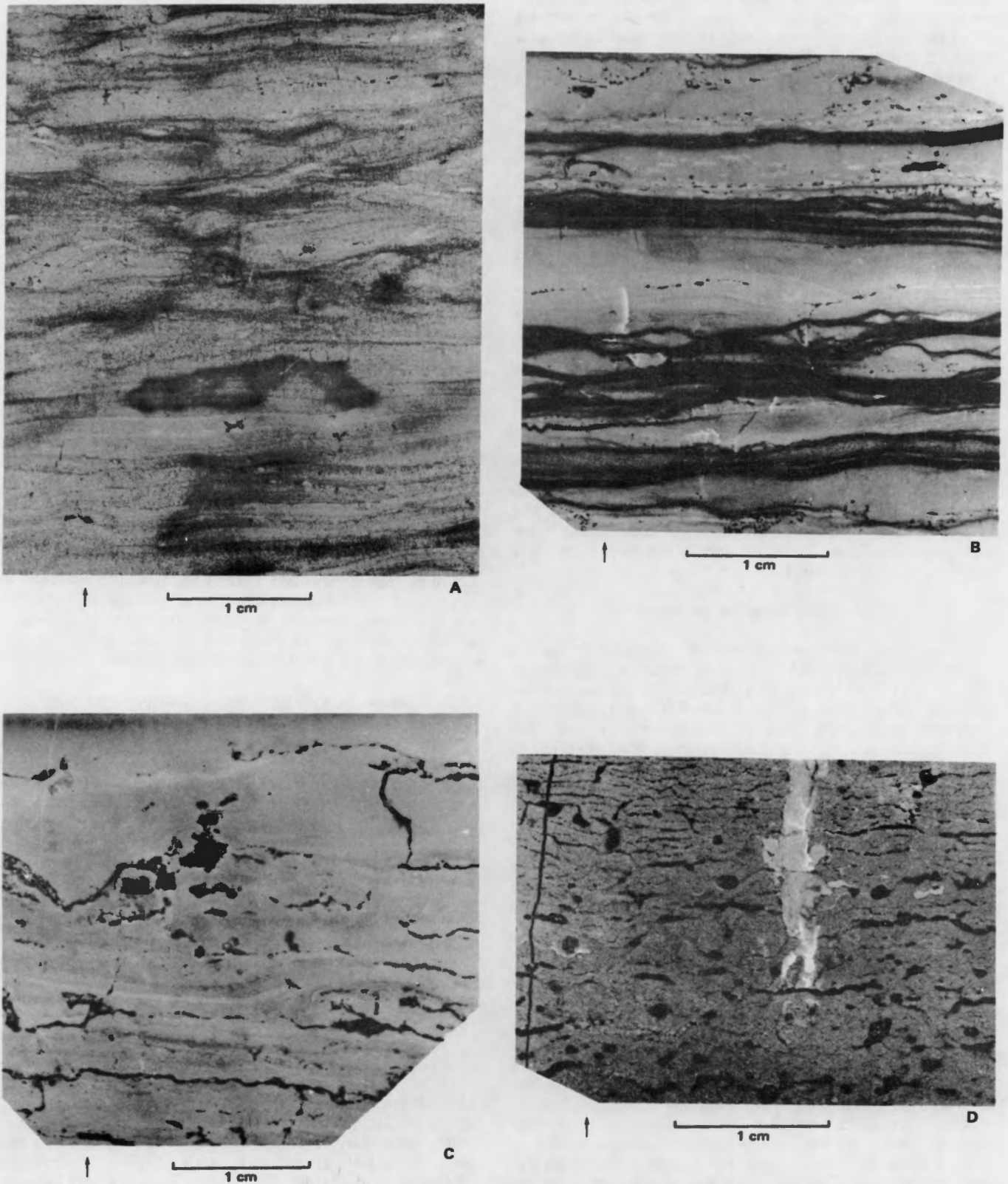


FIGURE 7.—Polished sections of supratidal facies. A, interlaminated micrite and dolomite. S-2405, 995'3". B, partially laminated micrite (light) interbedded with partially laminated dolomite (dark). S-2405, 956'6". C, laminated micrite with minor number of birdseyes and sheet cracks. S-2405, 882'. D, pelsparite with numerous sheet cracks and planar and nonplanar birdseyes. S-2507, 1011'.

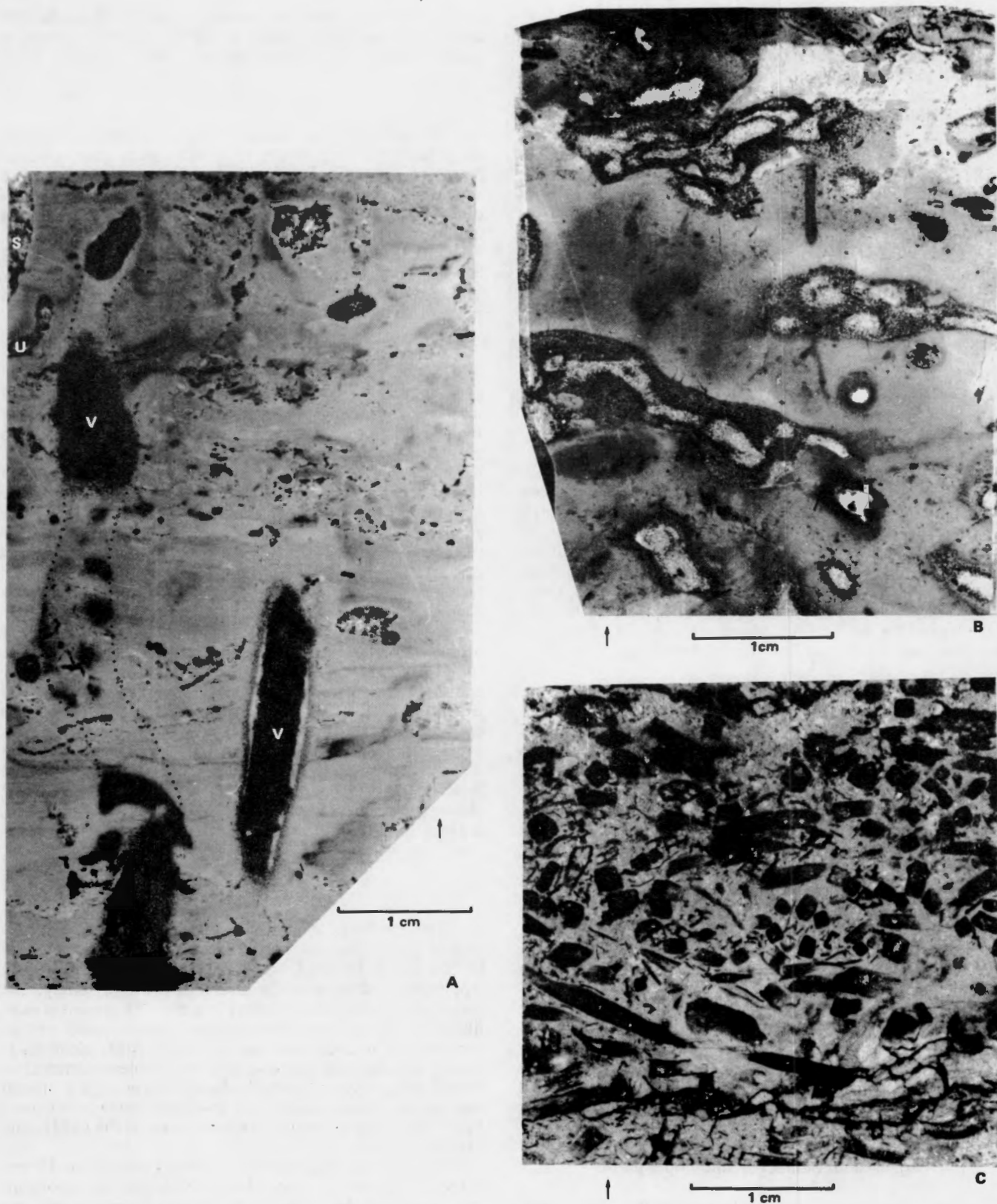


FIGURE 8.—Polished sections of intertidal and subtidal facies. A, intertidal; faintly laminated intraclastic micrite with vertical and U-shaped burrows; *s*, vertical burrow, sparry-calcite-filled; *u*, U-shaped burrow, sparry-calcite-filled; *v*, vertical burrow, dolomite-filled, dotted where out of plane of section. S-2499, 1323'3". B, subtidal; micrite with dolomite-filled horizontal burrows. S-2405, 1049'. C, subtidal, *Tetradium* biomicrite. S-2507, 1094'8".

Environment

Intertidal facies are the hardest to recognize because of the narrow diameter of the core samples available. Vertical and U-shaped burrows (Walker, 1973) are considered the most reliable indicators of intertidal deposition. The reduced numbers, small size, and faintness of desiccation features such as birdseyes and laminations also are considered indicative of intertidal deposition because of the common association of these features with vertical burrows. Mud-cracks are present, but, as in the supratidal facies, the core size prevents recognition of the number and size of the polygons. Fossils, although more plentiful than in the supratidal facies, are relatively sparse. They are mainly articulated and disarticulated ostracod valves and small broken *Tetradium* fragments. The ostracod biomicrite lithology is somewhat anomalous because in places it is laminated and has vertical burrows, and in other places it is pelsparite with a churned and burrowed appearance.

SUBTIDAL FACIES

Limestone with horizontal burrows

The limestone is a mixture of micrite and various combinations of bio-, pel-, and intra-micrite and sparite. The burrows are horizontal to inclined, range from 2 mm to 1 cm in diameter, and are mostly dolomitized (fig. 8B). A few burrows show relict pelsparite texture. Recognizable fossils include fragments of echinoderms, bryozoans, ostracods, brachiopods, pelecypods, gastropods, and *Tetradium*. In addition to the burrows, there are irregular to nodular interbeds and partings of fine-grained dolomite.

Limestone with dolomite interbeds

The limestone is biomicrite and biosparite and is pelletal and intraclastic in part. There are a moderate number to numerous irregular to nodular thin interbeds and partings of fine-grained dolomite. The rock is very similar to the burrowed limestone, but has no burrows.

Micrite with *Tetradium* fragments

The rock is micrite and biomicrite and is pelletal, intraclastic, and sparry in part. *Tetradium* fragments are moderate to numerous. Some fragments are unreplaced, others are replaced by sparry calcite (fig. 8C). *Tetradium* is the main faunal element, but some beds have a diverse fauna like the burrowed limestone.

Biopelsparite

The biopelsparite has a large, diverse fauna like the burrowed limestone. Fossils range from whole valves and tests to fragments nearly as small as pellets. There is faint crossbedding preserved in a few beds.

Argillaceous biomicrite and biopelsparite

This lithology is the subtidal equivalent of the laminated argillaceous limestone. The rock is interbedded biomicrite and biopelsparite and is very argillaceous and generally dark colored. The fauna is diverse, containing

corals, bryozoans, and gastropods, as well as others. Bioturbation is extensive, creating a lumpy, churned texture in part; however, some burrows are preserved.

Environment

The most obvious indicator of a subtidal environment in these rocks is the generally large and diverse marine fauna. Many of the *Tetradium*-bearing rocks are indicative of a somewhat restricted environment as shown by the lack of other fossils. Horizontal burrows are also a common indicator of subtidal sediments (Cressman and Noger, 1976). The limestone with dolomite interbeds is considered subtidal because of the presence of a marine fauna and the similarity of the dolomite interbeds to the dolomite associated with the horizontal burrows.

FACIES DISTRIBUTION

Distribution of the supratidal, intertidal, and subtidal facies in the Adams County and Brown County cores is shown in plate 3. The lower part of the Black River Group present in the Highland County core is mostly marine limestone that does not resemble the other two cores. The top of the upper argillaceous unit is the first recognizable horizon in the Highland County core because the lower argillaceous unit, the Carntown unit, and the lower part of the upper argillaceous unit are absent because of nondeposition. A few thin laminated limestone beds of the intertidal facies are found in the upper argillaceous unit in the Highland County core.

In all three cores, the first few feet of rock immediately below marker bed II are of the intertidal facies. Rocks of the supratidal and intertidal facies are concentrated in the lower and upper argillaceous units in the Adams County and Brown County cores and above marker bed I in all three cores. The upper third of the Black River is about two-thirds supratidal and intertidal facies in the Adams County and Brown County cores and one-third supratidal and intertidal facies in the Highland County core. Dolomite beds just above marker bed I, correlative to the Oregon Formation, are mostly of the supratidal and intertidal facies.

CHEMICAL RESULTS

The results of chemical analyses, computed as oxides except for sulfur and phosphorus, of the Adams County (S-2405) and Brown County (S-2507) cores are shown in Appendix B along with the results of the X-ray study. The major error in samples totalling less than 99 percent is most likely a low calcium determination. This is based on two factors: the accuracy of analyses of the other elements as shown by standard samples, and the problems inherent in determining calcium by AAS when it makes up the bulk of the sample. Consequently, the insoluble oxide totals are a better indicator of purity than is the total of the CaCO₃ and MgCO₃ columns.

Averages for high-carbonate zones greater than 15 feet thick are shown in Appendix C. Although no significant thicknesses of high-calcium rock were found in the two cores studied, there are several zones of high-carbonate rock of mineable thickness in each core. In general, the high-carbonate zones are the same as those found in the core

from Boone County, Kentucky (Dever, 1974).

The uppermost high-carbonate zone is not quite as pure as zones found lower in the Black River Group. This upper zone includes the upper part of the dolomite correlative to the Oregon Formation and 10 to 15 feet of rock immediately overlying the dolomite. Sample 2405, 960 feet to 1009 feet, and sample 2507, 1035 feet to 1054 feet, show almost 97 percent total carbonate (just over 3 percent insoluble oxides). The rocks in the middle third of the Black River contain one or two zones of high-carbonate rock between marker beds I and II and another zone immediately below marker bed II. The rock in these zones (S-2405, 1065 feet to 1134 feet and 1140 feet to 1179 feet; S-2507, 1090 feet to 1109 feet, 1140 feet to 1174 feet, and 1200 feet to 1234 feet) have between 97 and 98 percent total carbonate. The deepest and purest zone of high-carbonate rock in the Black River is the Carntown unit (S-2405, 1257 feet to 1317 feet; S-2507, 1310 feet to 1374 feet). This unit averages less than 2 percent insoluble oxides. Silica content is just over 1 percent; alumina and iron oxide are less than 0.5 and 0.2 percent, respectively. Sulfur is less than 0.1 percent and phosphorus is 0.002 percent (Appendix C).

