Geologic Cross Section *E–E′* through the Appalachian Basin from the Findlay Arch, Wood County, Ohio, to the Valley and Ridge Province, Pendleton County, West Virginia

By Robert T. Ryder, Christopher S. Swezey, Robert D. Crangle, Jr., and Michael H. Trippi

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Contents

Figures

[On map sheet 1]

Table

[On map sheet 1]

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Introduction

Geologic cross section *E–E′* is the first in a series of cross sections planned by the U.S. Geological Survey (USGS) to document and improve understanding of the geologic framework and petroleum systems of the Appalachian basin. Cross section *E–E′* provides a regional view of the structural and stratigraphic framework of the basin from the Findlay arch in northwestern Ohio to the Valley and Ridge province in eastern West Virginia, a distance of approximately 380 miles (mi) (fig. 1, on sheet 1). Cross section *E–E′* updates earlier geologic cross sections through the central Appalachian basin by Renfro and Feray (1970), Bennison (1978), and Bally and Snelson (1980) and a stratigraphic cross section by Colton (1970). Although other published cross sections through parts of the basin show more structural detail (for example, Shumaker, 1985; Kulander and Dean, 1986) and stratigraphic detail (for example, Ryder, 1992; de Witt and others, 1993; Hettinger, 2001), these other cross sections are of more limited extent geographically and stratigraphically.

Although specific petroleum systems in the Appalachian basin are not identified on the cross section, many of their key elements (such as source rocks, reservoir rocks, seals, and traps) can be inferred from lithologic units, unconformities, and geologic structures shown on the cross section. Other aspects of petroleum systems (such as the timing of petroleum generation and preferred migration pathways) may be evaluated by burial history, thermal history, and fluid flow models based on information shown on the cross section.

Cross section *E–E′* lacks the detail to illustrate key elements of coal systems (such as paleoclimate, coal quality, and coal rank), but it does provide a general framework (stratigraphic units and general rock types) for the coal-bearing section. Also, cross section *E–E′* may be used as a reconnaissance tool to identify plausible geologic structures and strata for the subsurface storage of liquid waste (for example, Colton, 1961; Lloyd and Reid, 1990) or for the sequestration of carbon dioxide (for example, Smith and others, 2002; Lucier and others, 2006).

Construction of the Cross Section

Cross section *E–E′* is oriented northwest-southeast, approximately normal to the structural grain of the basin. Several abrupt bends in the section, however, are required to accommodate key drill holes that penetrate the entire Paleozoic sedimentary section. Cross section *E–E′* follows the same line of section used by Ryder (1992) in his stratigraphic study of Cambrian and Ordovician rocks, but four drill holes have been added at the northwestern end of the section (fig. 1, on sheet 1; table 1, on sheet 1).

Cross section *E–E′* is based on geological and geophysical data from 16 deep drill holes, most of which penetrate the Paleozoic sedimentary rocks of the basin and bottom in Mesoproterozoic (Grenville-age) crystalline basement rocks. The locations of the tops of each stratigraphic unit penetrated in the 16 drill holes were converted from depth in feet (ft) below kelly bushing (KB) to depth below ground level (GL), and then plotted on the cross section with respect to mean sea level (MSL). Detailed depth information for the tops of the stratigraphic units in each drill hole is reported in Appendix A. In addition to the 16 deep drill holes used to construct the cross section (table 1), some of the details of Pennsylvanian stratigraphy were obtained from one “shallow” corehole (Dulong and others, 2002). Data from this corehole were projected into the cross section from a locality near drill hole 14. In addition, data were obtained from shallow coreholes near drill holes 9 and 10 (Couchot and others, 1980) and from selected wells near drill hole 15 (Schwietering, 1980; K.L. Avary, West Virginia Geological and Economic Survey, written commun., 2004).

The correlation of stratigraphic intervals between drill holes was based on a variety of geophysical (wireline) and lithologic logs. The most commonly used geophysical logs were the gamma-ray-neutron and gamma-ray-density log suites, and the most commonly used lithologic logs were those produced by the Geological Sample Log Company (table 1; Appendix B). Gamma-ray logs used for correlations were digitized as Log ASCII files (LAS), converted to graphic images, and then plotted next to their respective drill holes (Crangle, 2007). The lithology assigned to each stratigraphic interval was simplified to just a few rock types and lithologic modifiers. The topographic profile for the cross section was created from a Shuttle Radar Topography Mission (SRTM) 90-meter (m)-grid digital elevation model (DEM) for parts of Ohio, Pennsylvania, West Virginia, Maryland, and Virginia (http://gisdata.usgs.gov/website/seamless/index.asp). This topographic profile is approximate and should not be used to determine accurate surface elevations.

Although most correlations shown on section *E–E′* are based on our own interpretations, many correlations are adopted or modified from previous publications, and stratigraphic nomenclature follows existing terminology wherever possible. Useful references for stratigraphic correlations and (or) nomenclature include the following: Colton (1970), Patchen and others (1985), Milici and de Witt (1988), Swezey (2002), and Slucher (2004) for the entire Paleozoic section; Diecchio (1985), Filer (1985), Janssens (1973), Riley and Baranoski (1991a,b), Ryder (1992), Wickstrom and others (1992), Riley and others (1993), and Harris and others (2004) for the Cambrian-Ordovician rocks; Clifford (1973), Janssens (1977), Smosna and others (1977), Hettinger (2001), and Ryder (2004) for the Silurian rocks; Dennison (1970), Majchszak (1980a,b,c), Schweitering (1980), Filer (1985, 2002, 2003), Boswell and others (1987), Boswell (1988a,b), Dennison and others (1988), and de Witt and others (1993) for the Devonian rocks; Couchot and others (1980), Majchszak (1984), Filer (1985), Sweeney (1986), Hohn (1996), Vargo and Matchen (1996), and Dulong and others (2002) for the Mississippian and Pennsylvanian rocks. A summary of the stratigraphic units identified along section *E–E′* is shown in figure 2 (on sheet 1).

Only selected unconformities are shown on cross section *E–E′*. Regional unconformities shown on section *E–E′* and in figure 2 include the Middle Ordovician (Knox) unconformity (Harris and Repetski, 1982; Mussman and others, 1988), the Upper Ordovician-Lower Silurian Cherokee unconformity (Dennison and Head, 1975; Diecchio and Brodersen, 1994), the Middle-Upper Devonian unconformity (de Witt and others, 1993), and the Lower Pennsylvanian unconformity (Arkle and others, 1979; Beuthin, 1994). The correlation of these unconformities with North American sequences of Sloss (1988) is shown in figure 2 and by Swezey (2002).

Basement-involved structures along cross section *E–E′* are modified from structure contour maps by Shumaker (1996) and Baranoski (2002) and from seismic-based interpretations by Beardsley and Cable (1983) and Beardsley (1997). High-amplitude, complex, thin-skinned ramp anticlines (Elkins Valley, Horton, and Wills Mountain) near the Allegheny structural front were constructed on section *E–E′* on the basis of interpretations by Perry (1978) and Shumaker (1985). Low-amplitude anticlines in central West Virginia are based on a structural contour map by Cardwell (1982) on top of the Devonian Onondaga Limestone-Huntersville Chert. The Burning Springs anticline near the Ohio-West Virginia border is the westernmost thin-skinned ramp anticline shown on the cross section. Because cross section *E–E′* shows only the western flank of the west-verging Burning Springs anticline along a northerly profile that is highly oblique to the direction of structural transport, it differs from the cross sections by Filer (1985) and Morris (1990) that show both flanks of the anticline along east-west profiles that are subparallel to the direction of tectonic transport. Northwest of the Burning Springs anticline, structural dip along the cross section is largely determined by connecting equivalent formation tops between drill holes. However, in Ohio the regional dip is locally defined by structural contour maps of Gray (1982a,b) on the top of the Devonian-Mississippian Berea Sandstone and the Devonian Onondaga Limestone. Where applicable, stratigraphic units on the cross section are tied to the outcrop using the geologic maps of Ohio (Slucher and others, 2006) and West Virginia (Cardwell and others, 1968).

Structural Framework

The Wills Mountain anticline marks the western margin of the Valley and Ridge province (fig. 1), where a thick panel of Cambrian-Ordovician carbonate rocks was decoupled from underlying strata and thrust 8 to 10 mi westward up a major tectonic (footwall) ramp. This ramp, of which only the upper part is shown on the cross section, connects the basal zone of detachment (footwall flat) in the Lower Cambrian Waynesboro Formation with a higher zone of detachment (hanging wall flat) in the Upper Ordovician Reedsville Shale (thrust fault terminology from McClay, 1992). A net structural relief of about 2 mi was created by the duplicated Cambrian Elbrook Dolomite in the anticline. Another consequence of this major structural dislocation is the juxtaposition of steeply dipping lower Paleozoic carbonate and siliciclastic rocks of the Wills Mountain anticline against less deformed upper Paleozoic rocks of the Allegheny Plateau province (Kulander and Dean, 1986) (fig. 1). This abrupt juxtaposition of structural styles defines the Allegheny structural front.

Basement-involved and thin-skinned (terminology from Rodgers, 1949) structures are shown on cross section *E–E′*, and their geometry, style, and timing are briefly discussed. More detailed treatments of the structural styles of the central Appalachian basin are presented by Kulander and Dean (1986), Faill (1998), and Scanlin and Engelder (2003). The basement structures are largely extensional in origin, and several of them may have evolved during the Neoproterozoic-earliest Cambrian rifting of the eastern continental margin of North America (Rankin and others, 1989; Thomas, 1991). This rifting event was followed by the opening of the Iapetus Ocean and the construction of a passive margin along the east side of North America (Rankin and others, 1989; Thomas, 1991). A Middle Cambrian event, which was more moderate in scale than the Neoproterozoic-earliest Cambrian event, formed the Rome trough about 200 mi inland of the evolving passive margin (Beardsley and Cable, 1983; Read, 1989a,b; Shumaker, 1996). In contrast, the major thin-skinned structures are contractional in origin and probably developed during Late Mississippian-Permian continental collision (Alleghanian orogeny) between eastern North America and Africa (Rodgers, 1988; Hatcher and others, 1989). Crustal contraction that accompanied the collision caused large horizontal displacements of thick, competent panels of Paleozoic strata along thin, incompetent strata. Typical Appalachian thin-skinned structures are bedding-plane detachment zones, footwall ramps, ramp anticlines, and imbricate thrust faults (Gwinn, 1964; Shumaker, 1985; Kulander and Dean, 1986). In places, the Alleghanian orogeny reactivated basement faults and locally inverted the Rome trough (Harris, 1978; Shumaker and Wilson, 1996; Scanlin and Engelder, 2003; Kulander and Ryder, 2005).

Basement Structures

Basement rocks along cross section *E–E′* consist largely of granitic igneous and metamorphic rocks of the subsurface extension of the Grenville province (Rankin and others, 1993). Most isotopic ages of these rocks range between 950 and 1,350 Ma, and many ages cluster around 1,000 to 1,100 Ma (Rankin and others, 1993) (fig. 2). Lidiak and others (1966) reported a Rb-Sr age of 860 Ma for biotite granite in drill hole 5 and a K-Ar age of 850 Ma for granodiorite gneiss in drill hole 11. Although these ages reported by Lidiak and others (1966) are younger than the 950 Ma upper limit of Grenville basement rocks suggested by Rankin and others (1993), they are grouped in this report with rocks of the Grenville province (fig. 2). Basement rocks in drill holes 12 to 14 are described, respectively, as granite gneiss, gneiss and granite, and quartz-oligoclase-biotite gneiss that contains graphite and sillimanite (King and others, 1998). Van Schmus and others (1996) reported a Sm-Nd age of 1,272±32 Ma for gabbro basement in drill hole 3 (see Wickstrom and others, 1985 for a description of the rocks in the drill hole) but could not explain the absence of Grenville-age (Mesoproterozoic) penetrative deformation and associated resetting of the apparent age. The western margin of the Grenville province is marked by the Grenville front (fig. 1) along which intensely deformed Grenville-age metamorphic and igneous rocks (commonly characterized by west-verging thrust faults, Culotta and others, 1990) are juxtaposed against mildly deformed 1,470-Ma rocks of the eastern granite-rhyolite province (fig. 1). The basement-involved Bowling Green fault zone, located about 2 mi west of the northwestern end of the cross section, coincides with the Grenville front (fig. 1; Baranoski and Wickstrom, 1991; Wickstrom and others, 1992; Baranoski, 2002).

