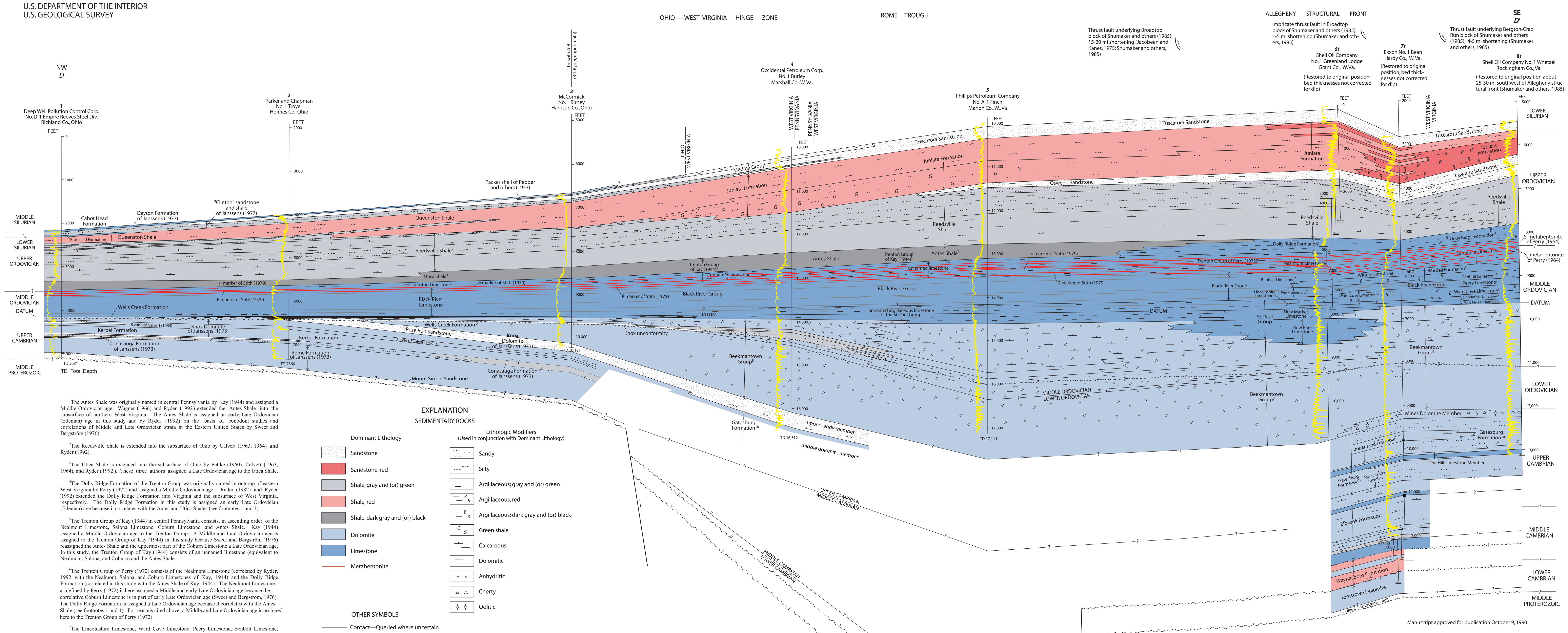

¹The Antes Shale was originally named in central Pennsylvania by Kay (1944) and assigned a Middle Ordovician age. Wagner (1966) and Ryder (1992) extended the Antes Shale into the subsurface of northern West Virginia. The Antes Shale is assigned an early Late Ordovician (Edenian) age in this study and by Ryder (1992) on the basis of conodont studies and correlations of Middle and Late Ordovician strata in the Eastern United States by Sweet and Bergström (1976).

²The Reedsville Shale is extended into the subsurface of Ohio by Calvert (1963, 1964) and Ryder (1992).

³The Utica Shale is extended into the subsurface of Ohio by Fettke (1960), Calvert (1963, 1964), and Ryder (1992). These three authors assigned a Late Ordovician age to the Utica Shale.

⁴The Dolly Ridge Formation of the Trenton Group was originally named in outcrop of eastern West Virginia by Perry (1972) and assigned a Middle Ordovician age. Rader (1982) and Ryder (1992) extended the Dolly Ridge Formation into Virginia and the subsurface of West Virginia, respectively. The Dolly Ridge Formation in this study is assigned an early Late Ordovician (Edenian) age because it correlates with the Antes and Utica Shales (see footnotes 1 and 3).