Both cores analyzed in this study contain appreciable amounts of dolomite throughout the Carntown unit. The dolomitized zone in the lower part of the unit is more persistent regionally than the dolomite in the upper and middle portions. The mine at Carntown, Kentucky, is in fairly low-magnesium stone, 1.80 percent MgO (Levine, 1971), of the Carntown unit. The core from southwestern Boone County, Kentucky, has approximately 15 feet of high-calcium stone near the middle of the Carntown unit (Dever, 1974). Dolomite can generally be inferred from the neutron side of a radioactivity log. Because the dolomite in the Black River Group generally is more porous than limestone, the neutron log will have a lower reading in dolomitic zones owing to the increased fluid content in the rock. Examination of gamma ray-neutron logs throughout southwestern Ohio indicates the dolomite content of the Carntown unit is as follows: upper section, low to moderate; middle section, low; basal section, moderate to high. The neutron logs also show that five wells in the study area may have 15 to 45 feet of high-calcium stone in the Carntown unit. These wells are listed in table 4 (some of the logs are shown on plates 1 and 2).

The other two wells (S-290 and S-751) in the X-ray study were not chemically analyzed, but the X-ray data on both confirm the high quality of the Carntown unit. Sample 290 is composed of cuttings from a well in Spring Valley Township, Greene County, Ohio; this well has no geophysical log. The cuttings X-rayed were from the Carntown unit and show a high-carbonate zone that is more dolomitic at the bottom than at the top (Appendix B). Sample 751 is a

short core from a well (P-2) in Concord Township, Fayette County. The core had been sampled previously and has broken unmatched core ends and uncertain continuity. A continuous quarter-split was made of this core; the splits from each 2-foot core box were crushed as one sample. X-ray diffraction analysis and insoluble residue determinations showed 18 feet of high-carbonate rock in the upper 20 feet of the Carntown unit (Appendix B).

SUMMARY

The Black River Group in southwestern Ohio contains large reserves of high-carbonate rock at depths of less than 2,000 feet (table 2). The highest quality rock (98+ percent carbonate) is found in the Carntown unit, in the lower part of the group. This unit is shallowest in the extreme southwestern part of the state. Along the Miami, Little Miami, and Ohio River valleys, depth to the top of the Carntown unit is 650 to 800 feet. Substantial thicknesses of 96 to 97+ percent carbonate rock are present in the 200 to 300 feet of section overlying the Carntown unit. Although the Black River is generally dolomitic to some extent, mineable thicknesses of high-calcium stone are probably present in some locations in Ohio (table 4).

The upper two-thirds of the Black River Group contains eight bentonitic and argillaceous marker beds that generally can be traced across the entire study area on geophysical logs. Micrite and dolomite in the upper third of the Black River correlate roughly with the Oregon Formation and Tyrone Limestone in Kentucky. The middle third of the Black River is similar in appearance to the typical outcrop lithology of the Camp Nelson Limestone. The lower third of the group can be divided into three units. The upper argillaceous unit and the Carntown unit correspond to Calvert's (1962) upper and middle Chazy Limestone. The lower argillaceous unit is the same as the argillaceous micritic limestone in the upper part of Calvert's lower Chazy.

The lithology of the Black River Group in the study area closely resembles that of the High Bridge Group in central Kentucky. The laminated and interlaminated micrite and dolomite, limestone with vertical burrows, *Tetradium*-bearing limestone, limestone with horizontal burrows, and biopelsparite are very similar to the rocks of the High Bridge described by Cressman and Noger (1976). Dolomite, laminations, *Tetradium* fragments, and vertical, U-shaped, and horizontal burrows are found in southwestern Ohio as they are in the type area of the Black River in New York. However, oolites, oncolites, calcareous algae fragments, and *Tetradium* supercolonies as reported by Walker (1973) in the type area were not found in this study. No crystal molds or other evidence of evaporites like those in Ontario (Mukherji, 1969) and in Arkansas (Young and others, 1972) were found.

Rocks of the supratidal and intertidal facies make up a large part of the Black River Group, particularly the upper third. Overall, supratidal and intertidal facies compose 40 percent of the Black River in the Adams County core and 30 percent in the Brown County core. Less than 20 percent of the Highland County core is supratidal and intertidal facies, but the Carntown unit and lower argillaceous unit are missing from this core because of nondeposition.

TABLE 4.—Gamma ray-neutron logs showing apparent very low dolomite rock in the Carntown unit

State	County	Township	Well permit no. or name
Ohio	Clermont	Pierce	5
	Butler	Lemon	4
	Butler	Wayne	2
	Miami	Staunton	8
Kentucky	Boone		Clarence Snow #1

REFERENCES CITED

- Calvert, W. L., 1962, Sub-Trenton rocks from Lee County, Virginia, to Fayette County, Ohio: Ohio Geological Survey Report of Investigations 45, 57 p.
- Carpenter, G. C., 1965, The lower dolomite member of the Ordovician Chazy Limestone and the St. Peter Sandstone of north-central Kentucky and southwestern Ohio: Ohio Journal of Science, v. 65, p. 85-94.
- Cressman, E. R., and Noger, M. C., 1976, Tidal-flat carbonate environments in the High Bridge Group (Middle Ordovician) of central Kentucky: Kentucky Geological Survey, ser. X, Report of Investigations 18, 15 p.
- Dever, G. R., Jr., 1974, High-carbonate rock in the High Bridge Group (Middle Ordovician), Boone County, Kentucky: Kentucky Geological Survey, ser. X, Information Circular 22, 35 p.
- Folk, R. L., 1959, Practical petrographic classification of limestones: American Association of Petroleum Geologists Bulletin, v. 43, p. 1-38.
- Ginsburg, R. N., ed., 1975, Tidal deposits, a casebook of Recent examples and fossil counterparts: New York, Springer-Verlag, 428 p.
- Huff, W. D., 1963, A study of Middle Ordovician K-bentonites in Kentucky and southern Ohio: University of Cincinnati, Ph.D. dissertation (unpublished), 115 p.
- Levine, Sidney, 1971, Radiation-convection coolers lower kiln gas temperatures: Rock Products, v. 74, no. 7, p. 51-56.
- McCreery, G. L., 1949, Improved mount for powdered specimens used on the geiger-counter X-ray spectrometer: American Ceramic Society Journal, v. 32, no. 4, p. 141-146.
- Mukherji, K. K., 1969, Supratidal carbonate rocks in the Black River (Middle Ordovician) Group of southwestern Ontario, Canada: Journal of Sedimentary Petrology, v. 39, p. 1530-1545.
- Shinn, E. A., 1968, Practical significance of birdseye structures in carbonate rocks: Journal of Sedimentary Petrology, v. 38, p. 215-223.
- Shinn, E. A., Lloyd, R. M., and Ginsburg, R. N., 1969, Anatomy of a modern carbonate tidal-flat, Andros Island, Bahamas: Journal of Sedimentary Petrology, v. 39, p. 1202-1228.
- U.S. Environmental Protection Agency, 1971, Methods for chemical analysis of water and wastes: Cincinnati, U.S. Environmental Protection Agency, Water Quality Office, Analytical Control Laboratory, p. 235-245.
- Votaw, R. B., 1972, Conodont biostratigraphy of the Black River Group (Middle Ordovician) and equivalent rocks of the eastern midcontinent, North America: Ohio State University, Ph.D. dissertation (unpublished), 170 p.
- Walker, K. R., 1973, Stratigraphy and environmental sedimentology of Middle Ordovician Black River Group in the type area—New York State: New York State Museum and Science Service Bulletin 419, 43 p.
- Young, L. M., Fiddler, L. C., and Jones, R. W., 1972, Carbonate facies in Ordovician of northern Arkansas: American Association of Petroleum Geologists Bulletin, v. 56, p. 68-80.

APPENDIXES

APPENDIX A.—SUMMARY OF WELL DATA

ABBREVIATIONS

<i>Elevation</i>		<i>Type of information</i>		<i>Depth</i>	
CM	cement marker	EL	electrical log	K	Knox Group
DF	derrick floor	IL	induction log	?	identification uncertain
G	ground level	IEL	induction-electrical log	x	unit absent because of nondeposition
KB	Kelly bushing	GRD	gamma ray-density		
SL	spirit level	GRN	gamma ray-neutron		
		LL	laterolog		

Permit no.	Township	Operator	Well no. and name	Elevation at well head (ft above sea level)	Type of information	Depth (ft) to top of				
						Black River Group (a marker)	Upper argillaceous unit	Carntown unit	Lower argillaceous unit	Wells Creek Formation
ADAMS CO.										
6	Monroe	Benz	1 Hughes	527 KB	GRN	848	1187	1250	1313	1355
7	Monroe	Cominco	CA-51 Hughes	532 G	Core	857	1191	1256	1318	1359
BROWN CO.										
5	Jackson	Cominco	CA-52 Rockey	990 G	Core	928	1249	1310	1375	1416
BUTLER CO.										
2	Wayne	Continental	1 Crist	990 KB	LL/GRN	992	1292	1342	1412	1440
4	Lemon	Armco	1 Armco	667 KB	GRN	667	975	1017	1087	1117
CHAMPAIGN CO.										
2	Goshen	Hodges	1 Ropp	1267 KB	GRN	1656	2008	2042	2094?	
3	Union	Kelly	1 Yocum	1227 KB	GRN	1627	1992	2037	2096	2116?
10	Concord	Southern Independent	1 Schultz	1133 DF	GRN	1438	1770	1820	1876	1898?
11	Salem	Southern Independent	1 McCandless	1072 DF	GRN	1398	1728	1783	1826?	1835?
12	Salem	Southern Independent	1 Detweiler	1069 DF	GRN	1393	1727	1784	1833?	
13	Johnson	Teeters	1 Vaughn	1126 DF	GRD	1437	1757	1810	1870?	
14	Salem	Tartan	2 McCandless	1076 DF	GRN	1394	1723	1774	1812?(K?)	
16	Union	Teeters	1 Perry	1239 DF	GRN	1634	1994	2040	2096	2118
17	Jackson	Teeters	1 Circle	1162 DF	GRN	1376	1698	1748	1808	1817
CLARK CO.										
2	Pleasant	Edmund <i>et al.</i>	1 Brown	1249 KB	IEL	1674	2035	2070	2130	2158
3	Harmony	Hodges	1 Elcamere Farms	1167 DF	GRN	1576	1936	1974	2026	2055
CLERMONT CO.										
3	Stonelick	Continental	1 Wikoff	817 KB	LL/GRN	704	1030	1090	1154	1184
5	Pierce	Earth Sci. Labs.	1 Callaway	681 DF	GRN	452	776	830	902	935
CLINTON CO.										
1	Wayne	Kewanee	1 Luttrell	1112 CM	GRN	1353	1703	1743	1805	1838
2	Wayne	Kewanee	1 Adams	1080 CM	EL	1260	1600	1645	1690?	
3	Wilson	Kewanee	1 Bock	1047 CM	LL	1293	1638	1685	1750	1780
4	Washington	Kewanee	1 Igo	1069 CM	IEL	1145	1480	1522	1596	1620
5	Wayne	Kewanee	1 Van Pelt	1092 KB	IL	1241	1570?	x	x	1630(K)
7	Wayne	Kewanee	1 McVey	1087 CM	IEL	1274	1610	1656	1725	1756

APPENDIX A.—SUMMARY OF WELL DATA—Continued

Permit no.	Township	Operator	Well no. and name	Elevation at well head (ft above sea level)	Type of information	Depth (ft) to top of				
						Black River Group (a marker)	Upper argillaceous unit	Carntown unit	Lower argillaceous unit	Wells Creek Formation
DARKE CO.										
64	Washington	An-Car	1 Martin	1077 DF	GRN	1238	1520	1562	1612	1632
FAYETTE CO.										
1	Union	Kewanee	1 Hopkins	965 CM	GRN	1435	1783	1820	1878?	
2	Concord	Kewanee	1 Wilson	1017 CM	GRN	1322	1654	1700	1750?	
3	Union	Kewanee	1 Cavinee	992 CM	GRN	1380	1723	1767	1825?	
4	Jasper	Kewanee	1 Barnes	1043 CM	GRN	1310	1650	1700	1755?	
7	Perry	Barnwell	1 Cockrill	1002 KB	IEL	1517	1850	1910	1970	2004
HAMILTON CO.										
1	Crosby	Continental	1 Brisbin	815 KB	LL/GRN	688	987	1041	1112	1133
HIGHLAND CO.										
1	Fairfield	Kewanee	1 Pavey	1043 KB	EL	1324	1658	1706	1750?	1783?
3	Paint	Ohio Valley	1 Peabodys	880 SL	GRN	1394	1750	1800	1872	1904
4	Penn	Amerada	1 Wright	1139 KB	GRN	1359	1700	1750	1820	1852
6	Fairfield	Cominco	CA-54 Swingley	1056 G	Core	1306	1632	x	x	1681(K)
MIAMI CO.										
1	Washington	Sun	1 Levering	994 DF	GRN	1210	1503	1547	1600?	
3	Lost Creek	National Assoc.	1 Walker	1035 KB	GRN	1265	1582	1635	1696	1714
8	Staunton	Pettit	1 Trojan Farms	801 SL	GRN	1037	1348	1401	1463	1486
9	Staunton	Pettit	1 Knoop	859 SL	GRN	1104	1418	1468	1530	1550
11	Brown	McHale	1 Roemisch	1138 DF	GRN	1435	1752	1804	1863	1883
SHELBY CO.										
12	Perry	Sun	1 Nelson	1050 DF	GRN	1364	1684	1727	1786?	
WARREN CO.										
7	Clear Creek	Continental	1 Sellars	927 KB	LL/GRN	955	1275	1320	1385	1415
8	Washington	Continental	1 Kittridge	945 KB	LL/GRN	1012	1340	1387	1455	1484
10	Clear Creek	Carter	1 Rainey-Whitaker	1048 KB	GRN	1120	1445	1494	1558	1584
INDIANA—RANDOLPH CO.										
	T18N, R14E	Continental	1 Johnting	1154 KB	LL/GRN	1178	1456	1497	1550	1570
INDIANA—UNION CO.										
	T11N, R1W	Continental	1 Sheets	1002 KB	GRN	950	1240	1286	1353	1384
KENTUCKY—BOONE CO.										
		Continental Earth Sci. Labs.	1 Snow 1 Bender	865 KB 461 DF	LL/GRN GRN	653 247	921 537	974 600	1030? 673	716
KENTUCKY—CAMPBELL CO.										
		Ashland	1 Wilson <i>et ux.</i>	758 KB	GRN	518	820	880	950	990