The Coshocton zone, a 50- to 60-mi-wide zone of east-verging penetrative deformation in the Grenville basement, is located in the eastern Ohio and western West Virginia part of cross section *E–E′*, approximately between drill holes 8 and 13. Identified by Culotta and others (1990) from deep seismic reflections on COCORP profiles, this zone is interpreted by them to mark the site of an intra-Grenville province suture zone. Younger basement structures discussed in the following paragraphs have no relation with structures in the Coshocton zone.

Typical of many foreland basins, the basement of the Appalachian basin forms a homoclinal ramp that dips gently southeastward from the interior craton to the external margin of the fold and thrust belt. Along section *E–E′*, this basement ramp deepens progressively southeastward from about 2,000 ft below mean sea level (MSL) beneath the Findlay arch to about 21,500 ft below MSL beneath the Allegheny structural front.

Near drill holes 6 and 7 in central Ohio, a subtle inflection point or hinge zone in the basement ramp coincides approximately with the Waverly arch (fig. 1), a north-trending paleotectonic feature identified by Woodward (1961) from isopach patterns in the Knox Dolomite and mapped by Janssens (1973) and Shearrow (1987). According to Root and Onasch (1999), the Waverly arch is a basement uplift that formed during the Taconic orogeny as a result of contrasting anisotropies across lithotectonic boundaries in the Grenville basement rocks. A broader hinge zone (Ohio-West Virginia hinge zone of Ryder, 1992) is located in the vicinity of drill holes 11 and 12 and coincides with the western margin of the Rome trough (fig. 1), a Middle Cambrian rift system that drops basement as much as 19,000 ft below MSL. Where section *E–E′* crosses the Rome trough, the trough is about 40 to 45 mi wide and has a structural relief on basement that ranges from several hundred feet at its western margin across down-to-the-east normal (extensional) faults to several thousand feet at its eastern margin across down-to-the-west normal (extensional) faults. A basement block, called the central West Virginia arch (Kulander and Dean, 1986), flanks the eastern margin of the Rome trough and dips gently toward the Allegheny structural front. The eastern part of this arch is probably broken into several sub-blocks by down-to-the-east normal (extensional) faults that underlie the Elkins Valley and Wills Mountain anticlines (Jacobeen and Kanes, 1975; Shumaker, 1985, 1996).

Most normal faults (extensional) associated with the Rome trough rift system were reactivated several times during the Paleozoic to produce either renewed subsidence or mild basin inversion (Shumaker and Wilson, 1996). For example, mild basin inversion has been documented along segments of the Rome trough in northern West Virginia and southwestern Pennsylvania where basement-involved normal (extensional) faults were reactivated as reverse (contractional) faults to create slightly inverted grabens (Kulander and Ryder, 2005; Scanlin and Engelder, 2003). Most of the mild inversion probably resulted from compression or transpression during the Late Mississippian-Permian Alleghanian orogeny.

An example of Alleghanian basin inversion on section *E–E′* is shown by the southwestern part of the Arches Fork anticline located about 7 mi east of drill hole 14 (fig. 1). As shown on the cross section, this anticline clearly involves the Middle Devonian Huntersville Chert (Cardwell, 1982). Furthermore, the anticline is interpreted here to be deeply rooted in lower Paleozoic strata, judging from the structural geometry shown by a seismic line (Kulander and Ryder, 2005) that crosses the Arches Fork anticline about 40 mi north of drill hole 14 (fig. 1). The deeply rooted Arches Fork anticline that involves lower Paleozoic strata and Mesoproterozoic basement rocks is interpreted here to have been caused by mild basin inversion associated with the reversal in motion of the eastern boundary fault of the Rome trough during the Alleghanian orogeny.

The east-verging anticline (Evans monocline of R. Perkey, 1981, West Virginia University; study cited in Filer, 1985) tested by drill hole 12 is interpreted to be another deeply rooted basement structure caused by reactivation of Rome trough normal faults during the Alleghanian orogeny. However, in this example, Alleghanian reactivation did not result in basin inversion. Instead, Alleghanian compression or transpression converted a major down-to-the-east western border fault of the Rome trough into a steeply west-dipping reverse fault that propagated upsection at least as far as Upper Ordovician strata. Another style of fault reactivation on section *E–E′* involves a deeply rooted anticline (near drill hole 13) that was created by Alleghanian reactivation of a west-verging, Grenville-age thrust fault as interpreted from seismic data by Beardsley (1997). Other examples of reactivated Grenville-age thrust faults in the Appalachian basin are reported by Beardsley and Cable (1983) and Riley and others (1993).

Yet another basement structure on section *E–E′* is the northwest-trending Cambridge cross strike structural discontinuity (arch) (Root, 1996; Baranoski, 2002), which is present between drill holes 9 and 10. On the basis of seismic evidence, Root (1996) demonstrated that the arch is a basement structure that involves a narrow horst block at its northern end and a positive flower structure at its southern end near the Ohio-West Virginia border. Baranoski (2002) showed very subtle structural relief on basement along the entire length of the arch. Structural contour maps by Gray (1982a,b) show the arch as a broad, southeast-plunging nose at the top of the Berea Sandstone and a poorly defined southeast-dipping homocline at the top of the Onondaga Limestone. The arch shows no structural relief on cross section *E–E′* because of the subtle nature of the arch, the subparallel orientation of the line of section with respect to the trend of the arch, and the large distance between control points that straddle the arch.

Thin-Skinned Structures

Thin-skinned structures on cross section *E–E′* include the Wills Mountain, Horton, Glady, Elkins Valley, and Hiram anticlines at the eastern end of cross section *E–E′*. These anticlines are high-amplitude, commonly west-verging structures that formed during the Late Mississippian-Permian Alleghanian orogeny (Gwinn, 1964; Perry, 1978; Shumaker, 1985; Kulander and Dean, 1986).

In drill hole 16, the master tectonic ramp-thrust fault of the Wills Mountain anticline is located 7,000 ft below sea level where allochthonous Cambrian rocks rest on an overturned syncline that involves Upper Ordovician carbonate rocks and shale (Perry, 1964). The drill hole bottomed in the upright limb of the syncline. According to Perry (1964, 1978), this syncline represents the top of a 9,000-ft-thick, sub-horizontal panel of parautochthonous rocks that have been repeated by the overlying thrust plate. However, the interpretation by Shumaker (1985), which is adopted in this cross section, differs slightly from the interpretation by Perry (1964, 1978) in that the overturned syncline is considered to be a horse block located between the main allochthon and the underlying sub-horizontal autochthon. An additional structural complication in the Wills Mountain anticline, as interpreted by Shumaker (1985) and shown on section *E–E′*, is the imbricate fault at the base of the horse block that cuts through and displaces the master thrust and disappears into Devonian shale. Jacobeen and Kanes (1975) and Shumaker (1985) suggested that a down-to-the-east normal fault (not shown on the cross section) may have offset basement rocks several miles east of drill hole 16 and may have caused the upward deflection of the basal detachment of the Wills Mountain anticline.

The Elkins Valley anticline, located about 27 mi west of the Wills Mountain anticline, is controlled by two footwall ramps that show a combined lateral shortening of about 1 mi (Shumaker, 1985). The lower footwall ramp cuts across about 10,000 ft of lower Paleozoic carbonate rocks between a footwall flat in the Waynesboro Formation and a hanging wall flat in the Reedsville Shale. Drill hole 15 penetrates the main branch of the footwall ramp at about 9,500 ft below MSL. A frontal imbricate of this lower ramp complex cuts drill hole 15 at about 10,500 ft below MSL and merges with the hanging wall flat about 2 mi west of the drill hole. Shumaker (1985) interpreted the footwall flat in the Waynesboro Formation to be a westward continuation of the basal detachment at the Wills Mountain anticline, and he interpreted the upward deflection of the basal detachment into the lower ramp complex at the Elkins Valley anticline to be controlled by a down-to-the-east normal fault. The detachment zone that constitutes the hanging wall flat in the Reedsville Shale is interpreted on section *E–E′* to continue 40 to 50 mi west of the Elkins Valley anticline, where the detachment zone has produced several small thrust faults and associated anticlines. The largest of these thrust faults merges with the hanging wall flat about 3 mi west of drill hole 15 and extends upsection about 4,500 ft into the lower part of the Upper Devonian strata beneath the Hiram anticline (Shumaker, 1985). Another thrust fault shown on section *E–E′* branches from the juncture of the lower footwall ramp and the hanging wall flat, about ½ mi west of drill hole 15, extends upsection for approximately 2,000 ft, and terminates in the Rose Hill Formation.

In contrast with the lower footwall ramp, the upper footwall ramp at the Elkins Valley anticline cuts through a thinner section of Paleozoic strata (~3,000 ft thick), but a greater amount of lateral shortening has occurred. The footwall flat of the upper footwall ramp is located in the Reedsville Shale (penetrated by drill hole 15 at about 7,600 ft below MSL) and coincides with the westward extension of the upper zone of detachment (hanging wall flat) at the Wills Mountain anticline (Shumaker, 1985). Several miles east of drill hole 15, imbricate faults that branch off the footwall flat in the Reedsville Shale repeat Silurian and Devonian strata several times in the core and eastern flank of the Elkins Valley anticline. The hanging wall flat of the upper footwall ramp at the Elkins Valley anticline is located in the lower part of the Upper Devonian strata (Shumaker, 1985). On cross section *E–E′*, this hanging wall flat produces several small thrust faults and anticlines for about 40 to 50 mi west of drill hole 15. According to Shumaker (1985), the hanging wall flat and accompanying Upper Devonian strata have been offset as much as several hundred feet by a thrust fault (described in the preceding paragraph) that branches off the hanging wall flat of the lower footwall ramp beneath the Elkins Valley and Hiram anticlines and terminates in the lower part of the Upper Devonian Brallier Formation.

Following Gwinn (1964), the upper footwall ramp also is interpreted on cross section *E–E′* to connect with a bedding-parallel detachment zone in the Upper Silurian Salina Group. Very likely, this additional zone of detachment started near drill hole 15, extended westward through Salina Group halite beds in drill hole 14, and terminated between drill holes 12 and 13. Other than the Burning Springs anticline (discussed later in this section), cross section *E–E′* shows no anticlines associated with the Salina detachment zone because the cross section flanks the southern perimeter of the salt basin and few halite beds are available for major bedding-parallel slip. However, it is possible that several of the low-amplitude anticlines between drill holes 14 and 15 are caused by detachment in the Salina Group rather than by detachment in the Reedsville Shale as interpreted on the cross section.