⁵The Trenton Group of Kay (1944) in central Pennsylvania consists, in ascending order, of the Nealmont Limestone, Salona Limestone, Coburn Limestone, and Antes Shale. Kay (1944) assigned a Middle Ordovician age to the Trenton Group. A Middle and Late Ordovician age is assigned to the Trenton Group of Kay (1944) in this study because Sweet and Bergström (1976) reassigned the Antes Shale and the uppermost part of the Coburn Limestone a Late Ordovician age. In this study, the Trenton Group of Kay (1944) consists of an unnamed limestone (equivalent to Nealmont, Salona, and Coburn) and the Antes Shale.

⁶The Trenton Group of Perry (1972) consists of the Nealmont Limestone (correlated by Ryder, 1992, with the Nealmont, Salona, and Coburn Limestones of Kay, 1944) and the Dolly Ridge Formation (correlated in this study with the Antes Shale of Kay, 1944). The Nealmont Limestone as defined by Perry (1972) is here assigned a Middle and early Late Ordovician age because the correlative Coburn Limestone is in part of early Late Ordovician age (Sweet and Bergstrom, 1976). The Dolly Ridge Formation is assigned a Late Ordovician age becuase it correlates with the Antes Shale (see footnotes 1 and 4). For reasons cited above, a Middle and Late Ordovician age is assigned here to the Trenton Group of Perry (1972).

⁷The Lincolnshire Limestone, Ward Cove Limestone, Peery Limestone, Benbolt Limestone, Wardell Formation, and Witten Limestone were first named in Virginia (Cooper and Prouty, 1943). The Lincolnshire, Ward Cove, Peery, and Benbolt Limestones have been extended into West Virginia by Kay (1956) and Read (1980), and the Wardell Formation and Witten Limestone have been extended into West Virginia by Read (1980). Kay (1956) and Perry (1964) applied the names McGlone Limestone and McGraw Limestone, respectively, to the intervals assigned by Read (1980) in West Virginia to the Wardell Formation and Witten Limestone. Following Kay (1956) and Read (1980), the names Lincolnshire, Ward Cove, Peery, and Benbolt Limestones have been extended into the subsurface of West Virginia in this study and in Ryder (1992). Moreover, the Wardell Formation and Witten Limestone as used by Read (1980) in West Virginia reflect more current usage than the McGlone and McGraw Limestones of Kay (1956) and Perry (1964) and, thus, are extended into the subsurface of West Virginia in this study and in Ryder (1992).

⁸The Lower and Middle Ordovician age assigned here to the Beekmantown Group in the subsurface of West Virginia follows Wagner (1966) and Ryder (1992).

⁹Ryder (1992) assigned a Late Cambrian age to the Rose Run Sandstone because it correlates with the upper sandy member of the Upper Cambrian Gatesburg Formation (Wilson, 1952; Wagner, 1966).

¹⁰Wagner (1966, 1976) and Ryder (1992) recognized the Gatesburg Formation in the subsurface of northern and eastern West Virginia. Subdivisions of the Gatesburg Formation recognized in these studies are the lower sandy member, middle dolomite member and the equivalent Ore Hill Limestone Member, upper sandy member, and Mines Dolomite Member. On the basis of lithologic similarity, the Gatesburg Formation in the subsurface of West Virginia and its lower sandy, Ore Hill, upper sandy, and Mines members are extended in this study into the subsurface of northern Virginia.