1060-1064	75.5	23.5	1.5	46.7	5.09	2.65	0.83	0.29	0.28	0.09	0.002	83.4	10.65	4.00	98.19
1065-1069	58.8	37.5	2.2	44.6	8.37	2.67	0.53	0.24	0.20	0.08	0.002	79.7	17.52	3.60	100.94
1070-1074	86.0	13.5	1.2	50.5	2.85	1.69	0.38	0.14	0.14	0.05	0.001	90.2	5.97	2.33	98.57
1075-1079	82.5	12.8	1.75	50.4	3.03	2.12	0.45	0.16	0.13	0.06	0.001	89.9	6.35	2.84	99.17
1080-1084	87.2	10.0	1.3	51.2	2.57	2.12	0.45	0.20	0.19	0.08	0.002	91.4	5.38	2.94	99.82
1085-1089	87.5	13.0	1.1	50.7	3.02	1.52	0.40	0.16	0.12	0.06	0.001	90.4	6.31	2.18	98.97
1090-1094	80.5	19.0	1.0	49.7	4.28	1.84	0.45	0.17	0.16	0.08	0.001	88.7	8.95	2.62	100.35
1095-1099	93.0	9.5	1.5	52.2	2.21	1.50	0.26	0.13	0.10	0.05	0.001	93.2	4.61	1.98	99.85
1100-1104	70.5	27.5	2.0	46.5	5.79	2.89	0.58	0.21	0.17	0.09	0.002	82.9	12.11	3.84	98.95
1105-1109	60.0	33.0	1.25	46.0	6.93	1.82	0.45	0.18	0.13	0.06	0.002	82.2	14.50	2.55	99.34
1110-1114	86.0	11.0	1.4	51.6	2.47	1.71	0.28	0.13	0.12	0.05	0.001	92.2	5.17	2.23	99.66
1115-1119	97.5	4.7	0.8	53.2	1.34	0.92	0.42	0.11	0.10	0.04	0.001	94.9	2.81	1.54	99.30
1120-1124	85.5	14.7	1.7	50.9	2.87	1.80	0.36	0.14	0.14	0.06	0.002	90.9	6.00	2.43	99.40
1125-1129	93.2	3.0	2.7	51.6	1.34	2.37	0.68	0.26	0.26	0.11	0.002	92.2	2.81	3.55	98.69
1130-1134	91.8	6.2	1.3	52.6	1.64	2.12	0.47	0.14	0.25	0.08	0.003	93.9	3.43	2.99	100.39
1135-1139	84.0	13.5	2.8	48.8	2.93	3.74	0.70	0.23	0.43	0.11	0.003	87.2	6.14	5.10	98.55
1140-1144	96.5	2.6	1.0	52.5	1.08	1.95	0.59	0.19	0.33	0.08	0.003	93.7	2.25	3.05	99.09
1145-1149	92.0	7.0	0.7	53.2	1.87	0.81	0.26	0.13	0.11	0.06	0.002	94.9	3.92	1.31	100.19
1150-1154	85.0	11.0	0.9	51.5	2.60	1.39	0.45	0.18	0.14	0.06	0.002	91.9	5.45	2.13	99.57
1155-1159	84.0	11.0	1.25	49.5	2.95	2.78	0.93	0.33	0.33	0.10	0.003	88.4	6.17	4.31	99.04
1160-1164	85.0	12.4	1.3	50.7	2.98	2.05	0.66	0.24	0.25	0.10	0.002	90.4	6.24	3.18	99.94
1165-1169	93.0	4.8	1.2	52.9	1.58	1.54	0.40	0.17	0.14	0.05	0.002	94.4	3.30	2.22	100.00
1170-1174	77.0	19.0	0.8	49.7	4.28	1.28	0.26	0.17	0.12	0.06	0.002	88.7	8.95	1.81	99.54
1175-1179	82.5	13.0	1.25	50.0	3.03	2.35	0.66	0.26	0.34	0.12	0.003	89.2	6.35	3.60	99.28
1180-1184	77.5	13.5	3.2	45.3	3.23	6.54	2.23	0.81	0.83	0.28	0.007	80.9	6.76	10.29	98.36
1185-1189	89.2	6.2	1.5	50.7	2.98	2.05	0.66	0.24	0.25	0.10	0.002	90.4	6.24	3.18	99.94
1190-1194	91.5	7.0	2.0	52.9	1.58	1.54	0.40	0.17	0.14	0.05	0.002	94.4	3.30	2.22	100.00
1195-1199	66.0	17.5	4.3	49.7	4.28	1.28	0.26	0.17	0.12	0.06	0.002	88.7	8.95	1.81	99.54
1200-1204	81.0	7.5	5.0	50.0	3.03	2.35	0.66	0.26	0.34	0.12	0.003	89.2	6.35	3.60	99.28
1205-1209	83.5	2.0	3.1	45.3	3.23	6.54	2.23	0.81	0.83	0.28	0.007	80.9	6.76	10.29	98.36
1210-1214	92.0	2.6	2.2	50.7	2.98	2.05	0.66	0.24	0.25	0.10	0.002	90.4	6.24	3.18	99.94
1215-1219	90.7	4.3	1.0	52.9	1.58	1.54	0.40	0.17	0.14	0.05	0.002	94.4	3.30	2.22	100.00
1220-1224	86.7	10.0	1.0	49.7	4.28	1.28	0.26	0.17	0.12	0.06	0.002	88.7	8.95	1.81	99.54
1225-1229	87.5	3.0	1.6	50.0	3.03	2.35	0.66	0.26	0.34	0.12	0.003	89.2	6.35	3.60	99.28
1230-1234	82.0	11.5	2.0	45.3	3.23	6.54	2.23	0.81	0.83	0.28	0.007	80.9	6.76	10.29	98.36
1235-1239	81.0	11.5	0.8	50.7	2.98	2.05	0.66	0.24	0.25	0.10	0.002	90.4	6.24	3.18	99.94
1240-1245	87.0	6.2	1.4	52.9	1.58	1.54	0.40	0.17	0.14	0.05	0.002	94.4	3.30	2.22	100.00
1246-1251	87.2	4.5	2.5	49.7	4.28	1.28	0.26	0.17	0.12	0.06	0.002	88.7	8.95	1.81	99.54
1252-1256	93.7	3.0	1.6	50.0	3.03	2.35	0.66	0.26	0.34	0.12	0.003	89.2	6.35	3.60	99.28
1257-1261	93.7	4.5	0.5	52.6	1.81	1.42	0.42	0.18	0.24	0.08	0.004	89.8	3.33	6.09	99.47
1262-1266	88.0	10.0	0.3	51.6	2.27	1.16	0.47	0.21	0.17	0.09	0.002	92.2	4.75	2.02	99.12
1267-1271	84.2	11.0	0.5	51.8	2.70	1.21	0.32	0.15	0.17	0.06	0.002	92.4	5.65	1.86	100.03
1272-1276	79.3	19.4	0.6	50.2	4.48	0.88	0.32	0.19	0.08	0.04	0.002	89.7	9.36	1.45	100.64
1277-1281	77.5	21.4	0.6	49.1	4.87	1.01	0.26	0.17	0.11	0.06	0.001	87.7	10.20	1.51	99.53
1282-1286	73.5	26.0	0.2	48.4	5.75	0.75	0.21	0.14	0.10	0.04	0.001	86.4	12.04	1.22	99.76
1287-1291	89.2	12.5	0.2	51.4	3.25	1.28	0.38	0.20	0.20	0.09	0.001	91.7	6.80	2.07	100.72
1292-1296	90.5	11.0	0.5	52.0	2.62	0.72	0.23	0.17	0.11	0.10	0.002	92.9	5.48	1.27	99.77
1297-1301	94.8	9.0	0.5	51.4	2.30	1.20	0.26	0.16	0.10	0.10	0.002	91.7	4.82	1.75	98.38
1302-1306	79.0	21.3	0.6	48.4	4.83	1.48	0.34	0.26	0.18	0.12	0.002	86.4	10.09	2.27	98.92
1307-1311	93.7	2.0	0.3	53.7	1.23	0.43	0.11	0.10	0.06	0.07	0.002	95.9	2.57	0.74	99.30
1312-1317	87.5	14.0	0.6	49.4	3.52	1.26	0.43	0.31	0.17	0.12	0.002	88.2	7.35	2.16	97.91
1318-1322	76.5	16.0	1.8	46.2	3.73	5.74	1.46	0.47	0.99	0.23	0.004	82.4	7.80	8.71	99.19

1.9

5.5

1.6

9.2

BLACK RIVER GROUP (MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO

APPENDIX B.—CHEMICAL AND X-RAY ANALYSIS DATA—Continued

Sample number	Sample interval (ft)	X-ray analysis			Chemical analysis										Calculations from chemical analyses				Insoluble residue (HCl)	
		Calcite (%)	Dolomite (%)	Quartz (%)	CaO (%)	MgO (%)	SiO ₂ (%)	Al ₂ O ₃ (%)	Fe ₂ O ₃ (%)	K ₂ O (%)	Na ₂ O (%)	SrO (%)	MnO (ppm)	S (%)	P (%)	CaCO ₃ (%)	MgCO ₃ (%)	Insoluble ¹ oxides (%)		Total ² (%)
FAYETTE CO., CONCORD TWP.																				
S-751	1698-1700	82.0	8.5	1.7																7.1
	1700-1702	89.3	5.5	1.5																5.6
	1702-1704	91.5	2.7	2.1																5.4
	1704-1706	91.5	3.7	1.0																1.2
	1706-1708	92.0	5.0	0.75																2.6
	1708-1710	93.0	2.5	0.75																3.3
	1710-1712	95.3	2.0	0.4																1.1
	1712-1714	89.3	5.3	0.75																3.6
1714-1716	90.1	7.8	0.5																1.7	
1716-1718	88.0	10.0	1.7																1.5	
1718-1720	91.5	5.6	0.6																2.1	
1720-1722	94.3	5.7	0.7																1.4	
1722-1724	87.6	6.7	0.7																5.5	
GREENE CO., SPRING VALLEY TWP.																				
S-290	1438-1443	85.3	4.2	1.4																
	1443-1448	87.5	9.3	1.25																
	1448-1453	89.2	6.0	1.5																
	1453-1458	90.2	6.2	1.3																
	1458-1463	94.3	2.0	0.8																
	1463-1468	90.5	5.2	0.6																
	1468-1473	90.5	8.5	0.5																
	1473-1478	92.0	8.2	0.8																
	1478-1483	72.7	23.5	0.4																
	1483-1488	93.2	7.0	0.8																
	1488-1493	76.9	23.0	0.25																
	1493-1498	47.8	47.8	0.7																
	1498-1503	27.2	72.6	0.1																
1503-1508	34.0	63.0	0.5																	
1508-1513	71.0	25.0	0.5																	
1513-1518	65.5	15.0	3.0																	
1518-1523	43.0	33.8	5.1																	
1523-1528	8.5	75.8	4.6																	

¹SiO₂ + Al₂O₃ + (½ · Fe₂O₃) + K₂O + Na₂O + S + P.
²CaCO₃ + MgCO₃ + insoluble oxides + (½ · Fe₂O₃) + SrO + MnO.

APPENDIX C.—CHEMICAL ANALYSIS AVERAGES FOR HIGH-CARBONATE ZONES¹

Sample number	Sample interval (ft)	Chemical analysis											Calculations from chemical analyses			
		CaO (%)	MgO (%)	SiO ₂ (%)	Al ₂ O ₃ (%)	Fe ₂ O ₃ (%)	K ₂ O (%)	Na ₂ O (%)	SrO (%)	MnO (ppm)	S (%)	P (%)	CaCO ₃ (%)	MgCO ₃ (%)	Insoluble ² oxides (%)	
ADAMS CO., MONROE TWP.																
S-2405	960-1009	48.2	4.85	2.21	0.50	0.26	0.25									
	1065-1134	50.1	3.48	1.94	0.44	0.17	0.16					0.08	0.003	86.0	10.14	3.17
	1140-1179	51.2	2.55	1.77	0.53	0.21	0.22					0.07	0.002	89.5	7.28	2.69
	1257-1317	50.8	3.30	1.07	0.31	0.19	0.14	0.023	0.032	50		0.08	0.002	91.4	5.33	2.70
												0.08	0.002	90.8	6.91	1.72
BROWN CO., JACKSON TWP.																
S-2507	1035-1054	49.5	3.62	2.15	0.48	0.23	0.20					0.09	0.003	88.4	7.59	3.04
	1090-1109	51.3	2.33	1.91	0.47	0.28	0.17	0.031	0.036	64	0.08	0.002	91.5	4.88	2.80	
	1140-1174	49.8	3.61	1.80	0.33	0.19	0.10	0.038	0.033	64	0.06	0.001	89.0	7.54	2.41	
	1200-1234	52.2	1.88	1.45	0.40	0.17	0.15	0.027	0.034	74	0.07	0.002	93.1	3.94	2.18	
	1310-1374	50.0	3.64	1.17	0.31	0.18	0.12		0.035	48	0.06	0.002	89.2	7.61	1.76	

¹Only analyses for zones greater than 15 feet thick were averaged.

²SiO₂ + Al₂O₃ + (½ · Fe₂O₃) + K₂O + Na₂O + S + P.