As shown on cross section *E–E′*, the Horton anticline, Glady anticline, and the unnamed anticline beneath the North Potomac syncline originated from minor imbricate splays that branched off the Reedsville Shale detachment zone between the Elkins Valley and Wills Mountain anticlines (Shumaker, 1985). The core of the Horton anticline was interpreted by Shumaker (1985) to be cut by both east-verging and west-verging imbricate faults. Although not recognized by Shumaker (1985), the low-relief faulted anticline beneath the North Potomac syncline is shown here on the basis of the presence of the Shaver’s Creek gas field in the Oriskany Sandstone (Diecchio and others, 1984) and the structurally high position of the Huntersville Chert in the Union Drilling No. 6 U.S. Forest Service drill hole (see cross section). Anticlines that involve the top of the Onondaga Limestone-Huntersville Chert between the Elkins Valley anticline and the western edge of the central West Virginia arch (Cardwell, 1982) may be caused by minor imbricate faults branching upward from the previously mentioned Reedsville Shale detachment zone.

Basal detachment in the Burning Springs anticline is located in the evaporite-bearing Upper Silurian Salina Group (Filer, 1985; Shumaker, 1986; Morris, 1990). This basal detachment is not shown on section *E–E′* because the detachment occurs several miles east of the line of section. Drill hole 11 shows that the Lower Devonian Oriskany Sandstone is repeated three times in the core of the anticline and that the strata below the Salina Group are largely undeformed. Imbricate faults repeat the Oriskany Sandstone, flatten upward, and terminate in Middle and Upper Devonian shale. The location of the Burning Springs anticline was interpreted by Rodgers (1963) to have been controlled by the western limit of Salina Group halite beds. The western edge of the Salina salt basin was probably controlled by a north-trending, down-to-the-east basement fault (fig. 1), which is shown by seismic profiles (Shumaker, 1986; Morris, 1990). This basement fault probably acted as a buttress, causing the Salina detachment to ramp upsection into Devonian strata and thus initiate the Burning Springs anticline (Filer, 1985; Shumaker, 1986; Morris, 1990). Milici (1980) suggested that thin-skinned deformation terminates at the Burning Springs anticline, whereas Faill (1998) suggested that thin-skinned deformation extends farther west into eastern Ohio.

Stratigraphic Framework

Sedimentary rocks shown on cross section *E–E′* span most of the Paleozoic Era, and their preserved thickness ranges from about 2,800 ft on the Findlay arch to about 25,000 ft near the Allegheny structural front. Lithology, nomenclature, depositional setting, and tectonic setting of the sedimentary rocks along cross section *E–E′* are briefly outlined and discussed in the following text. A more detailed treatment is available in regional geological summaries by Colton (1970), Milici and de Witt (1988), Read (1989a,b), and Faill (1997a,b, 1998). The papers by Faill (1997a,b, 1998) are the most comprehensive syntheses to date regarding the geologic evolution of the central Appalachians and, although the papers are focused on the

Pennsylvania region, much of the geologic history is applicable to the region traversed by cross section *E–E′*.

Most of the eastward thickening of Appalachian strata was caused by regional tectonism. Initial rifting and subsidence caused by the cooling and thermal contraction of the lithosphere, as the proto-Atlantic Ocean (Iapetus Ocean) opened, provided accommodation space for sediments to build the east-facing passive continental margin of Laurentia (North America) (Bond and others, 1988). At a later time, subsidence caused by thrust loading provided additional accommodation space for sediments to accumulate in several foreland basins (Quinlan and Beaumont, 1984). Eustatic changes also have played a role in the eastward thickening of Appalachian strata (Bond and others, 1988). For example, a rise in sea level caused load-induced subsidence (by sediments and overlying water column) that provided accommodation space for additional sediments on the outer continental shelf, whereas a fall in sea level caused erosion of the inner continental shelf.

Lower Cambrian to Upper Ordovician Siliciclastic and Carbonate Strata

Lower Cambrian to Upper Ordovician siliciclastic and carbonate strata are characterized by dolomite, anhydritic dolomite, and limestone and lesser amounts of gray shale, red shale, and sandstone. On section *E–E′*, these Lower Cambrian to Upper Ordovician strata thin dramatically from about 13,000 ft in eastern West Virginia to about 1,600 ft in northwestern Ohio. In the Rome trough in central West Virginia, these strata are as thick as 10,000 ft. In the eastern part of cross section *E–E′* (Rome trough to the Valley and Ridge province), the Lower Cambrian to Upper Ordovician siliciclastic and carbonate strata consist of the following units (in ascending order): the Chilhowee Group, Tomstown Dolomite, Waynesboro Formation, Conasauga Group-Elbrook Dolomite, Copper Ridge Dolomite, Rose Run Sandstone, Beekmantown Group (Dolomite), Black River Group, and Trenton Group (fig. 2). The use of the terms Chilhowee Group, Tomstown Dolomite, and Waynesboro Formation follows the preferred nomenclature for Lower Cambrian strata in northern West Virginia (Cardwell and others, 1968; Kulander and Dean, 1986) and northern Virginia (Virginia Division of Mineral Resources, 1993). In southern West Virginia and southern Virginia, equivalent strata are named the Chilhowee Group, Shady Dolomite, and Rome Formation, respectively.

In the western part of the cross section, equivalent Cambrian to Upper Ordovician strata consist of the following units (in ascending order): Mount Simon Sandstone, Conasauga Group, Knox Dolomite (Copper Ridge dolomite, Rose Run sandstone, Beekmantown dolomite), Wells Creek formation, Black River Group, and Trenton Limestone (fig. 2). The Rome Formation of Janssens (1973) in eastern and central Ohio is now considered to be an obsolete stratigraphic term (Harris and others, 2004) and is not used on cross section *E–E′*.

As interpreted on section *E–E′*, the Lower Cambrian Chilhowee Group and Tomstown Dolomite and the Lower and Middle Cambrian Waynesboro Formation have a combined thickness ranging from about 400 to 2,500 ft and are confined to the Rome trough and adjoining areas to the east, such as the central West Virginia arch. The down-to-the-east normal fault located several miles west of drill hole 11 is recognized here as the western limit of the Rome trough, whereas the down-to-the-west normal fault, about 15 mi east of drill hole 14, is recognized as the eastern limit of the Rome trough. The 50- to 250-ft-thick basal sandstone between the western margin of the Rome trough and drill hole 1 is recognized as the Middle(?)-Upper Cambrian Mount Simon Sandstone.

The Lower Cambrian Chilhowee Group (which rests unconformably on Mesoproterozoic Grenville basement) and the overlying Lower Cambrian Tomstown Dolomite are the two oldest sedimentary units on section *E–E′*. Both units were penetrated in drill holes 13 and 14, where the units have a combined thickness of about 400 ft. Although unsubstantiated by drilling, the Chilhowee and Tomstown intervals are interpreted to continue eastward beneath the Allegheny structural front and crop out in northern and central Virginia near the Blue Ridge structural front (fig. 1). Westward, the Chilhowee-Tomstown interval is interpreted here to terminate against a prominent basement fault block, about 5 mi west of drill hole 12, that defines part of the western margin of the Rome trough. The Chilhowee Group is interpreted as a transgressive marine deposit with the sediment source to the west. The overlying carbonate strata of the Tomstown Dolomite also are interpreted as transgressive marine deposits that accumulated on a marine shelf and carbonate ramp once the adjacent craton was submerged by the Iapetus Ocean (Read, 1989a,b).

In drill holes 13 and 14, the Chilhowee-Tomstown interval is overlain, possibly disconformably (fig. 2) (Ryder, 1992), by approximately 1,200 ft of the Lower to Middle Cambrian Waynesboro Formation. The sandstone, gray shale, and limestone that constitute the Waynesboro Formation strata at this locality were deposited largely during crustal extension that formed the Rome trough. These strata probably continue east of drill hole 14 for another 10 to 15 mi, and abut against the eastern border fault of the Rome trough. Across the central West Virginia arch and between the Elkins Valley and Wills Mountain anticlines, the character and distribution of the Waynesboro Formation is far more speculative. We suggest that the Waynesboro Formation beneath the Elkins Valley anticline is about 1,000 ft thick and thickens abruptly eastward to about 2,000 ft across a down-to-the-east normal (extensional) fault that is interpreted by Shumaker (1985). Westward across the central West Virginia arch, the Waynesboro Formation may progressively thin to an erosional pinchout near the crest of the arch. The lithology of the Waynesboro Formation at these localities is presumed to be red and gray shale, sandstone, and limestone-dolomite based on outcrops of the Waynesboro Formation in northern and central Virginia (Virginia Division of Mineral Resources, 1993). In the outcrop of eastern West Virginia and in the subsurface of the Rome trough, the Waynesboro Formation is interpreted as a shallow-water, nearshore marine deposit (Woodward, 1949; Donaldson and others, 1988).

At the western margin of the Rome trough, the Waynesboro Formation consists largely of sandstone with interbedded red shale, gray shale, and dolomite. Farther west, the Waynesboro Formation climbs abruptly upsection at the expense of the overlying Conasauga Group and steps westward across progressively higher fault blocks. In each successive fault block, the Waynesboro Formation is thinner, as interpreted between drill holes 13 and 12 (1,700 ft) and as shown in drill holes 12 (1,000 ft) and 11 (300 ft). In drill holes 11 and 12, the Waynesboro Formation rests directly on Grenville basement. West of the Rome trough, the Waynesboro Formation is replaced by the Middle(?) and Upper Cambrian Mount Simon Sandstone, a deposit that resulted from marine transgression and extends across the Ohio part of section *E–E′* (see drill holes 1–10).

The combined thickness of the Conasauga Group (and equivalent Elbrook Dolomite) through Trenton Limestone (Group) ranges from an estimated 10,500 ft beneath the Allegheny structural front to about 1,300 ft on the Findlay arch. The Middle and Upper Cambrian Conasauga Group penetrated in drill holes 13 and 14 is between 2,300 and 2,800 ft thick and consists of limestone, dolomite, gray shale, and sandstone. The Conasauga Group conformably overlies the Waynesboro Formation, except along the crest of the central West Virginia arch. In drill holes 13 and 14, the Conasauga Group is subdivided (in ascending order) into the Pumpkin Valley Shale, Rutledge Limestone, Rogersville Shale, Maryville Limestone, and Nolichucky Shale. The Pumpkin Valley, Rutledge, Rogersville, and the lower half of the Maryville are largely confined to the Rome trough, and they are interpreted as shallow-water, syn-rift deposits (Donaldson and others, 1988). Along the western margin of the Rome trough, these formations in the Conasauga Group probably pinch out into sandstone of the Waynesboro Formation. In contrast, the upper half of the Maryville Limestone, which is largely dolomite, and the Nolichucky Shale overstep the western margin of the trough and continue west across Ohio (Harris and others, 2004). At the western end of cross section *E–E′*’, the Conasauga Group is replaced by the sandstone-dominated Upper Cambrian Eau Claire Formation (Janssens, 1973). Along the eastern margin of the Rome trough, units of the Conasauga Group overstep the crest of the central west Virginia arch and pinch out by facies changes eastward into the 3,000- to 3,500-ft-thick Middle to Upper Cambrian Elbrook Dolomite. The Conasauga Group, as well as the overlying strata through the Trenton Limestone (Group), are interpreted as deposits of a post-rift passive margin sequence, where Middle Ordovician continental-scale erosion (Knox unconformity) occurred during a drop in eustatic sea level and (or) tectonic uplift that preceded the Taconic orogeny (Read, 1989a,b). The Conasauga Group in the Rome trough is interpreted as tidal-flat to shallow marine deposits (Donaldson and others, 1988). Moreover, the 150- to 400-ft-thick unnamed sandstone member in the middle part of the Maryville Limestone in drill holes 13 and 14 was probably deposited along the axis of the Rome trough from a cratonic source to the north.