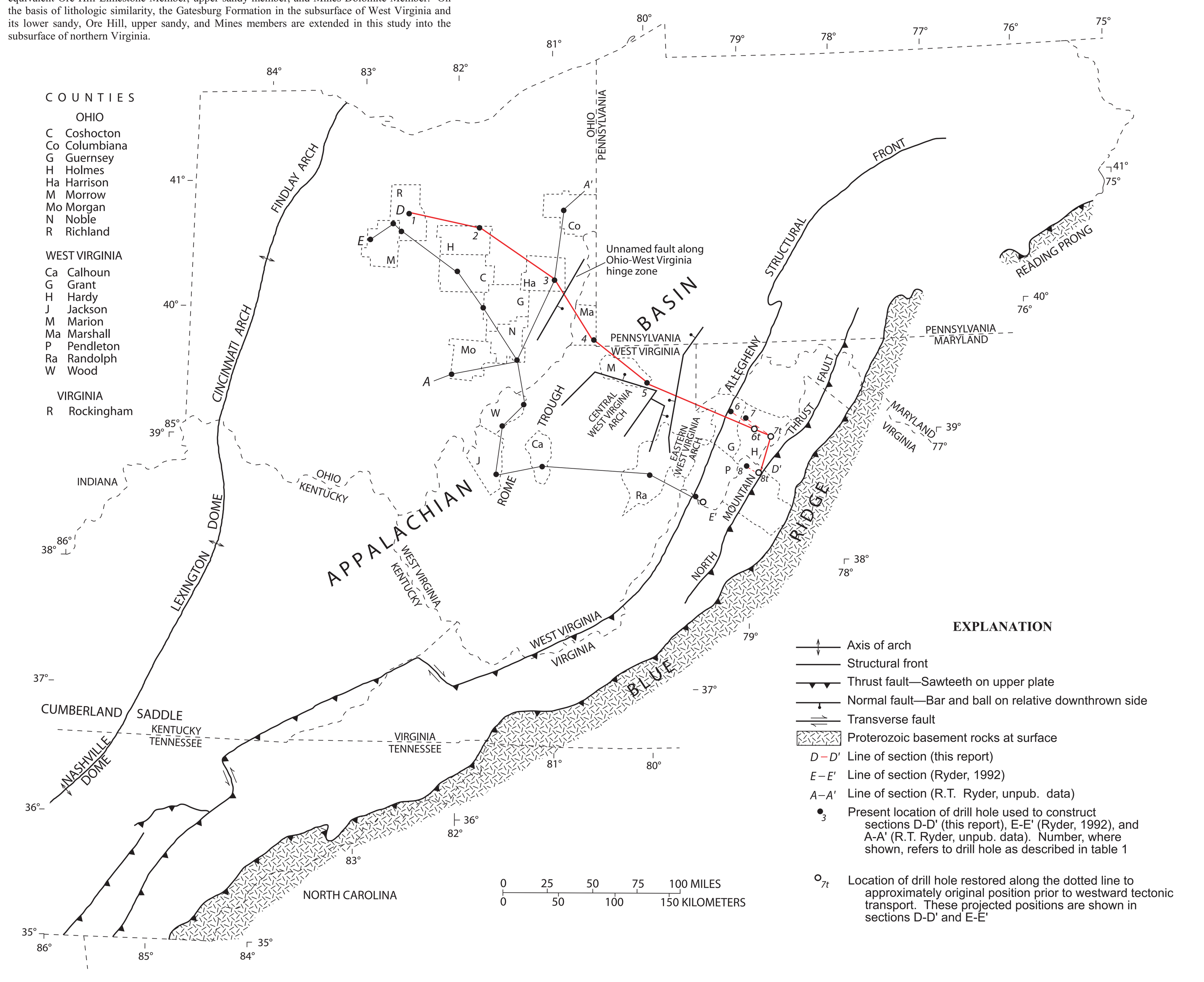

Figure 1.—Map of Ohio, West Virginia, Virginia, and adjoining States showing location of section D-D' and selected tectonic features.

Table 1.—Descriptions of drill holes used to construct section *D-D'*

Number	Name	Location	Permit number	Lithologic log	Cored intervals (formation)	Total depth (ft)	Age of oldest rocks penetrated (formation)
1	Deep Well Pollution Control Corporation No. D-1 Empire Reeves Steel Division	Madison Township, Richland Co., Ohio	448	Yes[1,2]		5,081	Late Cambrian (Mount Simon Sandstone).
2	Parker and Chapman No. 1 Troyer	Salt Creek Township, Holmes Co., Ohio	1283	Yes[1,2]		7,360	Late Cambrian (Rome Formation of Janssens, 1973).
3	McCormick No. 1 Birney	Green Township, Harrison Co., Ohio	103	Yes[1,2]		10,181	Late Cambrian? (Rose Run Sandstone).
4	Occidental Petroleum Corporation No. 1 Burley	Liberty District Marshall Co., W. Va.	539	Yes[1]		16,512	Late Cambrian (Gatesburg Formation).
5	Phillips Petroleum Company No. A-1 Finch	Winfield District, Marion Co., W. Va.	244	Yes[1,3]		17,111	Late Cambrian (Gatesburg Formation).
6	Shell Oil No. 1 Greenland Lodge	Union District, Grant Co., W. Va.	2	Yes[1]		13,000	Early and Middle Ordovician (Beekmantown Group) thrust over Early and Middle Ordovician (Beekmantown, St. Paul, and Black River Groups).
7	Exxon No. 1 Bean	Moorfield District, Hardy Co., W. Va.	21	Yes[4]	9,791-9,821 ft (Gatesburg Formation) 11,047 - 11,107 ft (Elbrook Formation)	16,075	Early Cambrian (Shady Dolomite) thrust over Early and Middle Ordovician (Beekmantown Group).
8	Shell Oil Company No. 1 Whetzel	Bergton District, Rockingham Co., Va.	W-1432	Yes[1]		14,176	Late Cambrian (Gatesburg Formation) thrust over Early and Middle Ordovician (Beekmantown, St. Paul, and Black River Groups).

