U.S. DEPARTMENT OF THE INTERIOR ALLEGHENY STRUCTURAL FRONT U.S. GEOLOGICAL SURVEY ROME TROUGH OHIO — WEST VIRGINIA HINGE ZONE Imbricate thrust fault in Broadtop Thrust fault underlying Bergton-Crab Thrust fault underlying Broadtop block of Shumaker and others (1985); Run block of Shumaker and others block of Shumaker and others (1985); 1-5 mi shortening (Shumaker and oth-(1985); 4-5 mi shortening (Shumaker 15-20 mi shortening (Jacobeen and and others, 1985) Kanes, 1975; Shumaker and others, Exxon No. 1 Bean Shell Oil Company Hardy Co., W.Va. No. 1 Greenland Lodge Shell Oil Company No. 1 Whetzel Grant Co., W.Va. Rockingham Co., Va. Occidental Petroleum Corp. position; bed thick-No. 1 Burley (Restored to original position about (Restored to original position; nesses not corrected bed thicknesses not corrected for dip) Marshall Co., W. Va. 25-30 mi southwest of Allegheny structural front (Shumaker and others, 1985)) Phillips Petroleum Company McCormick Parker and Chapman No. A-1 Finch No. 1 Birney Marion Co., W., Va Deep Well Pollution Control Corp Holmes Co., Ohio No. D-1 Empire Reeves Steel Div. Tuscarora Sandstone Richland Co., Ohio 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 Packer shell of Pepper 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 "Clinton" sandstone 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, SILURIAN 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 ORDOVICIAN 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 ORDOVICIAN Central West Virginia arch (horst) of Kulander and Dean (1978) is interpreted here to terminate ß marker of Stith (1979) within several miles of section *D-D*'. ORDOVICIAN METHODOLOGY AND STRATIGRAPHIC NOMENCLATURE Wells Creek Formation 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 TD 5081 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 / Mount Simon Sandstone modifications and additions are recommended. The following stratigraphic investigations of the Cambrian and (or) Ordovician System(s) were particularly applicable to this investigation: (1) ORDOVICIAN 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 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 time-stratigraphic position of the units identified in selected tectonic provinces along section D-D' **EXPLANATION** \triangle Mines Dolomite Member $\triangle \Diamond \triangle \uparrow \Diamond \triangle$ and summarizes the nomenclature assigned to them. Moreover, for comparison, this chart shows subsurface of northern West Virginia. The Antes Shale is assigned an early Late Ordovician SEDIMENTARY ROCKS the nomenclature and time-stratigraphic position of Cambrian and Ordovician units in the adjoining (Edenian) age in this study and by Ryder (1992) on the basis of conodont studies and North Mountain fault block in northern Virginia. correlations of Middle and Late Ordovician strata in the Eastern United States by Sweet and Dominant Lithology (Used in conjunction with Dominant Lithology) 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, Sandstone, red 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 __ — Argillaceous; gray and (or) green Shale, gray and (or) green Calvert, W.L., 1962, Sub-Trenton rocks from Lee County, Virginia to Fayette County, Ohio: Ohio West Virginia by Perry (1972) and assigned a Middle Ordovician age. Rader (1982) and Ryder Division of Geological Survey Report of Investigations 45, 57 p. (1992) extended the Dolly Ridge Formation into Virginia and the subsurface of West Virginia, — R Argillaceous; red -----1963, Sub-Trenton rocks of Ohio in cross sections from West Virginia and Pennsylvania respectively. The Dolly Ridge Formation in this study is assigned an early Late Ordovician to Michigan: Ohio Division of Geological Survey Report of Investigations 49, 5 p. (Edenian) age because it correlates with the Antes and Utica Shales (see footnotes 1 and 3). -----1964, Cambrian erosional remnants yield oil in central Ohio: World Oil, v. 158, no. 4, p. Argillaceous; dark gray and (or) black Shale, dark gray and (or) black ⁵The Trenton Group of Kay (1944) in central Pennsylvania consists, in ascending order, of the -----1965, Cambrian correlations in the Appalachians region, with emphasis on Ohio: Ontario Nealmont Limestone, Salona Limestone, Coburn Limestone, and Antes Shale. Kay (1944) Green shale Petroleum Institute, 4th Annual Conference Technical Paper 2, v. 4, 11 p. assigned a Middle Ordovician age to the Trenton Group. A Middle and Late Ordovician age is Cardwell, D.H., 1977, West Virginia gas development in Tuscarora and