In drill holes 13 and 14, the Conasauga Group is conformably overlain by the 1,100- to 1,200-ft-thick Upper Cambrian Copper Ridge Dolomite (including the basal sandstone member), which is, in turn, conformably overlain by the 200- to 350-ft-thick Upper Cambrian(?) Rose Run Sandstone. The stratigraphic terms Copper Ridge Dolomite, basal sandstone member, and Rose Run Sandstone as applied here replace the terms Gatesburg Formation, lower sandy member, and upper sandy member as used by Ryder (1992). The Rose Run Sandstone is overlain conformably by the 1,200- to 1,500-ft-thick Lower Ordovician Beekmantown Dolomite whose upper contact is truncated by the Middle Ordovician (Knox) unconformity. The Beekmantown Dolomite is overlain by a thin unnamed sandstone and a 500- to 800-ft-thick unnamed anhydritic dolomite of Middle Ordovician age. Along section *E–E′*, the unnamed sandstone is confined to the Rome trough, and it is believed to be equivalent to the Middle Ordovician St. Peter Sandstone. Thus, in this report, the Beekmantown Group terminology of Ryder (1992) is modified by restricting the term Beekmantown to the dolomite unit between the Rose Run Sandstone and the Knox unconformity, where the unconformity can be identified. However, where the unconformity cannot be identified (for example, near drill holes 15 and 16 and in outcrops in adjoining Virginia; see Harris and Repetski, 1982), the term “Beekmantown Group” is used for dolomite between the Rose Run Sandstone and the Black River Group (and Row Park Limestone?). Several hundred feet of limestone at the bottom of drill hole 15 are interpreted here to be the Row Park Limestone of the Middle to Upper Ordovician St. Paul Group, a possible equivalent of the unnamed anhydritic dolomite above the Beekmantown Dolomite in drill holes 11 to 14. The Copper Ridge Dolomite, Beekmantown Dolomite (Group), and unnamed anhydritic dolomite are prominent dolomite units, and they probably accumulated in a restricted marine environment on a passive margin (Harris, 1973; Read, 1989a,b). At the Wills Mountain anticline (drill hole 16), the Copper Ridge and Beekmantown have been thrust upward across the previously described tectonic (footwall) ramp to within several thousand feet of the present-day surface.

The Copper Ridge Dolomite, Rose Run Sandstone, Beekmantown Dolomite, and unnamed anhydritic dolomite are present in drill holes 11 and 12, near the western margin of the Rome trough in West Virginia, but they are at least several hundred feet thinner than in drill holes 13 and 14. Moreover, the Copper Ridge Dolomite, Rose Run Sandstone, and Beekmantown Dolomite continue into Ohio as informal units of the Knox Dolomite (Janssens, 1973; Slucher, 2004). This usage in Ohio differs somewhat from Ryder (1992), who used the Knox Dolomite of Janssens (1973) but gave the Rose Run Sandstone formal status and left the dolomite units unnamed.

East of drill hole 12, the basal sandstone member of the Copper Ridge Dolomite probably pinches out by facies change into the Nolichucky Shale. In drill holes 13 and 14, a 100-ft-thick silty and (or) sandy(?) dolomite unit in the middle of the Copper Ridge Dolomite correlates with the B zone of Calvert (1964) in Ohio. As described by Janssens (1973), the B zone is a glauconitic siltstone and very fine grained sandstone that forms a persistent marker bed over much of central Ohio. On cross section *E–E′*, the B zone extends into northwestern Ohio and is truncated between drill holes 3 and 4 by the Middle Ordovician (Knox) unconformity. At the northwestern end of the cross section, a 100-ft-thick, fine- to coarse-grained sandstone (the Kerbel Formation of Janssens, 1973) is located above the Eau Claire Formation-Conasauga Group and below the Knox Dolomite. Eastward, the Kerbel Formation becomes dolomitic, thins to about 20 ft in drill hole 8, and pinches out by a facies change about 10 mi east of the drill hole.

West of the Rome trough, the unnamed anhydritic dolomite unit changes lithology to an argillaceous dolomite named the Middle Ordovician Wells Creek formation. The Wells Creek Formation was formally introduced in Ohio by Patchen and others (1985) and Wickstrom and others (1992), on the basis of the Wells Creek Dolomite named by Lusk (1927) after a locality in western Tennessee. Wilson and Stearns (1968) discontinued the term in Tennessee when their geologic mapping failed to identify the Wells Creek Dolomite at the type locality. On section *E–E′*, however, we use the term Wells Creek formation as used by Wickstrom and others (1992) but informally because of its uncertainty in the type area.

In drill hole 10, the Wells Creek formation rests unconformably on the Lower Ordovician Beekmantown dolomite of the Knox Dolomite (Janssens, 1973; Slucher, 2004). Farther west, the Middle Ordovician (Knox) unconformity cuts downsection and places the Wells Creek formation on successively older rocks as follows: the Beekmantown dolomite is truncated between drill holes 8 and 9; the Rose Run sandstone is truncated about 5 mi west of drill hole 8; and, as noted earlier, the B zone is truncated between drill holes 3 and 4. At drill hole 2, near the northwestern end of the cross section, the Middle Ordovician (Knox) unconformity places the Wells Creek formation on the Knox Dolomite, within about 50 ft of the top of the Kerbel Formation.

The Upper Ordovician Black River Limestone (Group), consisting of carbonate mudstone and wackestone, and the overlying Upper Ordovician Trenton Limestone (Group), consisting of fossiliferous limestone (wackestone, packstone, and grainstone), are present across all of section *E–E′*. These limestone units are interpreted as carbonate ramp deposits (Read, 1980; Smosna, 1985). Farther west, the Black River-Trenton interval thins gradually from about 1,500 to 2,000 ft at the Allegheny structural front, about 1,200 ft in drill hole 13, to about 700 ft on the Findlay arch. The Black River Limestone (Group) rests conformably on the Row Park Limestone(?)-unnamed anhydritic dolomite-Wells Creek formation and, in turn, is overlain conformably by the Trenton Limestone (Group). As shown in figure 2, two widespread K-bentonite beds (Millbrig and Deicke Bentonite Beds of Huff and Kolata, 1990; α and β marker beds of Stith, 1979, respectively) are located in the uppermost part of the Black River Limestone (Group), where the Millbrig Bentonite Bed (α marker) defines the Black River-Trenton contact. These K-bentonite beds are thought to be derived from extensive volcanic ash falls that occurred during the Late Ordovician-Early Silurian Taconic orogeny (Huff and Kolata, 1990; Huff and others, 1992). In drill holes 15 and 16 and in figure 2, the S_2 bentonite bed (Perry, 1964) in the middle part of the Nealmont Limestone of the Trenton Group is the Millbrig Bentonite Bed (α marker). In these drill holes, the contact between the Black River and Trenton Groups is located about 150 ft below the Millbrig Bentonite Bed (S_2 bentonite bed of Perry, 1964), thus shifting the location of the contact to an older stratigraphic position. This downsection shift of the Black River-Trenton contact is located between drill holes 14 and 15. In drill hole 15, the Trenton Group (as defined by Perry, 1964, 1972) consists of the following two formations: the Nealmont Limestone and the overlying Dolly Ridge Formation. Between drill holes 12 and 13, approximately 200 ft of the upper Trenton Limestone, equivalent to the upper part of the Dolly Ridge Formation, are replaced by a facies change to calcareous black shale of the Upper Ordovician Utica Shale.

Upper Ordovician to Lower Silurian Siliciclastic Strata

Upper Ordovician to Lower Silurian siliciclastic strata are characterized by gray shale, red shale, sandstone, and black shale. On cross section *E–E′*, the combined thickness of the strata ranges from about 2,500 ft in the vicinity of the Allegheny structural front (also see isopach maps by Diecchio, 1985) to about 850 ft on the Findlay arch. The Upper Ordovician to Lower Silurian siliciclastic strata consist of the following units (in ascending order): the Utica Shale, Reedsville Shale-Cincinnati group (Perry, 1972; Ryder, 1992; Slucher, 2004), Juniata Formation-Queenston Shale, Tuscarora Sandstone-Clinton sandstone, and Rose Hill Formation-Rochester Shale (fig. 2).

The Upper Ordovician to Lower Silurian siliciclastic strata are interpreted as sediments derived from an easterly orogenic source and deposited in a rapidly subsiding foreland basin. This foreland basin and its sedimentary deposits are associated with the continent-island arc collision of the Taconic orogeny (Colton, 1970; Milici and de Witt, 1988; Drake and others, 1989; Pavlides, 1989).

The Upper Ordovician Utica Shale extends from a location between drill holes 12 and 13 to the northwestern end of the cross section. The Utica Shale is overlain by Upper Ordovician strata consisting of the Reedsville Shale-Cincinnati group (gray shale, siltstone, and minor sandstone with increasing amounts of limestone in Ohio), the Oswego Sandstone (sandstone, siltstone, and gray shale), and the Juniata Formation-Queenston Shale (red beds). The Utica Shale is interpreted as an anoxic deposit that accumulated in the distal part of the Taconic foreland basin during initial deepening of the Trenton-Black River carbonate platform (Castle, 2001), whereas the overlying Reedsville Shale-Cincinnati group, Oswego Sandstone, and Juniata Formation-Queenston Shale form a clastic wedge that is interpreted as shallow-marine and intertidal deposits (Diecchio, 1985; Castle, 2001).

The widespread Cherokee unconformity is present at the top of the Juniata Formation-Queenston Shale. According to Dennison and Head (1975), this unconformity resulted from a fall in eustatic sea level that was largely independent of the Taconic orogeny and the classic angular unconformity between Upper Ordovician and Lower Silurian rocks in eastern Pennsylvania (Pavlides and others, 1968).

From the Allegheny structural front to central Ohio, Lower Silurian siliciclastic strata lie unconformably (Cherokee unconformity) on Juniata-Queenston red beds. The eastern part of these siliciclastic strata is named the Lower Silurian Tuscarora Sandstone, which is about 150 ft thick where it intersects section *E–E′* in central and western West Virginia. In eastern and central Ohio, the Lower Silurian siliciclastic strata are approximately 100 ft thick and consist of the Clinton sandstone and the underlying Cabot Head Shale and Medina sandstone (Ryder, 2004). The Tuscarora Sandstone has a greater percentage of net sandstone and is typically coarser grained than the “Clinton” sandstone-Cabot Head Shale-Medina sandstone. Between drill holes 5 and 6, the “Clinton” sandstone pinches out westward and is replaced by the Cabot Head Shale. Furthermore, west of drill hole 8, the Medina sandstone is replaced by the Lower Silurian Brassfield Limestone, which extends to the northwestern end of the cross section. The Tuscarora-Clinton interval is interpreted as shallow-marine shelf, shoreface, and fluvial-estuarine deposits (Castle, 1998; Ryder, 2004) that accumulated as molasse during Early Silurian late-stage uplift in the Taconic source area (Dorsch and others, 1994).

The Lower Silurian Rose Hill Formation conformably overlies the Tuscarora Sandstone and consists of gray shale, dolomite and (or) limestone, red shale, and local hematitic sandstone. Between the Allegheny structural front and drill hole 11 on section *E–E′*, the Rose Hill Formation decreases in thickness from about 600 to 400 ft. West of drill hole 11, the Rose Hill Formation is replaced by the Lower Silurian Rochester Shale and an underlying unit of thin dolomite and (or) limestone and interbedded gray shale, identified on cross section *E–E′* as Lower Silurian carbonates and shales, undivided (fig. 2). The combined Lower Silurian carbonates and shales unit and the Rochester Shale overlie the Clinton sandstone and thin to about 150 ft in drill hole 8 and to less than 25 ft in drill hole 1. Kleffner (1985), Brett and others (1990), Hettinger (2001), and Slucher (2004) recognized an unconformity at the base of the Lower Silurian Dayton Limestone, which is included in the Lower Silurian carbonates and shales unit. This unconformity extends across much of central and eastern Ohio and probably extends into the Rose Hill Formation. A thin, but continuous, locally hematitic sandstone known as the Upper Silurian Keefer Sandstone conformably overlies the Rose Hill Formation and Rochester Shale across West Virginia and easternmost Ohio. The Rose Hill Formation is interpreted as a shallow-marine shelf deposit (Smosna and Patchen, 1978).