Sources of lithologic logs:
¹Geological Sample Log Company, Pittsburgh, PA 15234.
²Janssens (1973).
³Wagner (1966).
⁴Exxon Company, USA.

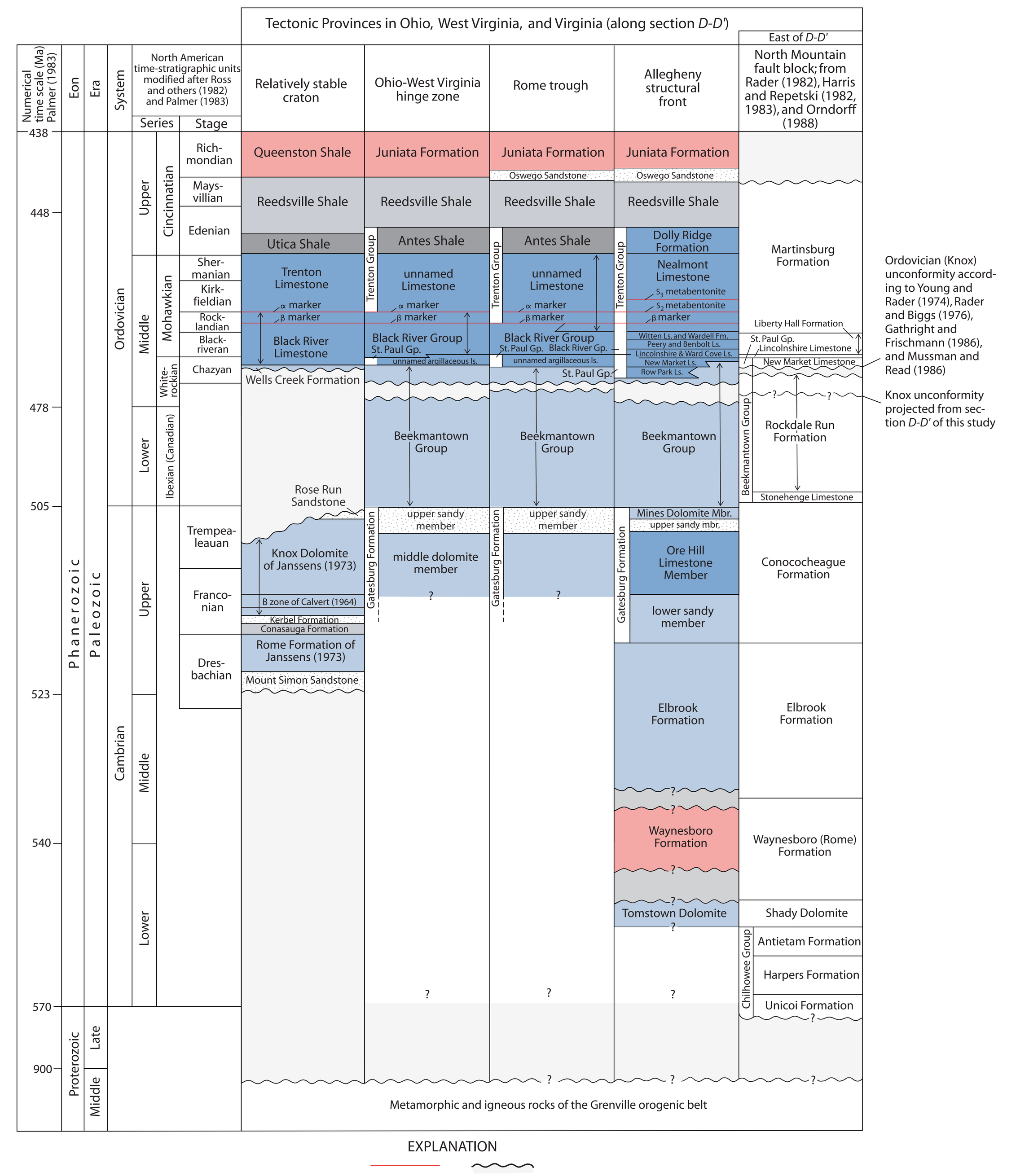

Figure 2.—Correlation chart of Middle Proterozoic, Cambrian, and Ordovician rocks along section D-D' and in the adjoining North Mountain fault block of northern Virginia.