APPENDIX D.—DESCRIPTIONS OF ADAMS COUNTY AND BROWN COUNTY CORES

Adams County Monroe Township Manchester Islands quadrangle		Property Owner: Noah Hughes Cominco American Inc. CA 51 Permit No. 7 Sample No. 2405 Elevation (G) 531.7 feet	897'1"	903'9"	est 4 inches. Chert nodules, white, 1½ inches long; at 892 feet and 893 feet 2 inches
	<i>Depth</i>				
840'0"	856'0"	Limestone, light- to medium-gray, fine- to coarse-grained, fossiliferous; some carbonaceous partings; some 1- to 2-inch black shaly zones. Chert, red-stained, argillaceous, shaly; 1½ inches at 847 feet			Limestone, light- to dark-gray; minor amount light-brownish-gray; micrite and biopelsparite; argillaceous in part; laminations and nodular interbeds of fine-grained argillaceous dark-gray dolomitic limestone; minor number horizontal burrows filled with argillaceous dark dolomite
BLACK RIVER GROUP					
856'0"	856'10"	Limestone, medium-brown and medium-brownish-gray; biopelsparite and intrasparite			Limestone, light-brownish-gray, light- to medium-gray, and light- to medium-greenish-gray; mottled and laminated dark-gray and dark-greenish-gray; laminated micrite and very argillaceous limestone; minor amount pelsparite; numerous planar birdseyes; numerous bubblelike birdseyes; sparse vertical burrows, some filled with sparry calcite, some filled with light-green biosparite. Marker bed Δ
856'10"	857'5½"	Shale, green and greenish-gray, bentonitic, fissile, exfoliated; abundant biotite (up to 2 mm in diameter). Marker bed α			
857'5½"	864'6"	Limestone, light- to medium-brown; biomicrite, biointrasparite, and micrite; abundant <i>Tetradium</i> ; moderate number randomly oriented sparry-calcite-filled cracks (shrinkage?) in featureless micrite; numerous nodular carbonaceous partings	910'6"	916'8"	Limestone as in sample from 897 feet 1 inch to 903 feet 9 inches, but dolomitic limestone dark gray and medium to dark greenish gray
864'6"	875'6"	Limestone, light- to medium-gray and light-brownish-gray; mottled dark-gray and light-greenish-gray in places; bioturbated argillaceous biomicrite and biopelsparite (corals, bryozoans, gastropods); some burrows filled with spar, others filled with coarse-grained argillaceous green limestone	916'8"	920'1"	Limestone as in sample from 903 feet 9 inches to 910 feet 6 inches; mudcrack from 917 feet 7 inches to 917 feet 8 inches; lowermost 5 inches predominantly laminated shaly medium- to dark-greenish-gray limestone
875'6"	876'0"	Shale, light-greenish-gray, bentonitic; sparse to moderate amount biotite (up to 1 mm in diameter). Marker bed β			Limestone, light- to medium-gray and light- to medium-brownish-gray; laminated micrite; numerous planar birdseyes; sparse to numerous layers and partings of fine-grained laminated medium- to dark-brown dolomitic limestone; minor number sparry-calcite-filled burrows; intrasparite in lowermost 6 inches
876'0"	881'2"	Limestone, light- to medium-gray and light- to medium-brownish-gray; biopelsparite; sparse micrite and biomicrite; <i>Tetradium</i> , ostracods, bryozoans, gastropods; sparse carbonaceous partings	928'6"	932'4"	Shale, greenish-gray. Limestone, greenish-gray, shaly, laminated, dense to fine-grained; burrowed in part; sparse planar birdseyes
881'2"	888'1"	Limestone, light-gray, light- to medium-brownish-gray; mottled medium-gray in part; laminated micrite; numerous planar birdseyes; sparse carbonaceous partings. Shale, green, bentonitic (biotite <1 mm in diameter); 1 inch at 882 feet 2 inches	932'4"	936'3"	Limestone, light-gray and light-brownish-gray; interbedded laminated micrite, pelsparite, and intrasparite; sparry-calcite-filled burrows; numerous planar birdseyes in micrite
888'1"	890'11"	Limestone, light- to medium-gray; laminated argillaceous biomicrite with minor amount pelsparite; sparse to moderate number carbonaceous and shaly medium- to dark-gray limestone partings and laminations; moderate number small planar birdseyes; numerous bubblelike birdseyes	936'3"	936'10"	Limestone, argillaceous, shaly; contorted bedding; burrowed; 3 inches. Shale, greenish-gray, bentonitic (biotite <1 mm in diameter); 4 inches. Marker bed α
890'11"	891'4"	Limestone as above; abundant carbonaceous and shaly laminations; 2½ inches. Shale, greenish-gray, bentonitic (biotite <1 mm in diameter); 2½ inches. Marker bed γ	936'10"	948'8"	Limestone, light- to medium-gray and light- to medium-brownish-gray; laminated micrite; minor amount pelsparite and intrasparite; sparse to numerous planar and nonplanar birdseyes; sparse to numerous vertical shrinkage cracks; sparse to numerous partings and laminations of fine-grained medium-gray dolomitic limestone
891'4"	897'1"	Limestone, light-brownish-gray and light-gray; mottled medium-gray in part; laminated micrite; interbedded medium- to dark-brown and medium-gray dolomite and laminated dolomitic micrite. Clay, green, disseminated; in low-	948'8"	954'2"	Limestone, light- to medium-gray; mottled dark-gray in part; laminated micrite; numerous argillaceous dark-gray and dark-greenish-gray dolomitic limestone laminations and partings; spar- and pellet-filled vertical burrows (concentrated from 949 feet 10 inches to

		950 feet 3 inches) deforming color laminations in micrite and dolomitic limestone			medium-gray and medium-brown dolomitic limestone; sparse to numerous dark-gray carbonaceous partings; mainly interbedded micrite and dolomite with numerous horizontal burrows from 1019 feet 6 inches to 1020 feet 6 inches; mainly laminated micrite with planar birdseyes from 1020 feet 6 inches to 1021 feet 6 inches; mainly intrasparite and biomicrite interbedded and burrowed with dolomitic limestone from 1021 feet 6 inches to 1026 feet 5 inches		
954'2"	954'9"	Limestone, fine- to medium-grained, argillaceous; interbedded minor amount dark-green bentonitic shale (biotite <1 mm in diameter); beds of ¼, ½, and 1 inch. Marker bed b					
954'9"	959'0"	Limestone, light- to medium-brownish-gray; sparse dark-gray mottling; laminated micrite; sparse planar birdseyes; moderate number to numerous laminations and interbeds of fine-grained laminated medium- to dark-brown dolomitic limestone; mudcracks	1026'5"	1033'2"	Limestone, medium- to dark-gray and medium-brownish-gray, argillaceous; mottled dark-gray in part; micrite and biomicrite; numerous interbeds and horizontal burrows of fine-grained dark-gray and dark-brown dolomitic limestone; sparse dark-gray carbonaceous partings. Marker bed 1		
959'0"	967'0"	Limestone, light-gray and light- to medium-brownish-gray; sparse to abundant dark-gray mottling; micrite; sparse faint laminations; sparse planar birdseyes; sparse laminations of fine-grained brown dolomitic limestone; cross-bedded in part; sparse horizontal partings of carbonaceous limestone; mud-cracked in part	1033'2"	1035'0"	Limestone, medium- to dark-brown; biomicrite and micrite; numerous sparry-calcite-filled <i>Tetradium</i> tubes		
967'0"	968'0"	Limestone, light-gray; micrite and pelsparite; sparse burrows filled with argillaceous green dolomitic limestone	1035'0"	1036'4"	Limestone, light- to medium-gray, medium-brown; mottled dark-gray in part; biomicrite and micrite; sparry-calcite-filled <i>Tetradium</i> ; sparse irregular beds of fine-grained brown dolomitic limestone		
968'0"	977'6"	Limestone, light- to medium-brownish-gray; mottled dark-gray in part; biomicrite and <i>Tetradium</i> biopelsparite; sparse to numerous interbeds and horizontal burrows of fine-grained medium- to dark-brown dolomitic limestone; biopelsparite concentrated in beds with biomicrite, cut by burrows and interbeds in other beds	1036'4"	1064'7"	Limestone, light- to medium-gray and medium-brown; mottled dark-gray in part; micrite and biomicrite; minor amount pelsparite; numerous horizontal burrows and minor number interbeds of fine-grained medium- to dark-brownish-gray dolomitic limestone		
977'6"	995'0"	Limestone, light-gray; sparse dark-gray mottling; laminated dolomitic micrite with minor amount micrite and biopelsparite; sparse planar birdseyes in micrite; increasingly dolomitic in lowermost 9 inches. Top of Oregon Formation correlative	1064'7"	1072'5"	Limestone, light-tan and light-gray; micrite, pelsparite, and biopelsparite; minor number dolomite rhombs; numerous horizontal burrows and interbeds of sucrosic fine-grained light- to medium-gray dolomitic limestone		
995'0"	1005'2"	Limestone, light- to medium-brownish-gray; mottled dark-gray; biopelsparite, biomicrite, and micrite; interbedded laminated medium- to dark-brown dolomitic limestone; minor number horizontal burrows filled with dolomitic limestone; scarce planar birdseyes in micrite. Interlaminated dolomite and micrite with desiccation features mainly in upper and lower one-third; biomicrite, biopelsparite, and horizontal burrows mainly in middle one-third	1072'5"	1076'6"	Limestone as in sample from 1036 feet 4 inches to 1064 feet 7 inches		
					1076'6"	1080'8"	Limestone as in sample from 1064 feet 7 inches to 1072 feet 5 inches
					1080'8"	1083'3"	Limestone as in sample from 1036 feet 4 inches to 1064 feet 7 inches
					1083'3"	1091'10"	Limestone as in sample from 1064 feet 7 inches to 1072 feet 5 inches, but light to medium brownish gray
					1091'10"	1100'4"	Limestone as above; intrasparite in part
					1100'4"	1102'0"	Limestone, medium-brownish-gray; micrite and pelsparite; interbedded fine-grained dark-gray dolomitic limestone
1005'2"	1006'8"	Limestone, light-gray, sparsely burrowed; diffuse dark-gray mottling; micrite and biomicrite (<i>Tetradium</i>); fossils and burrows filled with sparry calcite	1102'0"	1107'0"	Limestone, medium-gray and medium-brownish-gray, dolomitic, fine-grained, sucrosic, laminated; 2-inch bed of pelsparite at base		
1006'8"	1008'3"	Limestone, medium-brown; biomicrite and biopelsparite; sparry-calcite-filled <i>Tetradium</i> ; moderate number irregular layers of fine-grained medium-brown dolomitic limestone	1107'0"	1113'7"	Limestone as in sample from 1064 feet 7 inches to 1072 feet 5 inches; 4-inch bed of pelsparite at base		
1008'3"	1015'6"	Limestone, light- to medium-brownish-gray; mottled dark-gray; biopelsparite, biomicrite, and micrite; numerous interbeds and horizontal burrows of fine-grained light- to medium-brownish-gray dolomitic limestone; dolomitic limestone predominant in lower half	1113'7"	1115'7"	Limestone, light-gray and light-brownish-gray; micrite; numerous sparry-calcite-replaced <i>Tetradium</i>		
					1115'7"	1121'6"	Limestone, light-gray and light- to medium-brown; micrite, pelsparite, and biopelsparite; featureless except for minor number sparry-calcite-filled vertical shrinkage cracks; minor number interbeds and sparse burrows of partially dolomitized medium- to dark-brown limestone
1015'6"	1019'6"	Limestone, light-gray and light-brownish-gray, dolomitic, fine-grained, laminated; minor amount of laminated micrite. Base of Oregon Formation correlative	1121'6"	1123'1"	Limestone, light-gray and light-brownish-gray, dolomitic; minor amount micrite and intrasparite; sparse planar birdseyes in micrite; dolomite faintly laminated		
1019'6"	1026'5"	Limestone, medium-brownish-gray and light- to medium-gray; mottled dark-gray in part; laminated micrite, biomicrite, intrasparite, and biopelsparite; interbeds and burrows of fine-grained	1123'1"	1124'0"	Limestone, light-gray and light-brownish-gray; biomicrite; minor amount biopel-		

1124'0"	1129'7"	sparite; numerous <i>Tetradium</i> Limestone, medium- to dark-brownish-gray; biopelsparite, biointrasparite, and micrite; sparse to numerous interbeds and horizontal burrows of fine-grained light- to dark-gray dolomitic limestone. Top of marker bed II	1175'8"	1188'4"	pelsparite, biomicrite, and micrite; sparsely dolomitized; interbeds and horizontal burrows of fine-grained light- to dark-brownish-gray dolomitic limestone
1129'7"	1131'5½"	Limestone, light-gray; diffuse dark-gray mottling; biomicrite, micrite, and biopelsparite; horizontally laminated micrite; faint horizontal laminations in biopelsparite; scarce dolomite zones			Limestone, medium- to dark-brownish-gray and medium- to dark-gray; biopelsparite, pelsparite, and micrite; sparsely dolomitized in part; pelsparite faintly laminated in part; numerous nodular partings, regular interbeds, and horizontal burrow fillings of fine-grained medium- to dark-brownish-gray and medium- to dark-gray dolomitic limestone. Several ¼- to ½-inch zones of shaly carbonaceous dark-gray to black limestone from 1180 feet 7 inches to 1182 feet 1 inch
1131'5½"	1143'4"	Limestone, light- to medium-gray and light- to dark-brownish-gray; biopelsparite (argillaceous in part) and biomicrite; minor amount micrite; sparse to numerous interbeds and sparse horizontal burrows of fine-grained argillaceous medium- to dark-brownish-gray dolomitic limestone; several ¼- to ½-inch zones of shaly dark-gray limestone. Base of marker bed II	1188'4"	1190'9"	Limestone, medium-brown; mottled dark-gray; biopelsparite, pelsparite, and biomicrite; sparse to moderate number horizontal burrows and thin irregular partings of fine-grained carbonaceous dark-gray and dark-brownish-gray dolomitic limestone
1143'4"	1148'0"	Limestone, light-tan, light-gray, and light-brownish-gray; minor amount dark-gray mottling; ostracod biomicrite and micrite; slightly dolomitized in part; sparse horizontal and moderate number vertical sparry-calcite-filled and pelsparite-filled burrows; sparse thin interbeds of fine-grained light- to medium-brownish-gray dolomitic limestone	1190'9"	1197'11"	Limestone, medium- to dark-brownish-gray and medium- to dark-gray; pelsparite (crossbedded in part), biomicrite, and micrite; irregular to nodular partings and interbeds of shaly dark-gray to black limestone and fine-grained dolomitic limestone; gradational with limestone below. Top of upper argillaceous unit
1148'0"	1152'11"	Limestone, light-tan and light-brownish-gray; micrite, pelsparite, and biopelsparite; moderate number interbeds and horizontal burrows of fine-grained medium-brown dolomitic limestone	1197'11"	1211'4"	Limestone, medium- to dark-gray and medium-brownish-gray; biomicrite and fossiliferous intrasparite; interbedded with and grading into very argillaceous fine- to medium-grained limestone; laminated in part (color, argillaceous laminae, fossil-hash alignment); mainly laminations and irregular partings of shaly black limestone from 1198 feet 9½ inches to 1199 feet 7½ inches
1152'11"	1158'5"	Limestone, medium-gray and medium-brownish-gray; biopelsparite and biomicrite; numerous irregular partings and horizontal burrows of fine-grained light- to dark-gray dolomitic limestone. Zone of medium-grained medium- to dark-gray limestone and bentonitic black and dark-greenish-gray shale; biotite up to 2 mm in diameter sparse in limestone, abundant in shale; 5½ inches at 1156 feet 7 inches	1211'4"	1217'0"	Limestone, medium-brown and medium-brownish-gray; biomicrite and micrite; <i>Tetradium</i> ; sparry-calcite-filled fossils; minor number sparry-calcite-filled burrows; sparse faint laminations and planar birdseyes; sparse wavy to nodular interbeds and partings of fine-grained dark-brown and dark-brownish-gray dolomitic limestone; sparse irregular partings of shaly dark-brownish-gray limestone; moderate number shrinkage cracks in micrite adjacent to fine-grained interbeds
1158'5"	1161'4"	Limestone, light-tan and light-gray; micrite and pelsparite; sparsely fossiliferous (<i>Tetradium</i> , ostracods, gastropods, bryozoans); sparry-calcite-replaced fossils; minor number thin interbeds and horizontal burrows of fine-grained light- to medium-brownish-gray dolomitic limestone; sparse dolomite rhombs in micrite	1217'0"	1219'8"	Limestone, light-gray to white; micrite; sparse to moderate number dolomite rhombs; sparse to moderate number ostracods; faint lamination (color, grain size, and dolomite layers); sparse birdseyes
1161'4"	1164'9"	Limestone, medium-gray and medium-brownish-gray; biopelsparite, intrapelsparite, and biomicrite; numerous irregular to nodular partings of fine-grained light- to dark-gray dolomitic limestone	1219'8"	1222'4"	Limestone, medium- to dark-brownish-gray; interbedded micrite/biomicrite, biopelsparite/biopelmicrite, and intrasparite; faint lamination in some micrite and finer grained pelsparite; sparse to numerous nodular layers of fine-grained dark-brown dolomitic limestone, primarily in lowermost 6 inches
1164'9"	1166'9"	Limestone, light- to medium-brownish-gray; biomicrite and biopelsparite; numerous horizontal burrows filled with biopelsparite; minor number burrows filled with fine-grained light- to dark-gray dolomitic limestone	1222'4"	1223'8"	Limestone, light- to medium-gray; mottled dark-gray in part; ostracod biomicrite; pelletal in part; interbedded pelletal to fine-grained laminated dolomite; pelletal areas in biomicrite vaguely burrowed and churned
1166'9"	1169'2"	Limestone, light- to medium-brownish-gray; biomicrite and biointrasparite; numerous <i>Tetradium</i> fragments (some in growth position?)	1223'8"	1224'6"	Limestone, medium-brownish-gray; micrite and pelsparite; minor amount large-scale churning (burrowing?); faint laminations in pelsparite at top; minor number regular ¼-inch beds of fine-grained dark-brownish-gray dolomitic limestone
1169'2"	1170'8"	Limestone, light- to medium-brownish-gray; micrite and pelsparite; minor amount large-scale churning (burrowing?); faint laminations in pelsparite at top; minor number regular ¼-inch beds of fine-grained dark-brownish-gray dolomitic limestone			Limestone, light-tan and light-gray; bio-
1170'8"	1175'8"	Limestone, light-tan and light-gray; bio-			