Lower Silurian to Middle Devonian Carbonate and Evaporite Strata

Lower Silurian to Middle Devonian strata along cross section *E–E′* consist of a lithologically varied interval of limestone, dolomite, anhydrite, sandstone, gray shale, chert, and halite. The combined thickness of these stratigraphic units ranges from about 1,500 to 2,000 ft in the vicinity of the Allegheny structural front to about 800 ft near their outcrop limit on the eastern flank of the Findlay arch. Typical stratigraphic units in this interval are as follows (in ascending order): the Lockport Dolomite, Salina Group, Bass Islands Dolomite, Helderberg Limestone, Oriskany Sandstone, and Onondaga Limestone (fig. 2).

The Lower and Upper Silurian Lockport Dolomite in Ohio rests conformably on either the Rochester Shale or the Lower Silurian Keefer Sandstone, whereas the equivalent McKenzie Limestone in West Virginia rests conformably on the Keefer Sandstone (fig. 2). The Lockport Dolomite consists largely of finely crystalline dolomite with local algal bioherms, such as in drill hole 6 where the Lockport is abnormally thick. In drill hole 5, all but the lower 50 ft of the Lockport Dolomite is replaced by anhydritic, argillaceous dolomite of the Tymochtee and Greenfield Dolomites, undivided. The McKenzie Limestone consists of argillaceous to sandy carbonate mudstone and wackestone that locally are fossiliferous and oolitic. At several localities (such as drill hole 11), the McKenzie Limestone is nearly half dolomite.

The Salina Group on cross section *E–E′* consists predominately of anhydritic dolomite and anhydrite with only minor amounts of halite, because cross section *E–E′* traverses south and west of the halite-bearing part of the Salina Group (Colton, 1970; Clifford, 1973). Between drill holes 14 and 15, the Salina Group is replaced by the equivalent Upper Silurian Tonoloway Limestone, which consists of locally anhydritic limestone and dolomite. From between drill holes 10 and 11 to between drill holes 13 and 14, anhydritic, argillaceous dolomite of the Upper Silurian Wills Creek Formation replaces the basal 150 to 200 ft of the Salina Group. From between drill holes 13 and 14 to the eastern end of cross section *E–E′*, anhydrite is absent from the Wills Creek Formation. The Wills Creek Formation contains many interbeds of gray shale and limestone where it underlies the Tonoloway Limestone.

The uppermost Silurian unit present on the cross section is the Bass Islands Dolomite, an argillaceous dolomite (50 ft thick or less) that conformably overlies the Salina Group between drill holes 7 and 14. The Bass Islands Dolomite undergoes a facies changes to the Big Mountain Shale near drill hole 15 and on the flanks of the Wills Mountain anticline near drill hole 16 (Smosna and others, 1977).

The overall depositional setting of the Lower Silurian to Middle Devonian carbonate and evaporite rocks was a shallow basin with closed circulation where evaporites were surrounded by a carbonate shelf with normal sea water where limestone was deposited (Smosna and others, 1977). Dolomite and evaporite beds of the Upper Silurian Salina Group that conformably overlie the Lockport Dolomite signal an abrupt change on the carbonate shelf from normal circulation to greatly restricted circulation. This abrupt change to evaporite deposition was caused by an arid climate and possibly a drop in sea level (Cecil and others, 2004). The Upper Silurian Salina Group is interpreted as greatly restricted shallow-water and sabkha deposits (Tomastik, 1997). Because halite beds in the Salina Group terminate abruptly against the Cambridge arch, Root (1996) suggested that this structure during the time of Salina deposition was a topographic sill that separated hypersaline, halite-precipitating seawater on the east from less saline water on the west. An alternate explanation for the abrupt termination of the halite beds is offered by Farmerie and Coogan (1995), who suggested that the halite beds originally extended westward across the Cambridge arch and later were dissolved by downward-percolating ground water from a Lower Devonian erosion surface (pre-Oriskany Sandstone unconformity, discussed below). Either explanation requires that the Cambridge arch was a positive feature during the Silurian.

Strata that overlie the Silurian Salina Group-Tonoloway Limestone include the following (in ascending order): the Upper Silurian Bass Islands Dolomite and the Lower Devonian Keyser Limestone (upper), Mandata Shale, and Helderberg Limestone, all of which are penetrated in drill holes 11 through 14. The same units are recognized above the Tonoloway Limestone in drill hole 15 except the Bass Islands Dolomite, which is replaced by the Big Mountain Shale. The Helderberg Limestone is characterized by chert-bearing, locally fossiliferous limestone with interbeds of gray shale and siltstone. In outcrops (not shown on the cross section) east of the Wills Mountain anticline in West Virginia, the Helderberg Limestone is replaced by the Lower Devonian Shriver Chert of the Helderberg Group. The remainder of the Helderberg Group below the Shriver Chert consists of the following formations in descending order: the Lower Devonian Mandata Shale, Corriganville Limestone, and New Creek Limestone; the Upper Silurian-Lower Devonian Keyser Limestone (upper); and the Upper Silurian Big Mountain Shale and Keyser Limestone (lower). The Mandata Shale pinches out west of drill hole 11 near the Ohio-West Virginia border, beyond which the Keyser Limestone (upper) equivalent is included in the Helderberg Limestone. These strata are generally interpreted as normal marine deposits that accumulated on a carbonate shelf (Dorobek and Read, 1986). In eastern Ohio, the Helderberg Limestone rests unconformably on the Bass Islands Dolomite (Patchen and others, 1985; Slucher, 2004).

The clean, quartzose Lower Devonian Oriskany Sandstone overlies the Helderberg Limestone and extends along cross section *E–E′* from about 6 mi west of drill hole 9 to the Allegheny front. Regional unconformities at the top and base of the Oriskany Sandstone probably were caused by falls in eustatic sea level (Dennison and Head, 1975). Of the two unconformities, Dennison and Head (1975) considered the upper one to represent the longer period of emergence and perhaps the larger decrease in water depth. This post-Oriskany unconformity probably truncated the Oriskany Sandstone between drill holes 8 and 9 to form the pinchout mapped by Coogan and Reeve (1985). Westward of the Oriskany Sandstone pinchout, the two unconformities merge and cut progressively downsection across the Helderberg Limestone, Bass Islands Dolomite, and the uppermost part of the Salina Group. The Oriskany Sandstone has been interpreted as a shallow-marine deposit (Bruner, 1988), although Cecil (2004) has suggested a prior eolian provenance for the Oriskany Sandstone and adjacent chert beds (Shriver and Huntersville Cherts).

A 35- to 45-ft-thick sandstone and cherty carbonate unit that unconformably overlies the Salina Group in drill holes 4 and 6 probably correlates with the Lower Devonian Bois Blanc Formation recognized in northern Ohio by Dow (1962), Janssens (1968), Rickard (1984), Sparling (1988), and Slucher (2004). This unit is slightly younger than the Oriskany Sandstone (fig. 2). The sandstone and cherty carbonate unit is unconformably overlain by the Middle Devonian Columbus Limestone in drill hole 6 and by the Middle Devonian Detroit River Group in drill hole 4, as suggested by regional correlations (Dow, 1962; Slucher, 2004). Studies by Sparling (1988) indicate that the Bois Blanc Formation does not crop out on the Findlay arch. Although the correlation of this sandstone and cherty carbonate unit with the Bois Blanc Formation is favored in this report, several other possibilities exist. Conceivably, this unit might correlate with the Lower Devonian Sylvania Sandstone in northwestern Ohio and southwestern Ontario (Carman, 1936; Dow, 1964; Slucher, 2004) or with the Lower Devonian Hillsboro Sandstone in central and southwestern Ohio (Hansen, 1999; Slucher, 2004). To further complicate the correlation, the Sylvania and Hillsboro Sandstones might be equivalent units.

In drill holes 10–13, fossiliferous, cherty limestone of the Middle Devonian Onondaga Limestone conformably overlies the Oriskany Sandstone. East of drill hole 13, the Onondaga Limestone is replaced by an equivalent chert-dominated interval called the Huntersville Chert, which, in turn, is replaced farther to the east by black shale of the Middle Devonian Needmore Shale (fig. 2). In central Ohio, between drill holes 7 and 8, the Onondaga Limestone is replaced by the Columbus Limestone and the overlying Delaware Limestone. The Columbus and Delaware Limestones may be separated by an unconformity (Hansen, 1999; Slucher, 2004). The lower part of the Columbus Limestone in drill hole 4 and in outcrops along the eastern flank of the Findlay arch is replaced by sandy dolomite and limestone of the Detroit River Group (Sparling, 1988; Slucher, 2004). The Detroit River Group strata pinch out into the lower part of the Columbus Limestone probably within 5 to 10 mi south of drill hole 4.

Middle Devonian to Lower Mississippian Siliciclastic Strata

Middle Devonian to Lower Mississippian siliciclastic strata are characterized by gray shale, siltstone, sandstone, and red beds in eastern West Virginia and by black shale, gray shale, and siltstone with thin sandstone beds near the top in central Ohio. In the eastern West Virginia part of cross section *E–E′*, Middle Devonian to Lower Mississippian siliciclastic strata include the following units (in ascending order): the Middle Devonian Hamilton Group; the Upper Devonian Harrell Shale, Brallier Formation, Greenland Gap Group, and Hampshire Formation; and the Lower Mississippian Price Formation (fig. 2). Also in eastern West Virginia, the top of the 30- to 50-ft-thick Tully Limestone located between the Mahantango Formation and Harrell Shale marks the top of the Middle Devonian on the cross section (fig. 2). The Middle Devonian to Lower Mississippian strata shown on section *E–E′* thin dramatically from 6,000 to 7,000 ft in eastern West Virginia to about 3,000 ft in western West Virginia and to about 1,500 ft in central Ohio. In eastern Ohio and western West Virginia, the Middle Devonian to Lower Mississippian strata include the following units (in ascending order): the Middle Devonian Hamilton Group; the Upper Devonian Genesee Formation, Sonyea Formation, West Falls Formation, Java Formation, Huron Member of the Ohio Shale, and Chagrin Shale; the Upper Devonian-Lower Mississippian(?) Berea Sandstone; and the Lower Mississippian Sunbury Shale and Cuyahoga Formation (fig. 2).

The Upper Devonian to Lower Mississippian siliciclastic strata are interpreted as sediments derived from an easterly orogenic source and deposited in a rapidly subsiding foreland basin. This foreland basin and its sedimentary deposits (the Catskill delta complex) are associated with the Acadian orogeny (Colton, 1970; Milici and de Witt, 1988; Osberg and others, 1989).

The stratigraphy of the Middle and Upper Devonian black shales has been studied in great detail because of their role as hydrocarbon source rocks and reservoirs (Roen and Kepferle, 1993). Deposition of black shale of the Needmore Shale in the vicinity of the Allegheny structural front was followed by more widespread deposition of the Tioga Bentonite (Dennison and Head, 1975; Dennison and others, 1988) and the overlying black shale of the Marcellus Shale (fig. 2). The Marcellus Shale and the overlying gray shale of the Mahantango Formation of the Hamilton Group extend across the West Virginia part of section *E–E′* and into eastern Ohio (Patchen and others, 1985; Slucher, 2004). As shown on section *E–E′*, the Marcellus Shale pinches out between drill holes 7 and 8, but the Mahantango Formation of the Hamilton Group continues into central Ohio as a gray shale that is recognized as the Middle Devonian Olentangy Shale (lower).