DISCUSSION

INTRODUCTION

Cross section *D-D'* featured in this map is the second in a series of restored stratigraphic cross sections drawn by the author to show the stratigraphic framework of Cambrian and Ordovician rocks across the Appalachian basin from Pennsylvania to Tennessee. A second reason for drawing these cross sections is to better define the structure of the block-faulted Proterozoic basement rocks in the Appalachian basin. The first cross section in the series, section *E-E'* (Ryder, 1992), is situated 10 to 90 mi (16-144 km) south of section *D-D'* (see fig. 1). Section *D-D'* is about 215 mi (344 km) long, and eight drill holes, 10 to 52 mi (16-83 km) apart and 5,081 to 17,111 ft (1,549-5,215 m) deep, constitute the control (see fig. 1 and table 1). None of the eight drill holes bottomed in crystalline basement rocks of Proterozoic age. Drill holes 6, 7, and 8, located at or east of the Allegheny structural front, were restored from 5 to 30 mi (8-48 km) southeastward (fig. 1) to account for tectonic transport along underlying thrust faults (Jacobeen and Kanes, 1975; Shumaker and others, 1985).

BASEMENT STRUCTURE

Details of the block-faulted Proterozoic basement rocks underlying cross section *D-D'* are only beginning to be understood. The basement-involved normal faults and adjoining fault blocks shown on section *D-D'* are projected northward from cross section *E-E'* (fig. 1) where basement structure was interpreted from drill holes that bottomed in Proterozoic basement rocks (Cardwell, 1977) and from magnetic data (King and Zietz, 1978; Kulander and Dean, 1978). Because the basement faults underlying section *D-D'* are conjectural, they are shown as 25- to 75-mi- (40- to 120-km-) long, incomplete segments on figure 1. From northwest to southeast, section *D-D'* is interpreted here to cross the following basement-involved structures: (1) the relatively stable craton in eastern Ohio, (2) the Ohio-West Virginia hinge line, (3) the Rome trough, an extensive graben system first identified by Woodward (1961) and McGuire and Howell (1963), and (4) the Eastern West Virginia arch of Kulander and Dean (1978) (see fig. 1). Moreover, the northern end of the Central West Virginia arch (horst) of Kulander and Dean (1978) is interpreted here to terminate within several miles of section *D-D'*.

METHODOLOGY AND STRATIGRAPHIC NOMENCLATURE

Stratigraphic correlations between drill holes are based primarily on geophysical logs whereas lithofacies patterns between drill holes are based primarily on lithologic logs described by the Geological Sample Log Company (Pittsburgh, Pa.). Section *D-D'* has been restored to a horizontal datum located in the middle of the Middle Ordovician unnamed argillaceous limestone of the St. Paul Group in West Virginia. At the western end of section *D-D'* in Richland County, Ohio, the datum is located at the base of the Middle Ordovician Black River Limestone or, using local oil industry terminology, the base of the Gull River Formation.

Most of the stratigraphic nomenclature used in section *D-D'* follows the nomenclature used by Ryder (1992) in section *E-E'* (fig. 1). Existing nomenclature is preferred but in certain places modifications and additions are recommended. The following stratigraphic investigations of the Cambrian and (or) Ordovician System(s) were particularly applicable to this investigation: (1) Calvert (1962, 1963, 1965), Janssens (1973), Stith (1979), and Wickstrom and Gray (1988) in Ohio and (2) Wagner (1966, 1976) in West Virginia. The correlation chart (fig. 2) shows the specific time-stratigraphic position of the units identified in selected tectonic provinces along section *D-D'* and summarizes the nomenclature assigned to them. Moreover, for comparison, this chart shows the nomenclature and time-stratigraphic position of Cambrian and Ordovician units in the adjoining North Mountain fault block in northern Virginia.