1224*6"	1226*4"	medium- to dark-brownish-gray dolomitic limestone Limestone, light- to medium-gray; ostracod biomicrite; large churned areas and burrows filled with biopelsparite; sparse burrows filled with light-green argillaceous material; 2-inch bed of laminated biopelsparite (horizontal geopetal structures) from 1225 feet 2 inches to 1225 feet 3 inches			pelsparite in micrite; moderate number to numerous sparry-calcite-filled vertical burrows; moderate number irregular beds and partings of fine-grained dark-gray and dark-brownish-gray dolomitic limestone; sparse shaly dark-gray limestone partings; micrite with vertical burrows concentrated toward top; pelsparite and biomicrite concentrated toward base. Top of Carntown unit
1226*4"	1227*5"	Limestone, medium- to dark-gray, churned and burrowed; biomicrite and biopelmicrite; several channellike partings of black shale; 1-inch bed of calcareous fossiliferous dark-greenish-gray shale at base (no visible biotite)	1263*7"	1270*7"	Limestone, light- to medium-brownish-gray and medium-gray; biomicrite, biopelsparite, and micrite; numerous irregular partings and horizontal burrow fillings of fine-grained light- to medium-brownish-gray dolomitic limestone
1227*5"	1229*1"	Limestone, light-gray; minor amount dark-gray mottling; ostracod biomicrite; churned and burrowed to pelsparite	1270*7"	1283*8"	Limestone, light-tan; biomicrite, biopelsparite, and fossiliferous intrasparite; slightly dolomitized in part; numerous irregular partings and horizontal burrows of fine-grained light- to medium-brownish-gray dolomitic limestone
1229*1"	1234*½"	Limestone, medium-grayish-brown and medium-brown; diffuse dark-gray mottling; laminated micrite; sparse to moderate number planar birdseyes; numerous laminations of fine-grained medium- to dark-brown dolomitic limestone	1283*8"	1293*3"	Limestone, light- to medium-brownish-gray and light- to medium-gray; biomicrite and micrite; numerous irregular partings and horizontal burrow fillings of fine-grained medium- to dark-brownish-gray dolomitic limestone
1234*½"	1237*5"	Limestone, medium- to dark-gray and medium- to dark-brownish-gray, dolomitic, fine-grained, argillaceous; interbedded biopelsparite; minor amount micrite; bedding laminated and nodular/brecciated	1293*3"	1295*11"	Limestone, light-gray; sparse diffuse dark-gray mottling; faintly laminated micrite; sparse to moderate number small planar birdseyes
1237*5"	1240*8"	Limestone, light-gray and light-brownish-gray; laminated micrite; moderate number planar birdseyes; sparse laminations of fine-grained medium- to dark-brownish-gray dolomitic limestone	1295*11"	1297*6"	Limestone, medium-brown; laminated micrite; moderate number planar birdseyes; numerous laminations of fine-grained dark-brown dolomitic limestone; featureless micrite in lowermost 3 inches
1240*8"	1241*9"	Limestone, medium-gray and medium-greenish-gray; micrite; faint color laminations in part; laminated with fine-grained medium- to dark-gray dolomitic limestone; sparse vertical burrows in micrite	1297*6"	1309*8"	Limestone, light-gray; sparse diffuse dark-gray mottling; micrite; faintly laminated to laminated; minor amount featureless; sparse to numerous planar birdseyes; sparse nonplanar birdseyes; slightly dolomitic in part; sparse laminations of fine-grained medium-brown dolomitic limestone. Dolomite, medium-brownish-gray, laminated; 2 inches at 1299 feet 7½ inches. Dolomite, medium-brownish-gray, laminated; 1 inch at 1304 feet. Limestone, medium-gray, dolomitic, dense to fine-grained; laminated dark-gray; from 1305 feet 6 inches to 1306 feet 3 inches
1241*9"	1244*2"	Limestone, light- to medium-gray; ostracod biomicrite and biopelsparite; fossiliferous churned intrasparite; moderate number wavy laminations of fine-grained argillaceous dark-gray dolomitic limestone; minor amount light-green argillaceous material			
1244*2"	1244*11½"	Limestone, medium- to dark-gray; micrite. Limestone, dark-brownish-gray, very argillaceous, dolomitic; nodular bedding			
1244*11½"	1245*10"	Limestone, medium-brownish-gray; micrite and pelsparite; prominent 3-inch-high mudcrack; interbedded argillaceous dark-gray dolomitic limestone; nodular bedding	1309*8"	1318*0"	Limestone, light- to medium-brown and medium-brownish-gray; dark brown in lowest 6 inches; biomicrite and micrite; <i>Tetradium</i> ; micrite slightly dolomitic in part; sparse to moderate number irregular partings and horizontal burrow fillings of fine-grained medium- to dark-brownish-gray dolomitic limestone. Base of Carntown unit
1245*10"	1247*10"	Limestone, medium-gray and medium-brownish-gray; laminated micrite; numerous planar birdseyes; laminated with fine-grained dark-brown and dark-brownish-gray dolomitic limestone	1318*0"	1336*0"	Limestone, medium- to dark-brownish-gray and medium- to dark-gray, fine- to medium-grained; mottled dark-gray and greenish-gray; argillaceous in part; burrowed in part; interbedded minor amount partially laminated light- to dark-brownish-gray micrite, biomicrite (<i>Tetradium</i>), and pelsparite; burrowed in part; argillaceous in part; laminations of dark-brown and dark-gray dolomite. Top of lower argillaceous unit
1247*10"	1249*3"	Limestone, light-gray; diffuse dark-gray mottling; micrite; fossiliferous in part; churned to pelsparite in part; moderate number sparry-calcite-filled vertical burrows			
1249*3"	1256*5"	Limestone, light-gray and light-greenish-gray; light-brownish-gray toward base; micrite; laminated in part; numerous planar and nonplanar birdseyes; moderate number paper-thin to ¾-inch regular beds of shaly dark-greenish-gray and dark-brown limestone. Base of upper argillaceous unit	1336*0"	1337*2"	Limestone, medium-brown; laminated micrite; numerous planar and nonplanar birdseyes (nonplanar birdseyes grading into pelsparite at base); moderate number laminations of fine-grained medium- to dark-brown dolomitic limestone
1256*5"	1263*7"	Limestone, medium-gray and medium-brownish-gray; micrite and biomicrite; minor amount pelsparite; <i>Tetradium</i> fragments; sparse burrowlike areas of	1337*2"	1338*3"	Limestone, medium-brown; micrite; mod-

		erate number sparry-calcite-filled vertical cracks or burrows; minor number laminations of fine-grained dark-brown dolomitic limestone	930'0"	937'0"	coarse biotite flakes (up to 1 mm diameter). Chert; 3 inches at base. Marker bed α
1338'3"	1339'0"	Limestone, light-gray; micrite; moderate number sparry-calcite-filled vertical and horizontal burrows			Limestone, light- to medium-brown, bioturbated; <i>Tetradium</i> biomicrite, biopelsparite, and micrite; sparry-calcite-filled vertical shrinkage cracks in micrite; nodular bedding; sparse to numerous carbonaceous partings; some irregular 1/2-inch-thick chert nodules
1339'0"	1342'5"	Limestone, light-gray and light- to medium-brownish-gray; micrite; sparse sparry-calcite-filled vertical burrows; sparse 1/4- to 1/2-inch zones of fine-grained medium- to dark-brown dolomitic limestone	937'0"	947'3"	Limestone, light-gray and light- to medium-brownish-gray, argillaceous, bioturbated; mottled medium- to dark-brownish-gray and greenish-gray; biomicrite; minor amount micrite and biopelsparite; nodular bedded; numerous 1/16- to 1/8-inch irregular beds of dark-gray and dark-greenish-gray shale; burrow fillings of light-green argillaceous material
1342'5"	1342'9"	Limestone, medium- to dark-brownish-gray and medium- to dark-greenish-gray, dense to fine-grained, burrowed; argillaceous in part; nodular bedding			Shale, light-greenish-gray to dark-gray, bentonitic. Marker bed β
1342'9"	1346'5"	Limestone, light- to medium-brownish-gray and medium-brown; mottled dark-gray in part; laminated micrite; minor amount featureless micrite; moderate number planar and nonplanar birdseyes; sparse to moderate number laminations of fine-grained dolomitic limestone; grading into limestone below	947'3"	948'3"	Limestone, light- to medium-brown, burrowed; micrite, biomicrite, and intrasparite; burrows filled with fine- to medium-grained argillaceous dolomitic limestone; silicified in upper half
1346'5"	1347'5"	Limestone, medium-gray and dark-greenish-gray, shaly, fine- to medium-grained	948'3"	949'0"	Limestone, light- to medium-brown, burrowed; micrite, biomicrite, and intrasparite; burrows filled with fine- to medium-grained argillaceous dolomitic limestone; silicified in upper half
1347'5"	1349'5"	Limestone; grading from light gray at top to medium brown at base; laminated micrite; sparse to numerous planar and nonplanar birdseyes (particularly in upper part); sparse to numerous laminations of fine-grained dark-brown dolomitic limestone (particularly in lower part)	949'0"	951'6"	Limestone, white to light-gray, faintly laminated; minor amount medium-gray mottling; micrite; sparse planar and nonplanar birdseyes; numerous sparry-calcite-filled horizontal and vertical burrows; minor number burrows filled with very fine-grained white limestone. Chert nodule; 4 inches at 950 feet
1349'5"	1353'0"	Limestone as in sample from 1346 feet 5 inches to 1347 feet 5 inches; some dark gray	951'6"	953'11"	Limestone, medium-brownish-gray, stylonitic; micrite and <i>Tetradium</i> biomicrite; minor number burrows filled with fine-grained medium- to dark-brown dolomitic limestone; sparry-calcite-filled vertical shrinkage cracks in featureless micrite; lowermost 5 inches grading from intrasparite at top to pelsparite at base
1353'0"	1359'2"	Limestone, medium- to dark-gray and medium-brownish-gray; mottled dark-gray in part; laminated micrite; sparse planar birdseyes; sparse to numerous laminations of dolomitic limestone. Base of lower argillaceous unit	953'11"	955'7"	Limestone, tan and light-gray; micrite; laminated in upper part; numerous planar and nonplanar birdseyes; sparse laminations of fine-grained medium- to dark-brownish-gray dolomitic limestone
WELLS CREEK FORMATION					
1359'2"	1360'3"	Limestone, light-gray to light-greenish-gray, dense to fine-grained, argillaceous, dolomitic; sparse diffuse dark-gray mottling; grading into shale below	955'7"	961'10"	Limestone, light-brown and light- to medium-brownish-gray; mottled medium- to dark-gray in part; micrite and laminated micrite; sparse to moderate number laminations and interbeds of fine-grained argillaceous medium- to dark-brownish-gray dolomitic limestone; moderate number very small planar birdseyes in laminated micrite; sparse planar birdseyes in thinner beds of nonlaminated micrite; moderate number sparry-calcite-filled vertical burrows in thicker beds of nonlaminated micrite
1360'3"	1361'6"	Shale, dark-greenish-gray, subfissile			Limestone, medium- to dark-gray, laminated; argillaceous micrite; sparse to numerous laminations and partings of shaly medium- to dark-greenish-gray limestone; moderate number small planar birdseyes in micrite; numerous sparry-calcite-filled bubblelike voids. Shale, dark-greenish-gray, exfoliated; 1 1/2 inches at base. Marker bed γ
1361'6"	1361'10"	Dolomite, light-gray, very fine-grained, argillaceous, porous			Limestone, light-brownish-gray and light-gray, very thin-bedded; micrite; laminated by dark-brown carbonaceous films; mudcrack; very sparse planar birdseyes
1361'10"	1370'0"	Dolomite as above; some green shale, 2 to 4 inches thick	961'10"	963'6"	Limestone, light- to medium-brownish-gray and light-gray; micrite; laminated in part; sparse to numerous nonplanar
Brown County		Property Owner: Herbert Rockey			
Jackson Township		Cominco American Inc. CA 52			
Ash Ridge quadrangle		Permit No. 5			
		Sample No. 2507			
		Elevation (G) 990.3 feet			
896'0"	926'+	Limestone, medium-gray to medium-brownish-gray, dense- to medium-grained, fossiliferous, medium-bedded; wavy shale interbeddings; some 4- to 10-inch beds of dark-greenish-gray shale and hard shaly limestone. Chert nodule, reddish; 1 inch at 923 feet	963'6"	965'6"	Limestone, light-brownish-gray and light-gray, very thin-bedded; micrite; laminated by dark-brown carbonaceous films; mudcrack; very sparse planar birdseyes
BLACK RIVER GROUP					
926'+	928'+	Limestone, medium-gray to medium-brownish-gray; biopelsparite; minor amount biomicrite (<i>Tetradium</i>) near base	965'6"	967'5"	Limestone, light- to medium-brownish-gray and light-gray; micrite; laminated in part; sparse to numerous nonplanar
928'+	930'0"	Shale, light- to dark-green, bentonitic;			