deeper formations (with assigned to the Trenton Group of Kay (1944) in this study because Sweet and Bergström (1976) structural maps contoured on top of Ordovician and Precambrian): West Virginia Geological reassigned the Antes Shale and the uppermost part of the Coburn Limestone a Late Ordovician age. and Economic Survey Mineral Resources Series 8, 34 p. In this study, the Trenton Group of Kay (1944) consists of an unnamed limestone (equivalent to Cooper, B.N., and Prouty, C.E., 1943, Stratigraphy of the lower Middle Ordovician of Tazewell Nealmont, Salona, and Coburn) and the Antes Shale. County, Virginia: Geological Society of America Bulletin, v. 56, no. 6, p. 819-886. ----- Metabentonite Fettke, C.R., 1960, Well-sample descriptions in northwestern Pennsylvania and adjacent states: ⁶The Trenton Group of Perry (1972) consists of the Nealmont Limestone (correlated by Ryder, Pennsylvania Topographic and Geologic Survey Bulletin M40, 691 p. 1992, with the Nealmont, Salona, and Coburn Limestones of Kay, 1944) and the Dolly Ridge CAMBRIAN Gathright, T.M., II, and Frischmann, P.S., 1986, Geology of the Harrisonburg and Bridgewater Formation (correlated in this study with the Antes Shale of Kay, 1944). The Nealmont Limestone quadrangles, Virginia: Virginia Division of Mineral Resources Publication 60, 21 p., 1 map, 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). Harris, A.G., and Repetski, J.E., 1982, Conodonts revise the Lower-Middle Ordovician boundary The Dolly Ridge Formation is assigned a Late Ordovician age because it correlates with the Antes PROTEROZOIC and timing of miogeoclinal events in the east-central Appalachian basin [abs.]: Geological Shale (see footnotes 1 and 4). For reasons cited above, a Middle and Late Ordovician age is assigned Society of America Abstracts with Programs, v. 14, no. 5, p. 261. OTHER SYMBOLS -----1983, Conodonts document continuous to intermittent deposition across the Lower-Middle here to the Trenton Group of Perry (1972). Manuscript approved for publication October 9, 1990 Ordovician boundary - Northern Virginia to Bellefont (sic), PA [abs.]: The Virginia Journal of ———— Contact—Queried where uncertain ⁷The Lincolnshire Limestone, Ward Cove Limestone, Peery Limestone, Benbolt Limestone, Science, v. 34, no. 3, p. 172. Wardell Formation, and Witten Limestone were first named in Virginia (Cooper and Prouty, 1943). Jacobeen, Frank, Jr., and Kanes, W.H., 1975, Structure of Broadtop synclinorium, Wills Mountain ———— Informal marker bed—Queried where uncertain The Lincolnshire, Ward Cove, Peery, and Benbolt Limestones have been extended into West anticlinorium and Allegheny frontal zone: American Association of Petroleum Geologists Virginia by Kay (1956) and Read (1980), and the Wardell Formation and Witten Limestone have Bulletin, v. 59, no. 7, p. 1136-1150. Unconformity—Queried where uncertain been extended into West Virginia by Read (1980). Kay (1956) and Perry (1964) applied the names Janssens, Adriaan, 1973, Stratigraphy of the Cambrian and Lower Ordovician rocks in Ohio: Ohio Eastern West Virginia arch of Kulander and Dean (1978) McGlone Limestone and McGraw Limestone, respectively, to the intervals assigned by Read Division of Geological Survey Bulletin 64, 197 p. ——— Datum—Micritic limestone at base of Black River Limestone and near (1980) in West Virginia to the Wardell Formation and Witten Limestone. Following Kay (1956) -----1977, Silurian rocks in the subsurface of northwestern Ohio: Ohio Division of Geological middle part of unnamed argillaceous limestone of St. Paul Group and Read (1980), the names Lincolnshire, Ward Cove, Peery, and Benbolt Limestones have been Survey Bulletin 100, 96 p. extended into the subsurface of West Virginia in this study and in Ryder (1992). Moreover, the Kay, G.M., 1944, Middle Ordovician of central Pennsylvania: Journal of Geology, v. 52, no. 2, p. Cored intervals in drill hole 7t 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, Kay, Marshall, 1956, Ordovician limestones in the western anticlines of the Appalachians in West ——— Normal fault—Arrow shows relative movement. Faulting offsets only Middle thus, are extended into the subsurface of West Virginia in this study and in Ryder (1992). Virginia and Virginia northeast of the New River: Geological Society of America Bulletin, v. Proterozoic through Middle Cambrian rocks in the lower part of section *D-D'* 67, no. 1, p. 55-106. ⁸The Lower and Middle Ordovician age assigned here to the Beekmantown Group in the King, E.R., and Zietz, Isidore, 1978, The New York-Alabama lineament; Geophysical evidence for Thrust faults of the Alleghanian orogeny—Postdate restored section *D-D'* subsurface of West Virginia follows Wagner (1966) and Ryder (1992). a major crustal break in the basement beneath the Appalachian basin: Geology, v. 6, no. 5, p. ⁹Ryder (1992) assigned a Late Cambrian age to the Rose Run Sandstone because it Kulander, B.R., and Dean, S.L., 1978, Gravity, magnetics and structure Allegheny Plateau/western correlates with the upper sandy member of the Upper Cambrian Gatesburg Formation (Wilson, Valley and Ridge in West Virginia and adjacent states: West Virginia Geological and Gamma-ray curve.