REFERENCES CITED

Calvert, W.L., 1962, Sub-Trenton rocks from Lee County, Virginia to Fayette County, Ohio: Ohio Division of Geological Survey Report of Investigations 45, 57 p.
-------1963, Sub-Trenton rocks of Ohio in cross sections from West Virginia and Pennsylvania to Michigan: Ohio Division of Geological Survey Report of Investigations 49, 5 p.
-------1964, Cambrian erosional remnants yield oil in central Ohio: World Oil, v. 158, no. 4, p. 78, 80, 82, 84.
-------1965, Cambrian correlations in the Appalachians region, with emphasis on Ohio: Ontario Petroleum Institute, 4th Annual Conference Technical Paper 2, v. 4, 11 p.
Cardwell, D.H., 1977, West Virginia gas development in Tuscarora and deeper formations (with structural maps contoured on top of Ordovician and Precambrian): West Virginia Geological and Economic Survey Mineral Resources Series 8, 34 p.
Cooper, B.N., and Prouty, C.E., 1943, Stratigraphy of the lower Middle Ordovician of Tazewell County, Virginia: Geological Society of America Bulletin, v. 56, no. 6, p. 819-886.
Fettke, C.R., 1960, Well-sample descriptions in northwestern Pennsylvania and adjacent states: Pennsylvania Topographic and Geologic Survey Bulletin M40, 691 p.
Gathright, T.M., II, and Frischmann, P.S., 1986, Geology of the Harrisonburg and Bridgewater quadrangles, Virginia: Virginia Division of Mineral Resources Publication 60, 21 p., 1 map, scale 1:24,000.
Harris, A.G., and Repetski, J.E., 1982, Conodonts revise the Lower-Middle Ordovician boundary and timing of miogeoclinal events in the east-central Appalachian basin [abs.]: Geological Society of America Abstracts with Programs, v. 14, no. 5, p. 261.
-------1983, Conodonts document continuous to intermittent deposition across the Lower-Middle Ordovician boundary – Northern Virginia to Bellefont (sic), PA [abs.]: The Virginia Journal of Science, v. 34, no. 3, p. 172.
Jacobeen, Frank, Jr., and Kanes, W.H., 1975, Structure of Broadtop synclinorium, Wills Mountain anticlinorium and Allegheny frontal zone: American Association of Petroleum Geologists Bulletin, v. 59, no. 7, p. 1136-1150.
Janssens, Adriaan, 1973, Stratigraphy of the Cambrian and Lower Ordovician rocks in Ohio: Ohio Division of Geological Survey Bulletin 64, 197 p.
-------1977, Silurian rocks in the subsurface of northwestern Ohio: Ohio Division of Geological Survey Bulletin 100, 96 p.
Kay, G.M., 1944, Middle Ordovician of central Pennsylvania: Journal of Geology, v. 52, no. 2, p. 97-116.
Kay, Marshall, 1956, Ordovician limestones in the western anticlines of the Appalachians in West Virginia and Virginia northeast of the New River: Geological Society of America Bulletin, v. 67, no. 1, p. 55-106.
King, E.R., and Zietz, Isidore, 1978, The New York-Alabama lineament; Geophysical evidence for a major crustal break in the basement beneath the Appalachian basin: Geology, v. 6, no. 5, p. 312-318.
Kulander, B.R., and Dean, S.L., 1978, Gravity, magnetics and structure Allegheny Plateau/western Valley and Ridge in West Virginia and adjacent states: West Virginia Geological and Economic Survey Report of Investigation RI-27, 91 p., 3 sheets, scale 1:250,000.
McGuire, W.H., and Howell, Paul, 1963, Oil and gas possibilities of the Cambrian and Lower Ordovician in Kentucky: Spindletop Research Center, Lexington, Kentucky, 216 p.
Mussman, W.J., and Read, J.F., 1986, Sedimentology and development of a passive- to convergent-margin unconformity: Middle Ordovician Knox unconformity, Virginia Appalachians: Geological Society of America Bulletin, v. 97, no. 3, p. 282-295.
Orndorff, R.C., 1988, Latest Cambrian and earliest Ordovician conodonts from the Conococheague and Stonehenge Limestones of northwestern Virginia, Chapter A, *in* Sando, W.J., ed., Shorter contributions to paleontology and stratigraphy: U.S. Geological Survey Bulletin 1837, p. A1-A18.