967'5"	970'4"	birdseyes; sparse planar birdseyes Limestone, light- to medium-brownish-gray and medium-gray; <i>Tetradium</i> biomicrite; interbedded micrite and pelmicrite; moderate number burrows in lower part			rows, most sparry calcite filled, some pelsparite filled (some burrows definite, but many may be bubble tracks deforming color and shale laminations); sparse thin mudcracks
970'4"	976'0"	Limestone, medium- to dark-gray and light- to medium-brownish-gray; mottled in part; micrite and pelsparite; fossiliferous in part; moderate number to numerous burrows and nodular interbeds of argillaceous fine-grained dark-gray and light- to medium-greenish-gray dolomitic limestone	1024'10"	1025'4"	Shale, dark-greenish-gray, bentonitic, exfoliated; trace biotite (<1 mm diameter). Marker bed b
976'0"	977'7"	Limestone, medium-brownish-gray; micrite and pelsparite; numerous horizontal burrows of fine-grained medium-brownish-gray dolomitic limestone	1025'4"	1026'0"	Limestone, medium-gray; micrite; sparse sparry-calcite-filled vertical burrows
977'7"	988'6"	Limestone, medium-gray, medium-brownish-gray, and medium-greenish-gray; argillaceous bryozoan biomicrite; minor amount micrite and pelsparite; numerous nodular interbeds and minor number horizontal burrows of argillaceous fine-grained dark-gray and dark-greenish-gray dolomitic limestone. Marker bed Δ	1026'0"	1029'5"	Dolomite, light- to dark-brownish-gray, fine-grained, laminated; mottled dark-gray; interbedded and laminated with light- to medium-brownish-gray limestone; micrite, laminated micrite, and minor amount intrasparite; sparse planar birdseyes
988'6"	991'6"	Limestone, medium-gray and light- to medium-brownish-gray; micrite and pelsparite; moderate number nodular interbeds and horizontal burrows of fine-grained light- to dark-greenish-gray dolomitic limestone	1029'5"	1035'3"	Limestone, light- to medium-gray and medium-brownish-gray; micrite; minor amount pelsparite and intrasparite; sparse sparry-calcite-filled vertical burrows; sparse faint laminations; sparse small planar birdseyes; sparse thin nodular interbeds and laminations of fine-grained medium- to dark-brownish-gray dolomite. Limestone; biointrasparite; 2-inch bed 2 inches above base
991'6"	1000'6"	Limestone, light-gray and light-brownish-gray; sparse dark-gray mottling; micrite; moderate amount intrasparite; minor amount crossbedded pelsparite; moderate number vertical burrows, some filled with sparry calcite, some filled with light-green argillaceous material; moderate number vertical shrinkage cracks (mudcracks?); sparse planar birdseyes; birdseye zones faintly laminated; sparse laminations and interbeds of fine-grained dark-brown dolomitic limestone	1035'3"	1037'7"	Limestone, medium- to dark-brownish-gray and medium- to dark-brown; micrite and <i>Tetradium</i> biomicrite; interbedded fine-grained dark-brown and dark-brownish-gray dolomite; nodular bedded in part
1000'6"	1004'6"	Limestone, light-gray and light-brownish-gray; sparse dark-gray mottling; micrite; moderate amount intrasparite; minor amount crossbedded pelsparite; moderate number vertical burrows, some filled with sparry calcite, some filled with light-green argillaceous material; moderate number vertical shrinkage cracks (mudcracks?); sparse planar birdseyes; birdseye zones faintly laminated; sparse laminations and interbeds of fine-grained dark-brown dolomitic limestone	1037'7"	1039'4"	Limestone, light-brownish-gray; <i>Tetradium</i> biosparite and <i>Tetradium</i> biopelsparite
1004'6"	1019'6"	Limestone, light-gray, light-brown, and light- to medium-brownish-gray; mottled dark-gray in part; laminated micrite, intrasparite, pelsparite, and micrite; interbedded and laminated with fine-grained medium- to dark-brownish-gray laminated dolomite, concentrated at 1006 feet to 1007 feet 6 inches and 1010 feet 8 inches to 1015 feet; sparse to numerous planar birdseyes and sparse bubblelike birdseyes, mainly in laminated micrite, sparse in pelsparite; moderate number sparry-calcite-filled vertical burrows; minor number pelsparite-filled vertical burrows, mainly in pelsparite and nonlaminated micrite, sparse in laminated micrite	1039'4"	1043'9"	Limestone, light- to medium-brownish-gray; mottled dark-gray; <i>Tetradium</i> biosparite, biopelsparite, biomicrite, intrasparite, and micrite; dolomitized in part; in part burrowed and nodular interbedded fine-grained light-brown and medium- to dark-brownish-gray dolomite
1019'6"	1024'10"	Limestone, light- to medium-gray and light- to medium-greenish-gray; mottled dark-gray; laminated micrite with minor amount intrasparite; very argillaceous, grading to shale; sparse to moderate number small planar birdseyes; moderate number to numerous vertical bur-	1043'9"	1053'0"	Limestone, light- to medium-gray and light- to dark-brownish-gray; mottled dark-gray; micrite; moderate amount biomicrite; minor amount pelsparite, biopelsparite, and intrasparite; sparsely to highly dolomitized; faint to definite laminations of color, dolomite rhombs, and pellets, approximately 50%; sparse sparry-calcite-filled vertical burrows. Top of Oregon Formation correlative
			1053'0"	1056'0"	Limestone and dolomite, light-brownish-gray; mottled dark-gray; interlaminated dolomite and micrite; minor amount intrasparite
			1056'0"	1058'0"	Limestone, light-brownish-gray, thin-bedded; mottled dark-gray; laminated micrite; moderate number to numerous flat to nodular laminations of fine-grained light-brown dolomite
			1058'0"	1061'0"	Limestone, light-gray; sparse dark-gray mottling; 11 inches biomicrite and micrite (<i>Tetradium</i> fragments at top); sparse vertical to horizontal burrows filled with sparry calcite and fine-grained dolomite; grading into laminated micrite. 7 inches laminated micrite; moderate number very small planar birdseyes; moderate number bubblelike birdseyes; sparse dolomite rhombs. 3 inches dark-brown and dark-gray laminated dolomite, minor amount faintly laminated micrite. Micrite and biomicrite, nodular bedded in part, faint laminations in part; sparse dolomite rhombs; grading into limestone and dolomite below

1061'0"	1068'0"	Limestone and dolomite, light-gray and light-brownish-gray; mottled dark-gray; laminated dolomite; interlaminated dolomite and micrite; laminated micrite; minor amount micrite and intrasparite; sparse to moderate number planar birdseyes in laminated micrite	1120'6"	1127'6"	tal burrows and irregular interbeds of fine-grained medium- to dark-gray and medium- to dark-brownish-gray dolomitic limestone
1068'0"	1071'2"	Limestone, light- to dark-brownish-gray; biomicrite and micrite; minor amount pelsparite and biointrasparite; <i>Tetradium</i> fragments; most fossils replaced by sparry calcite	1127'6"	1156'0"	Limestone, light- to medium-brown; micrite; slightly to moderately dolomitic; numerous burrows and irregular interbeds of fine-grained medium-brownish-gray dolomitic limestone
1071'2"	1078'7"	Dolomite and limestone, light- to medium-gray and light- to medium-brownish-gray; dolomite; laminated dolomite; dolomitic micrite; minor amount interlaminated dolomite and micrite; minor amount pelsparite and intrasparite. Base of Oregon Formation correlative	1156'0"	1159'0"	Limestone, light- to medium-gray and light- to medium-brownish-gray; micrite, pelsparite, biopelsparite, pelmicrite, and biopelmicrite; sparse to moderate number horizontal burrows and irregular interbeds of fine-grained light- to dark-brownish-gray dolomitic limestone
1078'7"	1079'1"	Limestone, light- to medium-brownish-gray; mottled dark-gray and dark-brownish-gray; <i>Tetradium</i> biomicrite at base; micrite at top; sparse (base) to numerous (top) horizontal burrows filled with fine-grained dolomitic limestone	1159'0"	1162'0"	Limestone, light- to medium-gray, laminated, crossbedded; pelmicrite and pelsparite; sparse laminations and thin interbeds (up to ¼ inch thick) of fine-grained dark-gray dolomitic limestone
1079'1"	1080'8"	Limestone, light-brownish-gray; micrite; top 4 inches faintly laminated; moderate number nonplanar birdseyes; sparse very small planar birdseyes; middle 9 inches moderate number nodular brown dolomite laminations; basal 6 inches some irregular "disturbed" areas of nonplanar birdseyes (burrowed areas?)	1162'0"	1167'6"	Limestone, medium-gray, dolomitic; pelmicrite (laminated in part), micrite, and pelsparite; interbedded fine-grained dark-gray dolomite
1080'8"	1089'5"	Limestone, light- to medium-gray and light- to medium-greenish-gray; biomicrite and micrite; large fauna including <i>Tetradium</i> ; argillaceous in part; churned and burrowed in part; burrows filled with argillaceous light-green and medium- to dark-greenish-gray dolomite; concentrations of regular to nodular bedded and laminated carbonaceous dark-gray shale and shaly limestone at 1081 feet 1 inch to 1081 feet 5 inches, 1084 feet 1 inch to 1084 feet 7 inches (including ≈2-inch black shale bed), 1085 feet 1 inch to 1085 feet 3 inches, and 1088 feet 6 inches to 1089 feet 5 inches. Marker bed I	1167'6"	1168'11"	Limestone, tan and light- to medium-brownish-gray, dolomitic; micrite, pelmicrite, intrasparite, and biopelsparite; numerous irregular interbeds and horizontal burrows of fine-grained medium-brownish-gray dolomitic limestone
1089'5"	1097'0"	Limestone, light- to medium-brownish-gray and light- to medium-gray; <i>Tetradium</i> biomicrite; minor amount <i>Tetradium</i> biopelsparite, <i>Tetradium</i> biosparite, and micrite; uppermost 9 inches micrite and <i>Tetradium</i> biomicrite, very faint laminations, moderate number nonplanar birdseyes; uppermost 1 inch faintly laminated micrite with numerous vertical burrows filled with fine-grained argillaceous dark-brown dolomite	1168'11"	1172'6"	Limestone, light-gray, dolomitic; micrite, intrasparite, and pelmicrite; sparse irregular to nodular laminations of fine-grained light- to medium-gray dolomite
1097'0"	1107'0"	Limestone, medium-brownish-gray and medium-gray; micrite, biomicrite, and biopelsparite; minor amount pelsparite; moderate number horizontal burrows and irregular interbeds of fine-grained light- to medium-gray and light-greenish-gray dolomitic limestone	1172'6"	1175'6"	Limestone, light- to medium-gray and medium-brownish-gray; intrasparite, biointrasparite, and biopelsparite; minor amount micrite; sparse to moderate number irregular interbeds of fine-grained medium- to dark-brownish-gray and dark-brown dolomite
1107'0"	1111'4"	Limestone, light-brownish-gray; biopelmicrite and biopelsparite; minor amount biomicrite and intrasparite; sparse to moderate number horizontal burrows and irregular interbeds of fine-grained medium- to dark-brown dolomitic limestone	1175'6"	1176'4"	Limestone, light-gray and medium-brownish-gray; biomicrite and biopelsparite; <i>Tetradium</i> fragments; minor amount micrite
1111'4"	1120'6"	Limestone, light- to medium-gray and light- to medium-brownish-gray; pelmicrite, micrite, biopelsparite, and biomicrite; minor amount biopelmicrite; moderate number to numerous horizon-	1176'4"	1181'0"	Cavernous? zone; poor core; probably horizontally burrowed micrite
			1181'0"	1186'10"	Poor core recovery; ends broken and nonmatching; order uncertain; appears to be medium-gray micrite and dolomitic <i>Tetradium</i> biomicrite; overlain and underlain by biointrasparite, biopelsparite, and intrasparite
			1186'10"	1187'11"	Limestone, medium- to dark-gray and medium- to dark-brownish-gray; biomicrite, biopelsparite, biointrasparite, and intrasparite; minor amount micrite; argillaceous in part; dolomitic in part; sparse to moderate number irregular interbeds and sparse horizontal burrows of fine-grained dark-brownish-gray and dark-brown dolomitic limestone. Top of marker bed II
			1187'11"	1189'0"	Limestone, light-gray and light- to medium-brownish-gray; micrite and biomicrite; churned and burrowed to pelsparite in part; dolomitic in part; sparse ¼- to 1-inch interbeds of dark-brown dolomitic limestone in bottom half
			1189'0"	1199'4"	Poor core, core loss?; grayish-green and dark-gray shale and shaly limestone
					Limestone, medium- to dark-gray, medium- to dark-brownish-gray, and dark-brown; biomicrite, biopelsparite, and biointrasparite; argillaceous in large part; dolomitic in part; sparse to numerous irregular interbeds and horizontal