A regional Middle to Late Devonian unconformity, described and mapped by de Witt and others (1993), is present at the top of the Olentangy Shale (lower)-Hamilton Group and part of the Tully Limestone across most of cross section *E–E′* (fig. 2). Westward from near drill hole 15, where the partially eroded Tully Limestone is overlain by the Upper Devonian Genesee Formation, successively younger Upper Devonian strata downlap against the Middle to Late Devonian unconformity. For example, in drill hole 13, the Upper Devonian Sonyea Formation rests unconformably on the Mahantango Formation of the Hamilton Group, whereas farther west in drill hole 10, the Upper Devonian Rhinestreet Shale Member of the West Falls Formation rests unconformably on the Mahantango Formation of the Hamilton Group. In drill hole 5, the Upper Devonian Huron Member of the Ohio Shale rests unconformably on the Middle Devonian Olentangy Shale (lower), whereas in drill hole 4 and in outcrops on the eastern flank of the Findlay arch, the Huron Member rests unconformably on the Plum Brook Shale and Prout Limestone (Rickard, 1984; Slucher, 2004), which are equivalents of the Olentangy Shale (lower).

The dark-gray, shale-dominated Upper Devonian Harrell Shale extends westward from the Allegheny front to a short distance (5 mi) west of drill hole 15, where it crosses an arbitrary boundary into rocks of the Genesee Formation. Similarly, the overlying shale- and siltstone-dominated Upper Devonian Brallier Formation extends westward from the Allegheny front to about 12 mi west of drill hole 15, beyond which its lower part crosses an arbitrary boundary into rocks of the Sonyea Formation. The majority of the Brallier Formation in drill hole 15 continues westward into the subsurface as far as the eastern limits of the Rhinestreet and Huron black shale units, beyond which (in the vicinity of drill hole 14) Brallier-equivalent strata are included with undivided Upper Devonian strata.

The sandstone- and siltstone-dominated Upper Devonian Greenland Gap Group overlies the Brallier Formation between the Allegheny structural front and drill hole 15. As defined in outcrop by Dennison (1970) and Dennison and others (1988), the Greenland Gap Group is subdivided into the Scherr Formation and the overlying Foreknobs Formation. The approximate boundary between the Scherr and Foreknobs Formations is shown on section *E–E′*. The majority of the sandstone beds in the Greenland Gap Group are interpreted as nearshore marine and distributary channel deposits (Boswell and Jewell, 1988).

The Greenland Gap Formation was introduced by Boswell and others (1987) and Boswell (1988a) to identify a westward extension of the Foreknobs Formation part of the Greenland Gap Group that has a higher percentage of shale and siltstone. In cross section *E–E′*, the term “Foreknobs” is added to the Greenland Gap Formation (in parentheses) to emphasize the alternate nomenclature used by Dennison and others (1988) and implied by Filer (2002, 2003). The nomenclatural change from the Greenland Gap Group to the Greenland Gap (Foreknobs) Formation is interpreted to occur at drill hole 15 on section *E–E′*. The Greenland Gap (Foreknobs) Formation extends westward from drill hole 15 to about 6 mi west of drill hole 13, where it is replaced across a facies change by the Chagrin Shale. The approximate westward limit and the abrupt upward diachronous shifts in lithology (shown by arbitrary cutoffs) in the Greenland Gap (Foreknobs) Formation shown on section *E–E′* are based on percent siltstone and sandstone maps and on cross sections by Boswell (1988b) and Filer (2002). The Greenland Gap (Foreknobs) Formation in the vicinity of drill hole 15 is underlain by the uppermost part of the Brallier Formation that is equivalent to the Scherr Formation.

The red-bed-dominated Hampshire Formation (Dennison and others, 1988) occurs in several isolated outcrops between the Allegheny front and drill hole 15. West of drill hole 15, the Hampshire Formation is named the Hampshire Group (Boswell and others, 1987; Boswell, 1988a), and it continues westward from the drill hole for about 18 mi where it pinches out into the Venango Formation. The western limit of the Hampshire Group is based on the boundary between the Rowlesburg Formation of the Hampshire Group and the Venango Formation shown by Boswell (1988a). The lower part of the Hampshire Group (Cannon Hill Formation of Boswell and others, 1987) extends an additional 4 to 5 mi west of the overlying red beds and pinches out into the Greenland Gap (Foreknobs) Formation. The Venango Formation extends to within about 18 mi east of drill hole 14 where it crosses an arbitrary boundary and becomes the Greenland Gap (Foreknobs) Formation. The red beds in the Hampshire Formation (Group) are interpreted as subaerially exposed alluvial plain and fluvial deposits (Dennison and others, 1988).

The Brallier Formation, Greenland Gap (Foreknobs) Formation, Hampshire Group, Venango Formation, and equivalent strata such as the West Falls and Java Formations contain somewhat continuous, thin sandstone units (generally 10 to 40 ft thick) to which drillers have given informal names such as the Sycamore siltstone and the Elk, Alexander, Benson, Riley, Bradford, Warren, Fifth, and Gordon sandstones (Schwietering, 1980; Sweeney, 1986; Boswell and Jewell, 1988; Dennison and others, 1988). The Sycamore(?) siltstone and the Elk, Alexander, and Benson sandstones are included in the Elk play of Donaldson and others (1996), whereas the Riley and Bradford(?) sandstones are included in the Bradford play of Boswell, Thomas, and others (1996). The Warren, Fifth, and Gordon sandstones are included in the Venango play of Boswell, Heim, and others (1996). Sandstones in the Elk and Bradford plays are interpreted as deeper water prodeltaic turbidites and distal shelf deposits (Donaldson and others, 1996; Boswell, Thomas, and others, 1996), whereas sandstones of the Venango play are interpreted as marine shoreline and wave-dominated delta deposits (Boswell, Heim, and others, 1996).

In eastern Ohio and western and central West Virginia, thick intervals of black shale that constitute the Rhinestreet Shale and Huron Members intertongue with and pinch out eastward into gray shale and siltstone of the Upper Devonian Brallier Formation (fig. 2). These black shales are interpreted as anoxic marine deposits, but the origin of the anoxic conditions is controversial (Boswell, 1996).

On the basis of well-log studies at drill holes 12 and 14, Filer (1985) and Sweeney (1986), respectively, interpreted that siliciclastic strata of the Upper Devonian and Lower Mississippian Price Formation (Pocono Group of their terminology) rest conformably on Upper Devonian strata. In drill holes 12 and 14, the 300- to 350-ft-thick Price Formation consists of the following units (in ascending order): Upper Devonian Berea Sandstone (fig. 2); Lower Mississippian Sunbury Shale (fig. 2); and Lower Mississippian Weir and Big Injun sandstones (informal units of drillers’ usage not shown on cross section *E–E′* or figure 2) except for the Pocono Big Injun sandstone. Farther east, near the Columbian Carbon No. 1–3 GW 1297 drill hole (projected into section *E–E′* about 12 mi southeast of drill hole 15), Schwietering (1980) also interpreted the Price Formation (Pocono Group of his terminology) to rest conformably on Upper Devonian strata. Furthermore, in outcrops at the eastern end of section *E–E′* (in the vicinity of the Glady anticline), Dennison and others (1988) interpreted the Pocono (Price) Formation to rest conformably on the Hampshire Formation.

In contrast to these earlier interpretations, Kammer and Bjersted (1986), Bjersted and Kammer (1988), and Boswell and Jewell (1988) interpreted that the Price Formation rests unconformably on Upper Devonian strata. For example, near drill hole 15, Kammer and Bjersted (1986) and Bjersted and Kammer (1988) interpreted an unconformity at the base of the Price Formation that they identified as the sub-Berea unconformity. Boswell and Jewell (1988) adopted the sub-Berea unconformity of Kammer and Bjersted (1986) and Bjersted and Kammer (1988) and extended it westward across northern and central West Virginia at the base of the Berea Sandstone. Furthermore, Pashin and Ettensohn (1995) interpreted an unconformity at the base of the Berea Sandstone in northern West Virginia and northern Ohio that coincides with the sub-Berea unconformity.

The sub-Berea unconformity is interpreted to be present across much of cross section *E–E′*. For example, the unconformity is interpreted to underlie the Price Formation beneath the North Potomac syncline. Furthermore, the unconformity is interpreted to underlie the Berea Sandstone from a location beneath the Hiram anticline, through drill holes 11–14, to the

Ohio-West Virginia line. The Berea Sandstone and the sub-Berea unconformity continue into eastern Ohio through drill hole 10, to within 10 mi of drill hole 9.

Beneath the Hiram anticline, the sub-Berea unconformity is truncated by an unconformity at the base of the Middle to Upper Mississippian Greenbrier Limestone that places the Greenbrier on a thin section of the Price Formation or directly on the Hampshire Formation (Yeilding and Dennison, 1986). The thinned and truncated Price Formation probably was caused by erosion that accompanied the uplift of the West Virginia dome (Kammer and Bjersted, 1986; Yeilding and Dennison, 1986; Bjersted and Kammer, 1988; Boswell and Jewell, 1988).

The Price Formation, and the equivalent Cuyahoga Formation in Ohio, range in thickness from between 300 and 500 ft across section *E–E′*. In central Ohio, the upper part of the Lower Mississippian Cuyahoga Formation contains the Black Hand Member, which is also called the “Big Injun” sandstone of drillers’ usage (Majchszak, 1984; Slucher, 2004). The Cuyahoga interval in central Ohio is conformably overlain by the Middle Mississippian Logan Formation (Majchszak, 1984; Vargo and Matchen, 1996), a unit that is absent in the West Virginia part of cross section *E–E′* because the unit is truncated by an unconformity several miles west of drill hole 9.

Boswell, Heim, and others (1996) referred to the Price Formation as the Price-Rockwell delta complex, which they interpreted as the final phase of deposition in the foreland basin associated with the Late Devonian-Early Mississippian Acadian orogeny. Most of the Berea Sandstone, which is included with the Price interval on section *E–E′*, is interpreted as fluvial-deltaic, shallow-marine, and barrier island deposits derived from the north and east (Pepper and others, 1954; Tomastik, 1996). Sequence stratigraphic interpretations by Pashin and Ettensohn (1995) suggest that the Berea Sandstone is essentially a lowstand wedge, composed of sand-rich estuary deposits. The sub-Berea unconformity shown on cross section *E–E′* may be related to a eustatic drop in sea level possibly associated with glaciation (Pashin and Ettensohn, 1995).

Middle to Upper Mississippian Carbonate Strata

Middle to Upper Mississippian carbonate strata on cross section *E–E′* consist of a fossiliferous and oolitic limestone (grainstone, packstone, and wackestone) unit with local sandy limestone and sandstone beds at the base. These strata are assigned to the Middle to Upper Mississippian Greenbrier Limestone in West Virginia (fig. 2) (Flowers, 1956; Smosna, 1996). The Greenbrier Limestone rests unconformably on the Price Formation throughout West Virginia (Vargo and Matchen, 1996), and, locally, it rests unconformably on the Hampshire Formation (Yeilding and Dennison, 1986). This sub-Greenbrier unconformity is shown on section *E–E′* in drill holes 11, 13, and 14, and in outcrops near drill hole 15. In drill hole 14, the base of the Greenbrier Limestone consists of a 25-ft-thick quartzose sandstone (Sweeney, 1986) that is informally named the “Greenbrier Big Injun” sandstone (Matchen and Vargo, 1996). The “Greenbrier Big Injun” sandstone extends eastward to within about 15 mi of drill hole 15 and westward to about 5 mi west of drill hole 13. An older Big Injun sandstone, the “Pocono Big Injun” sandstone of Matchen and Vargo (1996) and Vargo and Matchen (1996), occupies the uppermost part of the Price Formation in drill hole 13 where it is unconformably overlain by the “Greenbrier Big Injun” sandstone. The carbonate strata are interpreted as predominantly shallow-marine deposits (Carney and Smosna, 1989; Al-Tawil and others, 2003).