Palmer, A.R., compiler, 1983, Decade of North American Geology 1983 Time Scale: Geology, v. 11, no. 9, p. 503-504.
Pepper, J.F., de Witt, Wallace, Jr., and Everhart, G.M., 1953, The "Clinton" sands in Canton, Dover, Massillon, and Navarre quadrangles, Ohio: U.S. Geological Survey Bulletin 1003-A, 13 p.
Perry, W.J., Jr., 1964, Geology of Ray Sponangle well, Pendleton County, West Virginia: American Association of Petroleum Geologists Bulletin, v. 48, no. 5, p. 659-669.
-------1972, The Trenton Group of Nittany anticlinorium, eastern West Virginia: West Virginia Geological and Economic Survey Circular 13, 30 p.
Rader, E.K., 1982, Valley and Ridge stratigraphic correlations, Virginia: Virginia Division of Mineral Resources Publication 37, 1 sheet.
Rader, E.K., and Biggs, T.H., 1976, Geology of the Strasburg and Toms Brook quadrangles, Virginia: Virginia Division of Mineral Resources Report of Investigations 45, 104 p., 2 maps, scale 1:24,000.
Read, J.F., 1980, Carbonate ramp-to-basin transitions and foreland basin evolution, Middle Ordovician, Virginia Appalachians: American Association of Petroleum Geologists Bulletin, v. 64, no. 10, p. 1575-1612.
Ryder, R.T., 1992, Stratigraphic framework of Cambrian and Ordovician rocks in the central Appalachian basin from Morrow County, Ohio, to Pendleton County, West Virginia: U.S. Geological Survey Bulletin 1839-G, p. G1-G25.
Shumaker, R.C., Wilson, T.H., Dunne, W.M., Knotts, Joseph, and Buckley, Rex, 1985, Chapter I-Pennsylvania, Virginia and West Virginia sections, *in* Woodward, N.B., ed., Valley and Ridge thrust belt; Balanced structural sections, Pennsylvania to Alabama: University of Tennessee Studies in Geology 12, p. 6-35.
Stith, D.A., 1979, Chemical composition, stratigraphy, and depositional environments of the Black River Group (Middle Ordovician), southwestern Ohio: Ohio Division of Geological Survey Report of Investigations 113, 36 p.
Sweet, W.C., and Bergström, S.M., 1976, Conodont biostratigraphy of the Middle and Upper Ordovician of the United States midcontinent, *in* Bassett, M.G., ed., The Ordovician System, Proceedings of Paleontological Association Symposium, Birmingham, England, 1974: University of Wales Press, p. 121-151.
Wagner, W.R., 1966, Stratigraphy of the Cambrian to Middle Ordovician rocks of central and western Pennsylvania: Pennsylvania Geological Survey Bulletin G49, 156 p.
-------1976, Growth faults in Cambrian and Lower Ordovician rocks of western Pennsylvania: American Association of Petroleum Geologists Bulletin, v. 60, no. 3, p. 414-427.
Wickstrom, L.H., and Gray, J.D., 1988, Geology of the Trenton Limestone in northwestern Ohio, *in* Keith, B.D., ed., The Trenton Group (Upper Ordovician Series) of eastern North America; Deposition, diagenesis, and petroleum: American Association of Petroleum Geologists Studies in Geology Series 29, p. 159-172.
Wilson, J.L., 1952, Upper Cambrian stratigraphy in the central Appalachians: Geological Society of America Bulletin, v. 63, no. 3, p. 275-322.
Woodward, H.P., 1961, Preliminary subsurface study of southeastern Appalachian Interior Plateau: American Association of Petroleum Geologists Bulletin, v. 45, no. 10, p. 1634-1655.
Young, R.S., and Rader, E.K., 1974, Geology of the Woodstock, Wolf Gap, Conicville, and Edinburg quadrangles, Virginia: Virginia Division of Mineral Resources Report of Investigations 35, 69 p., 4 maps, scale 1:24,000.

Manuscript approved for publication October 9, 1990

STRATIGRAPHIC FRAMEWORK OF CAMBRIAN AND ORDOVICIAN ROCKS IN THE CENTRAL APPALACHIAN BASIN FROM RICHLAND COUNTY, OHIO, TO ROCKINGHAM COUNTY, VIRGINIA

By
Robert T. Ryder
1991
Revised and Digitized By
Robert D. Crangle, Jr.
2002

For sale by U.S. Geological Survey, Map Distribution, Box 25286, Federal Center, Denver, CO 80225