		burrows of fine-grained dark-brownish-gray and dark-brown dolomite. Base of marker bed II			um- to dark-brownish-gray, and medium-greenish-gray; biomicrite and micrite; argillaceous in large part; moderate number irregular interbeds and sparse to moderate number horizontal burrows of fine-grained argillaceous medium- to dark-greenish-gray, light- to dark-brown, and medium- to dark-brownish-gray dolomitic limestone; sparse 1/16- to 1/8-inch carbonaceous black shale beds. Top of upper argillaceous unit
1199'4"	1200'10"	Limestone, light-brownish-gray; biopelsparite, biointrasparite, and biomicrite; sparse micrite; some dolomitization of sparry matrix			
1200'10"	1203'9"	Limestone, light-gray; micrite; moderate number vertical and sparse horizontal burrows filled with sparry calcite; sparse to moderate number ostracods			
1203'9"	1204'4"	Limestone, light-gray and light-brownish-gray; <i>Tetradium</i> biomicrite; sparse vertical burrows filled with sparry calcite and pelsparite	1256'0"	1261'4"	
1204'4"	1206'2"	Limestone, light-gray and light-brownish-gray; micrite and pelmicrite; sparse intrasparite; moderate number dolomite rhombs; sparse very faint laminations			
1206'2"	1207'9"	Limestone, medium-brownish-gray; micrite; interbedded medium- to dark-brownish-gray dolomite; moderate number sparry-calcite-filled vertical shrinkage cracks in micrite	1261'4"	1266'8"	
1207'9"	1216'7"	Limestone, medium-gray and light- to medium-brownish-gray; biomicrite, pelmicrite, biopelmicrite, pelsparite, and biopelsparite; minor amount micrite and intrasparite; sparse to moderate number irregular interbeds and horizontal burrows of fine-grained medium- to dark-gray and light- to dark-brownish-gray dolomitic limestone	1266'8"	1268'0"	
1216'7"	1220'5"	Limestone, light- to medium-gray; biointrasparite; sparse irregular partings of argillaceous fine-grained medium- to dark-brownish-gray dolomitic limestone, mainly in lowermost 6 inches	1268'0"	1269'10"	
1220'5"	1222'5"	Limestone, light-gray; micrite; sparsely fossiliferous, <i>Tetradium</i> fragments and ostracods; sparse dolomite rhombs; sparse sparry-calcite-filled vertical and horizontal burrows	1269'10"	1270'9"	
1222'5"	1227'0"	Limestone, medium-brownish-gray; micrite, biomicrite, biopelmicrite, and biointrasparite; sparse to moderate number <i>Tetradium</i> fragments; <i>Tetradium</i> in growth? position from 1222 feet 11 inches to 1223 feet 4 1/2 inches; minor number irregular interbeds of fine-grained medium- to dark-brownish-gray dolomitic limestone	1270'9"	1272'3"	
1227'0"	1230'6"	Limestone, light-brownish-gray; micrite, biomicrite, and biointrasparite; dolomitic and chalky in part; numerous irregular interbeds and moderate number horizontal burrows of fine-grained medium- to dark-brown dolomite; numerous sparry-calcite-filled shrinkage cracks in micrite, generally aligned approximately perpendicular to dolomite interbeds	1272'3"	1274'0"	
1230'6"	1249'3"	Limestone, medium- to dark-brownish-gray, medium- to dark-gray, and light- to dark-brown; biomicrite; moderate amount micrite, pelmicrite, and biopelsparite; minor amount biopelmicrite and pelsparite; sparse to numerous irregular interbeds and horizontal burrows of dark-brown, medium-brownish-gray, and dark-gray dolomitic limestone; moderate number partings and interbeds (up to 1/2 inch thick) of carbonaceous black shale and shaly limestone from 1236 feet to 1238 feet 5 inches; matrix moderately dolomitized from 1241 feet to 1243 feet; sandy biopelsparite, 2 inches at 1243 feet	1274'0"	1278'0"	
1249'3"	1256'0"	Limestone, medium- to dark-gray, medi-	1278'0"	1286'1"	
					Limestone, medium- to dark-brownish-gray and medium-greenish-gray, argillaceous; micrite, biopelsparite, and pelsparite; regularly interbedded argillaceous fine-grained dark-brownish-gray and dark-greenish-gray dolomite and carbonaceous dark-greenish-gray and dark-gray shale and shaly limestone
					Limestone, medium-gray and medium-brownish-gray; biomicrite; argillaceous in part; dolomitic in part; moderate number nodular to feathery interbeds and partings of carbonaceous medium- to dark-greenish-gray and dark-gray shale and shaly limestone; sparse irregular green-clay partings
					Limestone, light-gray and light-brownish-gray; biomicrite; argillaceous in part; bioturbated to biopelsparite in part
					Limestone, light-gray and light-brownish-gray; fossiliferous micrite and biomicrite (<i>Tetradium</i> and other corals, ostracods, gastropods); sparry-calcite-filled fossils; sparse sparry-calcite-filled vertical and horizontal burrows; zone of argillaceous biointrasparite from 1269 feet to 1269 feet 4 inches
					Limestone, medium- to dark-brownish-gray; some dark-gray mottling; micrite, biomicrite, biointrasparite, and dolomitic micrite; numerous irregular to nodular partings of carbonaceous black and dark-brownish-gray shale and shaly limestone
					Limestone, light-brownish-gray; micrite; moderate number sparry-calcite-replaced <i>Tetradium</i> fragments; moderate number sparry-calcite-filled horizontal and vertical burrows, filled with light-green argillaceous material in uppermost 4 inches
					Limestone, medium-brown; mottled medium- to dark-brownish-gray; micrite; sparse to moderate number sparry-calcite-filled vertical shrinkage cracks; moderate number nodular partings of fine-grained medium- to dark-brown dolomitic limestone
					Limestone, medium-brown and medium- to dark-brownish-gray; micrite, biomicrite (<i>Tetradium</i> , ostracods, gastropods), and pelsparite; sparse horizontal burrows of dolomitic limestone; several wavy partings and interbeds (up to 1/8 inch thick) of shaly black and dark-gray limestone from 1276 feet 11 inches to 1277 feet 6 inches
					Limestone, light- to medium-gray and light- to medium-brownish-gray; minor amount medium- to dark-gray mottling; micrite and pelmicrite; churned and burrowed to pelsparite in part; slightly fossiliferous in part; minor number sparry-calcite-filled vertical burrows; moderate number swirled burrows; very sparse faint laminations of color or micrite and intrasparite; sparse dark-green and dark-gray shale interbeds

		(mainly from 1282 feet 6 inches to 1284 feet 6 inches)			shrinkage cracks; minor number horizontal and inclined burrows, some filled with medium-grained light-gray dolomite, some with dolomitic pelsparite; minor number nodular interbeds of argillaceous dark-brown dolomite. Base of upper argillaceous unit
1286'1"	1286'4"	Shale, dark-greenish-gray, carbonaceous. Limestone, dark-greenish-gray, shaly			
1286'4"	1287'11"	Limestone, dark-brownish-gray; minor amount dark-gray mottling; micrite; minor amount biomicrite (very thin ostracod tests); sparse amount pelsparite; sparse to moderate number horizontal burrows (mainly in uppermost 8 inches) and moderate number irregular to nodular interbeds of shaly black and dark-gray dolomite	1310'3"	1313'6"	Limestone, light- to medium-brown; dolomitic in part; biomicrite, micrite, intrasparite, and intrapelsparite; moderate number to numerous horizontal burrows and minor number nodular interbeds of fine-grained light- to medium-brown dolomite. Top of Carntown unit
1287'11"	1289'4"	Limestone, light-gray and light-brownish-gray; laminated micrite; faint wavy color laminations; very sparse planar birdseyes; moderate number very thin sparry-calcite-filled mudcracks; numerous vertical tubelike striations (<0.5 mm wide, ≈5 mm long)	1313'6"	1316'0"	Limestone very similar to sample from 1307 feet 1 inch to 1310 feet 3 inches; core jumbled(?); some ends don't match from 1310 feet to 1316 feet
1289'4"	1290'10"	Limestone, light- to medium-brownish-gray and medium-brown; micrite; moderate number very faint wavy laminations; numerous very thin sparry-calcite-filled mudcracks; sparse to moderate number vertical tubelike striations	1316'0"	1337'0"	Limestone, light- to medium-brown and medium-brownish-gray; mainly dolomitic; biomicrite, biopelsparite, and pelsparite; minor amount micrite; moderate number to numerous horizontal burrows and nodular interbeds of fine-grained light- to medium-brown dolomite; moderate number sparry-calcite-filled shrinkage cracks
1290'10"	1293'4"	Limestone, medium-brownish-gray and medium-brown; micrite; sparse wavy laminations; moderate number to numerous sparry-calcite-filled shrinkage cracks adjacent and perpendicular to partings	1337'0"	1338'1"	Limestone, medium-gray and medium-brownish-gray; pelmicrite and biopelmicrite; sparse to numerous horizontal burrows and irregular interbeds of fine-grained medium-gray dolomite. Limestone, medium- to coarse-grained, bioclastic; 3-inch bed at base
1293'4"	1297'0"	Limestone, medium-gray; minor amount dark-gray mottling; micrite; sparse biomicrite and biointrasparite; sparse sparry-calcite-filled shrinkage cracks; moderate number to numerous horizontal burrows and irregular interbeds of fine-grained medium- to dark-gray and medium-greenish-gray dolomitic limestone	1338'1"	1341'5"	Limestone, light-brown and light- to medium-brownish-gray; dolomitic in part; micrite, biomicrite, and biopelsparite; numerous burrows of fine-grained light-brown and light- to medium-gray dolomite
1297'0"	1299'3"	Limestone, medium-brown and medium-brownish-gray; minor amount dark-gray mottling; micrite, biomicrite, biopelsparite, biointrasparite, and pelmicrite; sparry-calcite-filled vertical shrinkage cracks in micrite; sparse to moderate number vertical to horizontal burrows, some filled with fine-grained light- to dark-gray and light- to medium-greenish-gray dolomite, some with biopelsparite and biointrasparite	1341'5"	1347'6"	Limestone, light- to medium-brown and light- to medium-brownish-gray; dolomitic in part; micrite and biomicrite; sparse to numerous horizontal burrows and nodular interbeds of fine-grained light- to medium-brown dolomite, some burrows filled with sparry calcite in lowermost 3 inches
1299'3"	1300'6"	Limestone, medium-brownish-gray, bioturbated; minor amount medium- to dark-gray mottling; biointrasparite, biointrapelsparite, and biomicrite; slightly dolomitic in part; burrows filled with light- to dark-gray dolomite, dolomitic limestone, and biopelsparite	1347'6"	1349'11"	Limestone, medium-gray; pelmicrite; moderate number to numerous horizontal burrows and nodular interbeds of fine-grained light- to medium-gray dolomite
1300'6"	1302'9"	Limestone, medium-gray and medium-brownish-gray; micrite, biomicrite, and biopelsparite; moderate number sparry-calcite-filled vertical shrinkage cracks in micrite; moderate number nodular to regular beds (up to ½ inch thick) of fine-grained argillaceous dark-gray dolomite	1349'11"	1350'6"	Limestone, light- to medium-gray; mottled medium- to dark-gray; micrite; minor amount biomicrite and intrapelsparite; moderate number nodular interbeds of fine-grained medium- to dark-gray dolomite
1302'9"	1307'11"	Limestone, medium-brownish-gray; minor amount medium-gray mottling; <i>Tetradium</i> biomicrite and micrite; minor number sparry-calcite-filled vertical shrinkage cracks in micrite; minor number horizontal burrows and irregular interbeds of fine-grained light- to medium-brown, brownish-gray, and medium- to dark-greenish-gray dolomitic limestone	1350'6"	1351'5"	Limestone, light- to medium-brown and brownish-gray; dolomitic in part; micrite, biomicrite, and biopelsparite; bioturbated in part; moderate number horizontal burrows and nodular interbeds of fine-grained medium-brownish-gray dolomite
1307'11"	1310'3"	Limestone, medium-brownish-gray; micrite; moderate amount biomicrite; minor amount biointrasparite; minor number sparry-calcite-filled vertical	1351'5"	1352'3"	Limestone, light- to medium-brown; largely dolomitic; pelsparite (laminated in part) and intrasparite
			1352'3"	1353'3"	Limestone, light-gray to white; micrite; faint laminations in part; minor amount flat-pebble intrasparite; numerous small planar and nonplanar birdseyes
			1353'3"	1355'8"	Limestone, light- to medium-brown; laminated micrite; minor number pelsparite laminations; numerous laminations of fine-grained medium- to dark-brown dolomite; sparse to numerous very small planar and nonplanar birdseyes
			1355'8"	1356'9"	Limestone, light-brownish-gray; micrite;