—Log scale generally from 0 to 200 API units 30 KILOMETERS 1952; Wagner, 1966). 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 ~~~;~~~ Tectonic Provinces in Ohio, West Virginia, and Virginia (along section D-D') Ordovician in Kentucky: Spindletop Research Center, Lexington, Kentucky, 216 p. ¹⁰Wagner (1966, 1976) and Ryder (1992) recognized the Gatesburg Formation in the subsurface of northern and eastern West Virginia. Subdivisions of the Gatesburg Formation Mussman, W.J., and Read, J.F., 1986, Sedimentology and development of a passive- to convergent-North Mountain recognized in these studies are the lower sandy member, middle dolomite member and the margin unconformity: Middle Ordovician Knox unconformity, Virginia Appalachians: North American fault block; from equivalent Ore Hill Limestone Member, upper sandy member, and Mines Dolomite Member. On Geological Society of America Bulletin, v. 97, no. 3, p. 282-295. ~~~?~~~ modified after Ross and others (1982) Ohio-West Virginia | Rader (1982), Harris the basis of lithologic similarity, the Gatesburg Formation in the subsurface of West Virginia and Rome trough Orndorff, R.C., 1988, Latest Cambrian and earliest Ordovician conodonts from the Conococheague and Repetski (1982, its lower sandy, Ore Hill, upper sandy, and Mines members are extended in this study into the craton and Stonehenge Limestones of northwestern Virginia, Chapter A, in Sando, W.J., ed., Shorter and Palmer (1983) 1983), and Orndorff subsurface of northern Virginia. contributions to paleontology and stratigraphy: U.S. Geological Survey Bulletin 1837, p. A1-(1988) Palmer, A.R., compiler, 1983, Decade of North American Geology 1983 Time Scale: Geology, v. Queenston Shale | Juniata Formation | Juniata Formation | Juniata Formation 11, no. 9, p. 503-504. Pepper, J.F., de Witt, Wallace, Jr., and Everhart, G.M., 1953, The "Clinton" sands in Canton, COUNTIES Dover, Massillon, and Navarre quadrangles, Ohio: U.S. Geological Survey Bulletin 1003-A, 13 OHIO Reedsville Shale | Reedsville Sh Perry, W.J., Jr., 1964, Geology of Ray Sponangle well, Pendleton County, West Virginia: C Coshocton American Association of Petroleum Geologists Bulletin, v. 48, no. 5, p. 659-669. Co Columbiana -----1972, The Trenton Group of Nittany anticlinorium, eastern West Virginia: West Virginia Antes Shale Antes Shale G Guernsey Geological and Economic Survey Circular 13, 30 p. H Holmes Ordovician (Knox) Rader, E.K., 1982, Valley and Ridge stratigraphic correlations, Virginia: Virginia Division of Ha Harrison unconformity accord-Mineral Resources Publication 37, 1 sheet. Limestone M Morrow ing to Young and Rader, E.K., and Biggs, T.H., 1976, Geology of the Strasburg and Toms Brook quadrangles, Mo Morgan Rader (1974), Rader Virginia: Virginia Division of Mineral Resources Report of Investigations 45, 104 p., 2 maps, N Noble and Biggs (1976), **Table 1.**—Descriptions of drill holes used to construct section *D-D'* Liberty Hall Formation scale 1:24,000. R Richland Gathright and Black River Group Read, J.F., 1980, Carbonate ramp-to-basin transitions and foreland basin evolution, Middle Frischmann (1986), WEST VIRGINIA Permit Lithologic Cored intervals Age of oldest rocks Ordovician, Virginia Appalachians: American Association of Petroleum Geologists Bulletin, v. and Mussman and Ohio-West Virginia, number log (formation) Total depth (ft) penetrated (formation) Location Read (1986) 64, no. 10, p. 1575-1612. Ca Calhoun hinge zone Ryder, R.T., 1992, Stratigraphic framework of Cambrian and Ordovician rocks in the central Knox unconformity H Hardy Appalachian basin from Morrow County, Ohio, to Pendleton County, West Virginia: U.S. Deep Well Pollution Madison Township, Late Cambrian projected from sec-Control Corporation Richland Co., Ohio (Mount Simon Sandstone). Geological Survey Bulletin 1839-G, p. G1-G25. Jackson tion *D-D'* of this study Shumaker, R.C., Wilson, T.H., Dunne, W.M., Knotts, Joseph, and