Upper Mississippian, Pennsylvanian, and Permian Siliciclastic Strata

The Upper Mississippian to Permian siliciclastic strata on cross section *E–E′* consist of conglomeratic sandstone, sandstone, red and gray shale, and siltstone. Commonly these siliciclastic strata contain coal beds and, locally, they contain thin beds of limestone. The Upper Mississippian and Pennsylvanian siliciclastic strata range from 1,500 to 2,000 ft thick, whereas the Permian strata range from 50 to 450 ft thick. These siliciclastic strata include the following units (in ascending order): the Mississippian Mauch Chunk Group; the Pennsylvanian Pottsville Group, undivided, New River and Kanawha Formations of the Pottsville Group, Allegheny Group, Conemaugh Group, and Monongahela Group; and the Upper Pennsylvanian-Lower Permian Dunkard Group (fig. 2). Although present in most of the Pennsylvanian-Permian strata along section *E–E′*, coal beds are most common and widespread in the Allegheny Group and in the Kanawha Formation of the Pottsville Group.

The Upper Mississippian to Permian siliciclastic strata are interpreted as predominantly nonmarine sediments derived from an easterly source and deposited in a rapidly subsiding foreland basin. This foreland basin and its sedimentary deposits are associated with the Alleghanian orogeny (Colton, 1970; Milici and de Witt, 1988; Hatcher and others, 1989).

At most localities along section *E–E′*, a sequence of Pennsylvanian sandstones of the Pottsville Group (as much as 350 ft thick) unconformably overlies the Middle and Upper Mississippian Greenbrier Limestone and Pocono Group-Price Formation (Arkle and others, 1979; Beuthin, 1994; Hohn, 1996). However, along an 80-mi-long section from near drill hole 13 to the western flank of the Elkins Valley anticline, the Pennsylvanian Pottsville Group unconformably overlies a 50- to 500-ft-thick unit of sandstone, gray and red shale, and locally fossiliferous limestone of the Upper Mississippian Mauch Chunk Group that conformably overlies the Greenbrier Limestone. Also, the Mauch Chunk Group is present between sandstone of the Pottsville Group and the Greenbrier Limestone in the North Potomac syncline.

Between drill holes 15 and 12, a Lower Pennsylvanian unconformity cuts progressively downsection through the Upper Mississippian Mauch Chunk Group, the Upper Mississippian Greenbrier Limestone, and into the upper part of the Upper Devonian-Lower Mississippian Price Formation (Filer, 1985; Sweeney, 1986). A small remnant of the Greenbrier Limestone is preserved beneath this unconformity in drill hole 11. In eastern Ohio, the Greenbrier Limestone is absent and the unconformity rests on the upper part of the Cuyahoga Formation. Between drill holes 8 and 9, over a distance of 15 to 20 mi, the unconformity shifts abruptly upsection to the Upper Mississippian Logan Formation (Majchszak, 1984), where it remains to the western limit of Pennsylvanian outcrops.

Strata of the Lower and Middle Pennsylvanian Pottsville Group overlie the Lower Pennsylvanian unconformity (fig. 2). In outcrops near drill hole 15 (Cardwell and others, 1968), in drill hole 14, and in USGS corehole no. 8 (Dulong and others, 2002), the Pottsville Group consists of the sandstone-dominated New River and Kanawha Formations. In these areas, the New River Formation is the basal Pennsylvanian unit. West of drill hole 14, the New River Formation downlaps against the unconformity and is subsequently replaced in drill hole 13 by the overlying Middle Pennsylvanian Kanawha Formation as the basal Pennsylvanian unit. About 10 mi west of drill hole 13, across an arbitrary boundary, the Kanawha Formation changes to rocks of the Pottsville Group, undivided. The Pottsville Group, undivided, constitutes the basal Pennsylvanian unit in drill holes 11 and 12 (Filer, 1985; Hohn, 1996) and along the Ohio part of the cross section (Couchot and others, 1980; Hohn, 1996).

The Middle Pennsylvanian Allegheny Group, which consists of coal beds (such as the Upper Freeport coal bed in drill hole 10), gray shale, and sandstone, conformably overlies the Kanawha Formation and the Pottsville Group, undivided. The Allegheny Group extends westward across section *E–E′* from outcrops near drill hole 15 to outcrops between drill holes 8 and 9 (Couchot and others, 1980; Hohn, 1996; Dulong and others, 2002). Conformably overlying the Allegheny Group is the Upper Pennsylvanian Conemaugh Group, which consists of gray and red shale, sandstone, and local coal beds. In most drill holes along cross section *E–E′*, the base of the Conemaugh Group is marked by a 50- to 100-ft-thick sandstone that is probably correlative with the Mahoning Sandstone Member of the Glenshaw Formation of the Conemaugh Group (Rice and others, 1994).

Above the Conemaugh Group are the Upper Pennsylvanian Monongahela Group and the overlying Upper Pennsylvanian(?) to Lower Permian Dunkard Group, which are the youngest Paleozoic strata in the Appalachian basin (Cardwell and others, 1968; Arkle and others, 1979). Both the Monongahela and Dunkard Groups consist largely of gray to red shale, sandstone, limestone, and coal beds. One of these coal beds is the Pittsburgh coal bed, the base of which marks the base of the Monongahela Group (Berryhill and Swanson, 1962). The Pittsburgh coal bed is present near drill hole 10 (Couchot and others, 1980) but is very thin to absent along most of the cross section. Donaldson (1974) interpreted the siliciclastic and carbonate rocks in the Monongahela Group and Dunkard Group as alluvial plain, delta plain, and lacustrine deposits, and Cecil and others (1985) interpreted the coal beds as topogenous, planar swamp deposits that accumulated under humid climate conditions.

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Appendices A and B

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 1	Greenfield Dolomite	Lockport Dolomite	Greenfield Dolomite	Huron Member of the Ohio Shale	Cleveland Member of the Ohio Shale	Black Hand Member of the Cuyahoga Formation	Logan Formation	Pottsville Group, undivided
System or series	Silurian	Silurian	Silurian	Upper Devonian	Upper Devonian	Mississippian	Mississippian	Pennsylvanian
Formation top (relative to KB) (ft)	-7	-9	n/a	-8	-9	-12.5	-12	-10
Formation top (relative to GL) (ft)	0	0	0	0	0	0	0	0
Formation top (relative to SL) (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
Formation 2	Lockport Dolomite	Rochester Shale[1]	Lockport Dolomite	Plum Brook Shale and Prout Limestone	Three Lick Bed	Cuyahoga Formation	Black Hand Member	Logan Formation
System or series	Silurian	Silurian	Silurian	Middle Devonian	Upper Devonian	Mississippian	Mississippian	Mississippian
Formation top (relative to KB) (ft)	-75	-354	n/a	-250	-14	-75	-113	-100
Formation top (relative to GL) (ft)	-68	-345	-51	-242	-5	-62.5	-101	-90
Formation top (relative to SL) (ft)	598	293	646	758	1,002	1,323	1,303	940
Formation 3	Rochester Shale[1]	Dayton Limestone[1]	Rochester Shale[1]	Delaware Limestone-Columbus Limestone-Detroit River Group	Huron Member of the Ohio Shale	Sunbury Shale	Cuyahoga Formation	Black Hand Member
System or series	Silurian	Silurian	Silurian	Middle Devonian	Upper Devonian	Mississippian	Mississippian	Mississippian
Formation top (relative to KB) (ft)	-280	-360	n/a	-286	-90	-402	-260	-440
Formation top (relative to GL) (ft)	-273	-351	-395	-278	-81	-389.5	-248	-430
Formation top (relative to SL) (ft)	393	287	302	722	926	996	1,156	600
Formation 4	Dayton Limestone[1]	Cabot Head Shale	Dayton Limestone[1]	Bois Blanc Formation(?)	Olentangy Shale (lower)	Berea Sandstone	Sunbury Shale	Cuyahoga Formation
System or series	Silurian	Silurian	Silurian	Lower Devonian	Middle Devonian	Upper Devonian	Mississippian	Mississippian
Formation top (relative to KB) (ft)	-288	-380	n/a	-432	-310	-405	-660	-530
Formation top (relative to GL) (ft)	-281	-371	-403	-424	-301	-392.5	-648	-520
Formation top (relative to SL) (ft)	385	267	294	576	706	993	756	510
Formation 5	Cabot Head Shale	Brassfield Limestone	Cabot Head Shale	Salina Group	Delaware Limestone	Bedford Shale	Berea Sandstone	Sunbury Shale
System or series	Silurian	Silurian	Silurian	Silurian	Middle Devonian	Upper Devonian	Upper Devonian	Mississippian
Formation top (relative to KB) (ft)	-302	-480	n/a	-475	-340	-424	-665	-980
Formation top (relative to GL) (ft)	-295	-471	-420	-467	-331	-411.5	-653	-970
Formation top (relative to SL) (ft)	371	167	277	533	676	974	751	60

[1]Included in Rochester Shale and Lower Silurian carbonates and shales, undivided.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[2]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 1	Conemaugh Group	Monongahela Group	Pottsville Group, undiv.	Dunkard Group	Dunkard Group	Monongahela Group	Brallier Formation	Reedsville Shale
System or series	Pennsylvanian	Pennsylvanian	Pennsylvanian	Permian	Permian	Pennsylvanian	Upper Devonian	Upper Ordovician
Formation top (relative to KB) (ft)	-12	-13.3	-15.5	-33	-28	-27	-14	-14.2
Formation top (relative to GL) (ft)	0	0	1	0	0	0	0	0
Formation top (relative to SL) (ft)	995	1,021.7	1,040	693	912	1,203	2,036	2,984.7
Formation 2	Mahoning Sandstone	Conemaugh Group	Greenbrier Limestone	Monongahela Group	Monongahela Group	Conemaugh Group	Harrell Shale[3]	Dolly Ridge Formation
System or series	Pennsylvanian	Pennsylvanian	Mississippian	Pennsylvanian	Pennsylvanian	Pennsylvanian	Upper Devonian	Upper Ordovician
Formation top (relative to KB) (ft)	-392	-300	-220	-520	-390	-373	-1,990	-155
Formation top (relative to GL) (ft)	-380	-286.7	-203.5	-487	-362	-346	-1,976	-140.8
Formation top (relative to SL) (ft)	615	735	835.5	206	550	857	60	2,843.9
Formation 3	Allegheny Group	Mahoning Sandstone	Price Formation	Conemaugh Group	Conemaugh Group	Allegheny Group	Tully Limestone	Nealmont Limestone
System or series	Pennsylvanian	Pennsylvanian	Mississippian	Pennsylvanian	Pennsylvanian	Pennsylvanian	Middle Devonian	Upper Ordovician
Formation top (relative to KB) (ft)	-440	-767	-240	-770	-650	-880	-2,280	-555
Formation top (relative to GL) (ft)	-428	-753.7	-223.5	-737	-622	-853	-2,266	-540.8
Formation top (relative to SL) (ft)	567	267.7	815.5	-44	290	350	-230	2,443.9
Formation 4	Pottsville Group, undiv.	Allegheny Group	Sunbury Shale	Mahoning Sandstone	Mahoning Sandstone	Kanawha Formation	Mahantango Formation	Black River Group
System or series	Pennsylvanian	Pennsylvanian	Mississippian	Pennsylvanian	Pennsylvanian	Pennsylvanian	Middle Devonian	Upper and Middle Ordovician
Formation top (relative to KB) (ft)	-650	-880	-740	-1,314	-1,155	-1,510	-2,310	-785
Formation top (relative to GL) (ft)	-638	-866.7	-723.5	-1,281	-1,127	-1,483	-2,296	-770.8
Formation top (relative to SL) (ft)	357	155	315.5	-588	-215	-280	-260	2,213.9
Formation 5	Cuyahoga Formation	Pottsville Group, undiv.	Berea Sandstone	Allegheny Group	Allegheny Group	New River Formation	Marcellus Shale	Beekmantown Group
System or series	Mississippian	Pennsylvanian	Upper Devonian	Pennsylvanian	Pennsylvanian	Pennsylvanian	Middle Devonian	Lower and Middle Ordovician
Formation top (relative to KB) (ft)	-840	-1,200	-755	-1,415	-1,250	-1,790	-2,408	-1,650
Formation top (relative to GL) (ft)	-828	-1,186.7	-738.5	-1,382	-1,222	-1,763	-2,394	-1,635.8
Formation top (relative to SL) (ft)	167	-165	283.2	-689	-310	-560	-358	1,348.9