		faintly laminated in part; sparse dolomite laminations and interbeds; sparse to moderate number small planar birdseyes; sparse small nonplanar birdseyes; slightly fossiliferous in part, including <i>Tetradium</i>			aceous in part; micrite, biosparite, and biomicrite; interlaminated and nodular bedded with dark-gray, dark-brownish-gray, and light- to dark-greenish-gray shale. Shale and limestone, interbedded; numerous planar birdseyes; uppermost few inches. Shale, laminated and nodular bedded; minor amount limestone; upper half. Limestone, nodular bedded featureless micrite with minor amount shale; mudcracks in upper part; faint laminations and sparse vertical burrows in lower part; lower half. Limestone and shale, fossiliferous; lowermost 7 inches
1356'9"	1359'0"	Limestone, light-gray; minor amount medium-gray mottling; micrite; largely featureless; sparse nodular laminations and interbeds of fine-grained medium-gray dolomite; sparse sparry-calcite-filled vertical burrows; sparse <i>Tetradium</i> fragments. <i>Tetradium</i> biomicrite, 1½ inches at base			
1359'0"	1372'4"	Limestone, light- to medium-brown; largely dolomitic; micrite, <i>Tetradium</i> biomicrite, and biomicrite; numerous horizontal burrows and irregular interbeds of fine-grained medium-brown dolomite	1392'1"	1394'11"	Limestone, medium-brown; micrite; minor number intrasparite laminations; numerous (top) to sparse (bottom) planar and nonplanar birdseyes; sparse laminations of fine-grained dark-brown dolomite. Limestone, mottled light- to dark-greenish-gray; micrite; numerous nonplanar birdseyes; laminated and interbedded dark-greenish-gray shale; grading into shale below; lowermost 5 inches
1372'4"	1374'8"	Limestone, medium-brownish-gray; micrite and biomicrite; bioturbated in part; slightly argillaceous; moderate number irregular to nodular interbeds of fine-grained medium- to dark-brownish-gray dolomite. Base of Carntown unit	1394'11"	1395'4½"	Shale, medium- to dark-green and greenish-gray; nodular fragments of biomicrite
1374'8"	1376'10"	Limestone, medium- to dark-brownish-gray, argillaceous; biomicrite, biopelsparite, and biointrasparite; very finely recrystallized in part; dolomitic in part; algae-coated fossil fragments in lower part. Top of lower argillaceous unit	1395'4½"	1396'2"	Limestone, light-gray; micrite; sparse to moderate number sparry-calcite-filled vertical burrows
1376'10"	1378'8"	Limestone, dark-gray, very argillaceous, bioturbated; mottled light- to dark-greenish-gray; biomicrite; moderate number to numerous nodular and feathery interbeds of dark-greenish-gray and light-green shale	1396'2"	1398'10"	Limestone, medium-brownish-gray; mottled dark-brownish-gray near base; biomicrite (<i>Tetradium</i> fragments) and micrite; argillaceous near base
1378'8"	1379'8"	Limestone, medium- to dark-brownish-gray; minor amount dark-gray mottling; micrite; churned(?) and bioturbated(?) to pelsparite; faint laminations in pelsparite in bottom half	1398'10"	1400'9"	Limestone, medium-greenish-gray, argillaceous; biomicrite and micrite; nodular to feathery interbeds of dark-gray and dark-greenish-gray shale
1379'8"	1381'10"	Limestone, light-gray and light- to medium-brownish-gray; <i>Tetradium</i> biomicrite and micrite; sparse irregular partings and interbeds of dark-greenish-gray and dark-brown shale; sparsely fossiliferous micrite, very numerous sparry-calcite-filled shrinkage cracks (randomly oriented) in uppermost 2 inches	1400'9"	1402'1"	Limestone, medium-brownish-gray, bioturbated; micrite and biomicrite; burrows filled with intrasparite, pelsparite, and fine-grained medium- to dark-brownish-gray dolomite. Shale, dark-greenish-gray; nodular to feathery interbeds of biomicrite, biopelsparite, and biointrasparite; lowermost 4 inches
1381'10"	1382'8"	Limestone, medium-brownish-gray; moderate amount dark-gray mottling; micrite; sparse sparry-calcite-filled vertical shrinkage cracks; sparse vertical burrows filled with sucrosic light-gray dolomite; moderate number way to nodular partings (up to ¼ inch thick) of dark-gray and dark-brown shale	1402'1"	1402'8"	Limestone, dolomite, and shale, light- to medium-gray and light- to medium-greenish-gray; interlaminated; mainly thin layers of micrite with numerous shale partings and laminations of dolomite rhombs
1382'8"	1384'6"	Limestone similar to sample from 1376 feet 10 inches to 1378 feet 8 inches; but more shale	1402'8"	1403'8"	Limestone, light-gray; moderate amount dark-gray mottling; laminated micrite; numerous small planar and nonplanar birdseyes; small mudcracks; moderate number to numerous laminations of medium-brown dolomite; grading into limestone below
1384'6"	1386'0"	Limestone, mottled dark-brown and dark-brownish-gray; micrite; faintly laminated in part; pelletal in part; dolomitic in part; moderate number way to nodular partings and interbeds (up to ¼ inch thick) of dark-gray and dark-brownish-gray shale	1403'8"	1405'1"	Limestone, light-gray and light-brownish-gray; micrite; sparse to moderate number faint laminations; very small planar birdseyes; very thin mudcracks; all decreasing in number toward base
1386'0"	1388'7"	Limestone, medium-gray and medium-brownish-gray; mottled medium-greenish-gray; biomicrite; minor amount micrite and biointrasparite; all very argillaceous; sparse to moderate number irregular to feathery interbeds of dark-gray and dark-greenish-gray shale	1405'1"	1407'9"	Shale, light- to dark-greenish-gray, calcareous. Limestone, light- to medium-gray and greenish-gray; micrite and pelsparite; dolomitic in part. Upper one-third mainly pelsparite with nodular to feathery interbeds of shale. Middle one-third mainly laminated calcareous shale. Lower one-third mainly interlaminated shale and micrite with numerous mudcracks; small planar birdseyes; dolomite rhombs; gradational with limestone below
1388'7"	1392'1"	Limestone, medium-brownish-gray and light- to medium-greenish-gray; argilla-	1407'9"	1411'8"	Limestone, medium-brownish-gray; mottled dark-greenish-gray; laminated mi-

BLACK RIVER GROUP (MIDDLE ORDOVICIAN), SOUTHWESTERN OHIO

		crite; argillaceous in part; sparse to moderate number planar and nonplanar birdseyes, decreasing in number toward base; moderate number thin mudcracks; moderate number to numerous laminations and interbeds of dark-greenish-gray shale; moderate number laminations of dolomite rhombs, decreasing toward base; gradational with limestone below	1415'7"	1416'6"	intrasparite, micrite, and laminated micrite; sparse to moderate number small planar and nonplanar birdseyes; sparse to moderate number laminations of dark-brown dolomite
1411'8"	1412'8"	Limestone, mottled medium-brownish-gray and dark-brownish-gray; micrite and shale; laminated at top; nodular and contorted bedding at bottom. Sphalerite, pale-yellow; opaque crystals; at 1412 feet 4 inches. Gradational with limestone below			Limestone and dolomite, medium- to dark-brownish-gray, argillaceous. Shale, dark-greenish-gray. Interlaminated micrite, dolomite, and shale; gradational with shale below. Base of lower argillaceous unit
			WELLS CREEK FORMATION		
			1416'6"	1418'0"	Shale, dark-greenish-gray, calcareous; grading into fissile dark-green shale
1412'8"	1415'7"	Limestone, light- to medium-brownish-gray and medium-gray; interbedded	1418'0"	1421'+	Dolomite, light-gray, fine-grained, porous, argillaceous; carbonaceous laminae

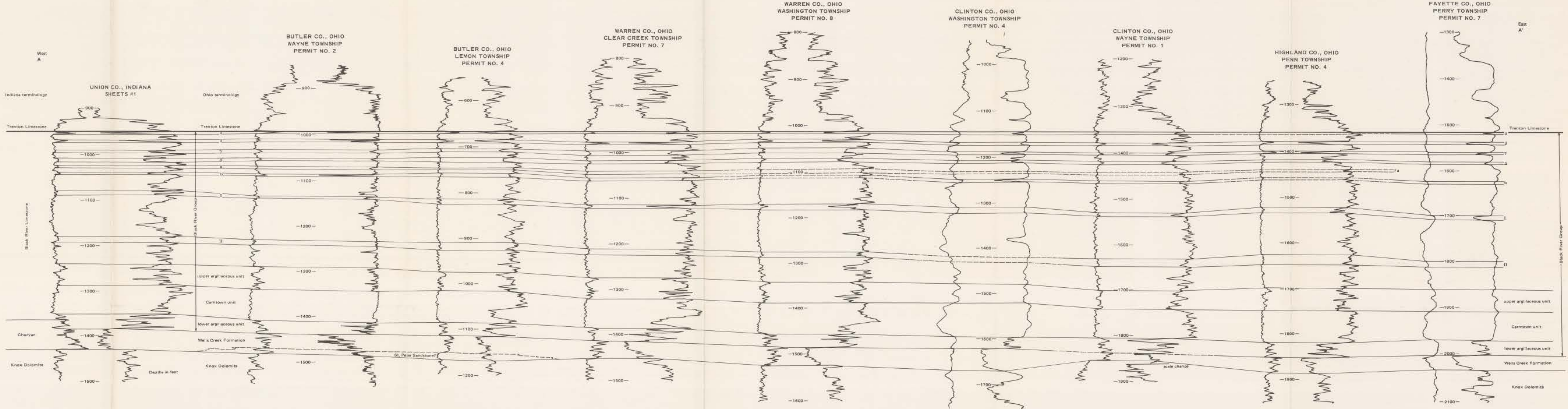
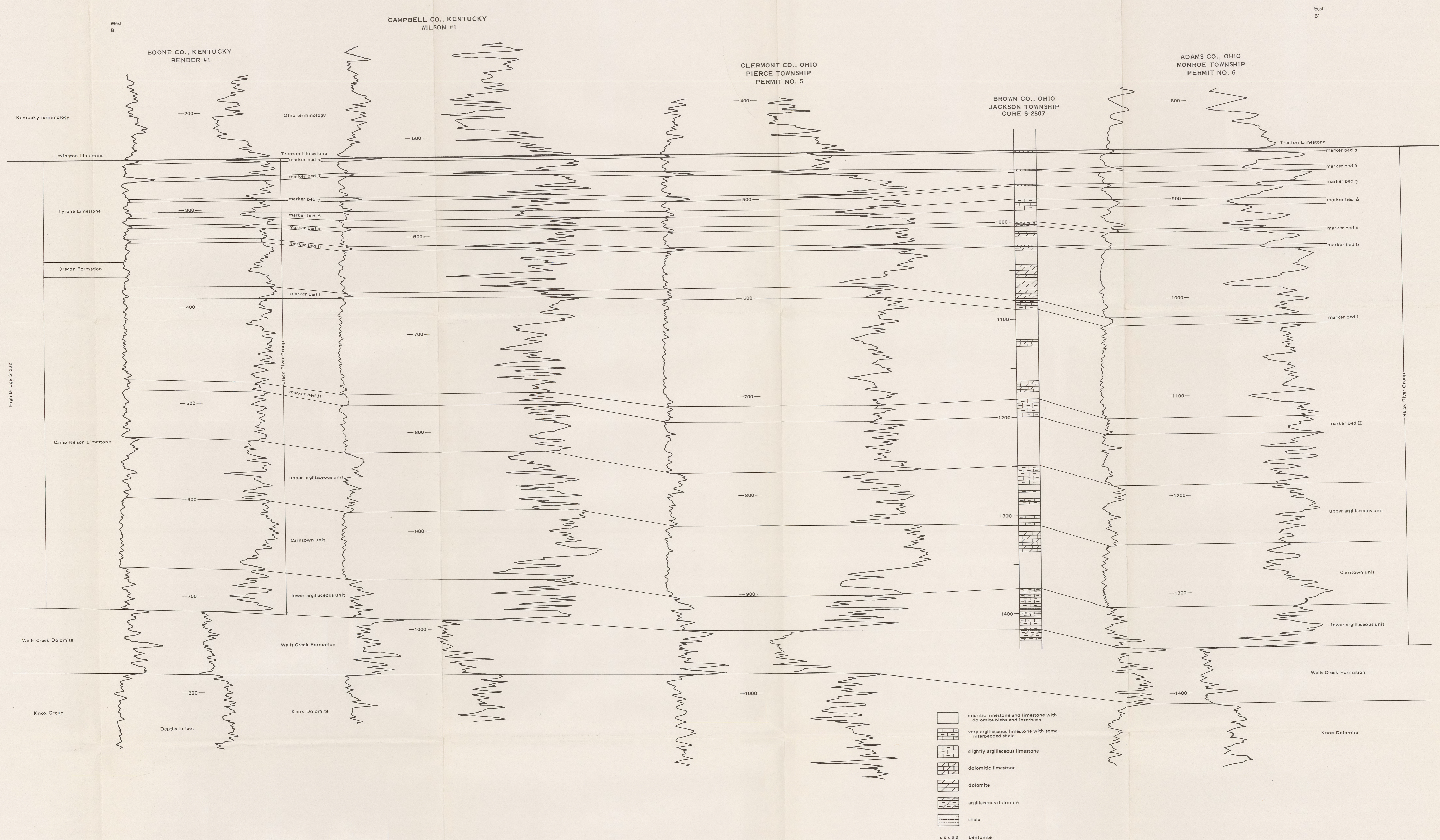


Plate 1 Geophysical-log cross section of the Black River Group from Union County, Indiana, to Fayette County, Ohio

Datum is top of marker bed a. See figure 1 for location of cross section.

STATE OF OHIO
James A. Rhodes, Governor
DEPARTMENT OF NATURAL RESOURCES
Robert W. Teater, Director
DIVISION OF GEOLOGICAL SURVEY
Horace R. Collins, Chief



Datum is top of marker bed a. See figure 1 for location of cross section.

Plate 2. Geophysical-log and core cross section of the Black River Group from Boone County, Kentucky, to Adams County, Ohio

ADAMS COUNTY, OHIO
 MONROE TOWNSHIP
 S-2405

BROWN COUNTY, OHIO
 JACKSON TOWNSHIP
 S-2507

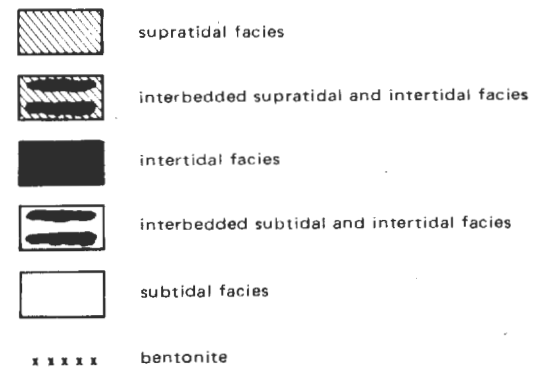
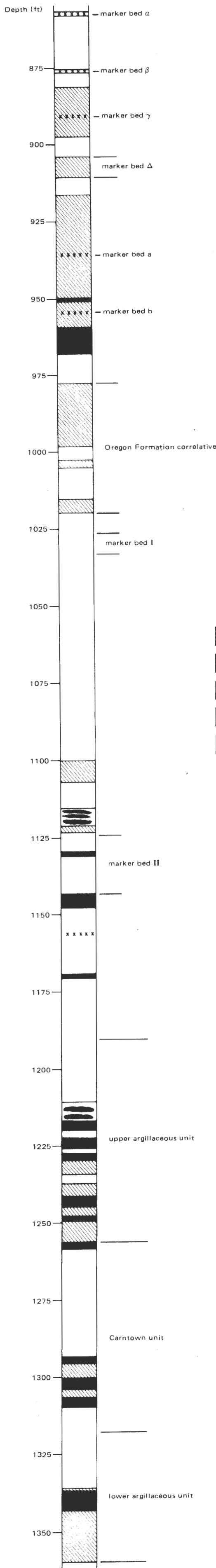
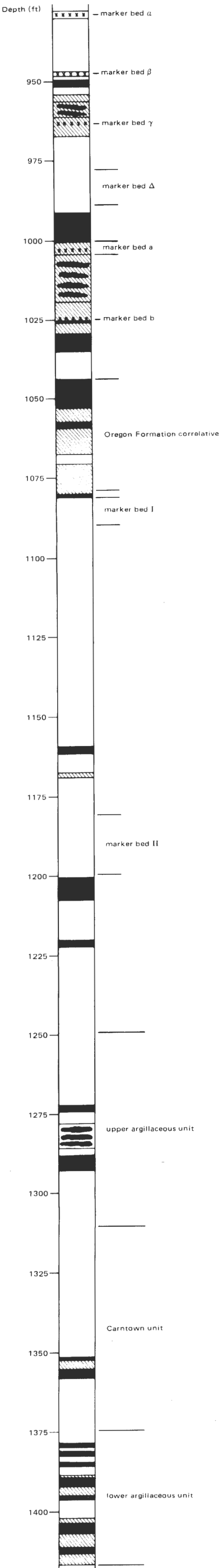


Plate 3 Environmental interpretations of Adams County
 and Brown County cores