Buckley, Rex, 1985, Chapter I-M Marion No. D-1 Empire Beekmantown Formation Pennsylvania, Virginia and West Virginia sections, in Woodward, N.B., ed., Valley and Ridge Ma Marshall Reeves Steel Division thrust belt; Balanced structural sections, Pennsylvania to Alabama: University of Tennessee P Pendleton Parker and Chapman Salt Creek Township, 1283 Yes^{1,2} Late Cambrian Studies in Geology 12, p. 6-35. Holmes Co., Ohio (Rome Formation of Janssens, Stith, D.A., 1979, Chemical composition, stratigraphy, and depositional environments of the Black W Wood River Group (Middle Ordovician), southwestern Ohio: Ohio Division of Geological Survey Sandstone VIRGINIA upper sandy member Mines Dolomite Mbr. Report of Investigations 113, 36 p. upper sandy 5 member # 10,181 Late Cambrian? McCormick Sweet, W.C., and Bergström, S.M., 1976, Conodont biostratigraphy of the Middle and Upper R Rockingham Ordovician of the United States midcontinent, in Bassett, M.G., ed., The Ordovician System, Ore Hill Proceedings of Paleontological Association Symposium, Birmingham, England, 1974: Occidental Petroleum Liberty District 16,512 Late Cambrian Limestone Member Conococheague of Janssens (1973) University of Wales Press, p. 121-151. Corporation Marshall Co., W. Va. (Gatesburg Formation). Wagner, W.R., 1966, Stratigraphy of the Cambrian to Middle Ordovician rocks of central and No. 1 Burley Phanerozo western Pennsylvania: Pennsylvania Geological Survey Bulletin G49, 156 p. lower sandy -----1976, Growth faults in Cambrian and Lower Ordovician rocks of western Pennsylvania. Phillips Petroleum Winfield District, Late Cambrian member Company No. A-1 Marion Co., W. Va. (Gatesburg Formation). 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 Rome Formation of Keith, B.D., ed., The Trenton Group (Upper Ordovician Series) of eastern North America; Janssens (1973) Deposition, diagenesis, and petroleum: American Association of Petroleum Geologists Studies Union District, Early and Middle Greenland Lodge Grant Co., W. Va. Ordovician (Beekmantown in Geology Series 29, p. 159-172. Group) thrust over Early Wilson, J.L., 1952, Upper Cambrian stratigraphy in the central Appalachians: Geological Society of America Bulletin, v. 63, no. 3, p. 275-322. and Middle Ordovician Formation (Beekmantown, St. Paul, Woodward, H.P., 1961, Preliminary subsurface study of southeastern Appalachian Interior Plateau: and Black River Groups). 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 Exxon No. 1 Bean Moorfield District, 9,791-9,821 ft Early Cambrian Edinburg quadrangles, Virginia: Virginia Division of Mineral Resources Report of **EXPLANATION** Hardy Co., W. Va. (Gatesburg (Shady Dolomite) Investigations 35, 69 p., 4 maps, scale 1:24,000. Axis of arch Formation) thrust over Early ~~!~~ 11,047 - 11,107 ft and Middle Ordovician ~~!~~ — Structural front (Beekmantown Group). (Elbrook Formation) Thrust fault—Sawteeth on upper plate Shell Oil Company Bergton District, W-1432 Yes¹ Waynesboro (Rome Late Cambrian (Gatesburg Formation Normal fault—Bar and ball on relative downthrown side Formation No. 1 Whetzel Rockingham Co., Va. Formation) thrust over CUMBERLAND SADDLE Early and Middle ~~?~~ Transverse fault Ordovician (Beekmantowr _KENTUCKY Proterozoic basement rocks at surface St. Paul, and Black River Groups). Shady Dolomite D-D' Line of section (this report) Tomstown Dolomite E-E' Line of section (Ryder, 1992) Sources of lithologic logs: Antietam Formation ¹Geological Sample Log Company, Pittsburgh, PA 15234. A-A' Line of section (R.T. Ryder, unpub. data) ²Janssens (1973). ³Wagner (1966). Harpers Formation Present location of drill hole used to construct ⁴Exxon Company, USA. sections D-D' (this report), E-E' (Ryder, 1992), and A-A' (R.T. Ryder, unpub. data). Number, where Unicoi Formation shown, refers to drill hole as described in table 1 Location of drill hole restored along the dotted line to approximately original position prior to westward tectonic NORTH CAROLINA transport. These projected positions are shown in sections D-D' and E-E' Metamorphic and igneous rocks of the Grenville orogenic belt EXPLANATION ~~~

Figure 1.—Map of Ohio, West Virginia, Virginia, and adjoining States showing location

of section D-D' and selected tectonic features.

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

Metabentonite Hiatus

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.

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

MISCELLANEOUS INVESTIGATIONS SERIES

DISCUSSION

INTRODUCTION

BASEMENT STRUCTURE

REFERENCES CITED