[2]At original well. [3]Middlesex Shale Member of the Sonyea Formation and the Genesee Formation equivalent.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E'*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
API no.	**34–173–20237**	**34–143–20147**	**34–147–60840**	**34–033–20050**	**34–117–20012**	**34–117–20047**	**34–139–20289**	**34–031–22053**
Lease name	**No. 1 Carter**	**No. 1 Paul Kerbel**	**M and B Asphalt Co.**	**No. 1 V.E. Leonhardt**	**No. 3 Orrie Myers**	**No. 1 A.C. Windbigler**	**No. 1 J. Palmer**	**No. 1 Edwin L. Lee**
Permanent datum	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**666**	**638**	**697**	**1,000**	**1,007**	**1,385.5**	**1,404**	**1,030**
KB elevation (ft)	**673**	**647**	**n/a**	**1,008**	**1,016**	**1,398**	**1,416**	**1,040**
Measured from	**Kelly bushing**	**Kelly bushing**	**Ground level**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**2,821**	**2,785**	**2,870**	**3,772**	**4,100**	**4,890**	**4,775**	**6,970**
Formation 6	Brassfield Limestone	Queenston Shale	Brassfield Limestone	Lockport Dolomite	Columbus Limestone	Cleveland Member of the Ohio Shale	Bedford Shale	Berea Sandstone
System or series	Silurian	Upper Ordovician	Silurian	Silurian	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-385	-500	n/a	-736	-375	-570	-672	-1,033
Formation top (relative to GL) (ft)	-378	-491	-521	-728	-366	-557.5	-660	-1,023
Formation top (relative to SL) (ft)	288	147	176	272	641	828	744	7
Formation 7	Cincinnati group	Whitewater Formation equivalent	Queenston Shale	Rochester Shale[1]	Salina Group	Three Lick Bed	Cleveland Member of the Ohio Shale	Bedford Shale
System or series	Upper Ordovician	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-401	-620	n/a	-1,121	-512	-645	-800	-1,053
Formation top (relative to GL) (ft)	-394	-611	-559	-1,113	-503	-632.5	-788	-1,043
Formation top (relative to SL) (ft)	272	27	138	-113	504	753	616	-13
Formation 8	Utica Shale	Cincinnati group	Whitewater Formation equivalent	Dayton Limestone[1]	Tymochtee and Greenfield Dolomites, undivided	Huron Member of the Ohio Shale	Three Lick Bed	Cleveland Member of the Ohio Shale
System or series	Upper Ordovician	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-1,030	-750	n/a	-1,131	-820	-712	-880	-1,155
Formation top (relative to GL) (ft)	-1,023	-741	-637	-1,123	-811	-699.5	-868	-1,145
Formation top (relative to SL) (ft)	-357	-103	60	-123	196	686	536	-115
Formation 9	Trenton Limestone	Utica Shale	Cincinnati group	Cabot Head Shale	Lockport Dolomite	Olentangy Shale (upper)	Huron Member of the Ohio Shale	Chagrin Shale equivalent beds
System or series	Upper Ordovician	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-1,175	-1,095	n/a	-1,160	-1,038	-1,006	-957	-1,170
Formation top (relative to GL) (ft)	-1,168	-1,086	-750	-1,152	-1,029	-993.5	-945	-1,160
Formation top (relative to SL) (ft)	-502	-448	-53	-152	-22	392	459	-130
Formation 10	Black River Group	Trenton Limestone	Utica Shale	Brassfield Limestone	Rochester Shale and Lower Silurian carbonates and shales, undivided	Olentangy Shale (lower)	Olentangy Shale (upper)	Huron Member of the Ohio Shale
System or series	Upper and Middle Ordovician	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Middle Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-1,402	-1,250	n/a	-1,250	-1,100	-1,035	-1,300	-1,882
Formation top (relative to GL) (ft)	-1,395	-1,241	-1,200	-1,242	-1,091	-1,022.5	-1,288	-1,872
Formation top (relative to SL) (ft)	-729	-603	-503	-242	-84	363	116	-842

[1]Included in Rochester Shale and Lower Silurian carbonates and shales, undivided.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[2]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 6	Sunbury Shale	Cuyahoga Formation	Chagrin Shale[3]	Pottsville Group, undiv.	Kanawha Formation	Mauch Chunk Group	Huntersville Chert	upper sandstone member[5]
System or series	Mississippian	Mississippian	Upper Devonian	Pennsylvanian	Pennsylvanian	Mississippian	Middle Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-1,180	-1,525	-763	-1,645	-1,640	-2,090	-2,510	-4,370
Formation top (relative to GL) (ft)	-1,168	-1,511.7	-746.5	-1,612	-1,612	-2,063	-2,496	-4,355.8
Formation top (relative to SL) (ft)	-173	-490	292.5	-919	-700	-860	-460	-1,371.2
Formation 7	Berea Sandstone	Sunbury Shale	Chagrin Shale[4]	Price Formation	Greenbrier Limestone	Greenbrier Limestone	Oriskany Sandstone	Copper Ridge Dolomite
System or series	Upper Devonian	Mississippian	Upper Devonian	Mississippian	Mississippian	Mississippian	Lower Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-1,220	-1,850	-1,595	-1,985	-1,906	-2,138	-2,695	-4,615
Formation top (relative to GL) (ft)	-1,208	-1,836.7	-1,578.5	-1,952	-1,878	-2,111	-2,681	-4,600.8
Formation top (relative to SL) (ft)	-213	-815	-539.5	-1,259	-966	-908	-645	-1,616.2
Formation 8	Chagrin Shale	Berea Sandstone	Huron Member of the Ohio Shale	Sunbury Shale	Greenbrier Big Injun sandstone	Greenbrier Big Injun sandstone	Helderberg Limestone	lower sandstone member[5]
System or series	Upper Devonian	Upper Devonian	Upper Devonian	Mississippian	Mississippian	Mississippian	Lower Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-1,295	-1,906	-2,430	-2,300	-2,033	-2,240	-2,830	-6,370
Formation top (relative to GL) (ft)	-1,283	-1,892.7	-2,413.5	-2,267	-2,005	-2,213	-2,816	-6,355.8
Formation top (relative to SL) (ft)	-288	-871	-1,374.5	-1,574	-1,093	-1,010	-780	-3,371.2
Formation 9	Huron Member of the Ohio Shale	Chagrin Shale[3]	Java Formation	Berea Sandstone	Pocono Big Injun sandstone	Price Formation	Mandata Shale	Elbrook Dolomite[6]
System or series	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Mississippian	Mississippian	Lower Devonian	Middle and Upper Cambrian
Formation top (relative to KB) (ft)	-2,375	-1,910	-2,700	-2,315	-2,055	-2,265	-3,100	-6,805
Formation top (relative to GL) (ft)	-2,363	-1,896.7	-2,683.5	-2,282	-2,027	-2,238	-3,086	-6,790.8
Formation top (relative to SL) (ft)	-1,368	-875	-1,644.5	-1,589	-1,115	-1,035	-1,050	-3,806.2
Formation 10	Java Formation	Chagrin Shale[4]	Angola Shale Member	Chagrin Shale[3]	Price Formation	Sunbury Shale	Keyser Limestone (upper)	Trenton Group (overturned)
System or series	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Mississippian	Mississippian	Lower Devonian	Upper Ordovician
Formation top (relative to KB) (ft)	-2,793	-2,260	-2,963	-2,320	-2,120	-2,600	-3,152	-10,030
Formation top (relative to GL) (ft)	-2,781	-2,246.7	-2,946.5	-2,287	-2,092	-2,573	-3,138	-10,015.8
Formation top (relative to SL) (ft)	-1,786	-1,225	-1,907.5	-1,594	-1,180	-1,370	-1,102	-7,031.2

[2]At original well. [3]Silty facies. [4]Shale facies. [5]Member of the Copper Ridge Dolomite. [6]Conasauga Group equivalent.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
API no.	**34–173–20237**	**34–143–20147**	**34–147–60840**	**34–033–20050**	**34–117–20012**	**34–117–20047**	**34–139–20289**	**34–031–22053**
Lease name	**No. 1 Carter**	**No. 1 Paul Kerbel**	**M and B Asphalt Co.**	**No. 1 V.E. Leonhardt**	**No. 3 Orrie Myers**	**No. 1 A.C. Windbigler**	**No. 1 J. Palmer**	**No. 1 Edwin L. Lee**
Permanent datum	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**666**	**638**	**697**	**1,000**	**1,007**	**1,385.5**	**1,404**	**1,030**
KB elevation (ft)	**673**	**647**	**n/a**	**1,008**	**1,016**	**1,398**	**1,416**	**1,040**
Measured from	**Kelly bushing**	**Kelly bushing**	**Ground level**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**2,821**	**2,785**	**2,870**	**3,772**	**4,100**	**4,890**	**4,775**	**6,970**
Formation 11	Knox Dolomite	Black River Group	Trenton Limestone	Queenston Shale	Cabot Head Shale	Delaware Limestone	Olentangy Shale (lower)	Java Formation
System or series	Upper Cambrian	Upper Ordovician	Upper Ordovician	Upper Ordovician	Silurian	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-1,944	-1,524	n/a	-1,280	-1,150	-1,060	-1,350	-2,175
Formation top (relative to GL) (ft)	-1,937	-1,515	-1,450	-1,272	-1,141	-1,047.5	-1,338	-2,165
Formation top (relative to SL) (ft)	-1,271	-877	-753	-272	-134	338	66	-1,135
Formation 12	Kerbel Formation	Wells Creek formation	Black River Group	Cincinnati group	Brassfield Limestone	Columbus Limestone	Delaware Limestone	Angola Shale Member
System or series	Upper Cambrian	Middle Ordovician	Upper Ordovician	Upper Ordovician	Silurian	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-2,140	-2,050	n/a	-1,388	-1,228	-1,080	-1,380	-2,250
Formation top (relative to GL) (ft)	-2,133	-2,041	-1,590	-1,380	-1,219	-1,067.5	-1,368	-2,240
Formation top (relative to SL) (ft)	-1,467	-1,403	-893	-380	-212	318	36	-1,210
Formation 13	Eau Claire Formation	Knox Dolomite	Wells Creek formation	Cincinnati group[1]	Queenston Shale	Bois Blanc Formation(?)	Columbus Limestone	Rhinestreet Shale Member
System or series	Upper Cambrian	Upper Cambrian	Middle Ordovician	Upper Ordovician	Upper Ordovician	Lower Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-2,250	-2,060	n/a	-1,520	-1,264	-1,185	-1,396	-2,300
Formation top (relative to GL) (ft)	-2,243	-2,051	-2,118	-1,512	-1,255	-1,172.5	-1,384	-2,290
Formation top (relative to SL) (ft)	-1,577	-1,413	-1,421	-512	-248	213	20	-1,260
Formation 14	Eau Claire Formation[2]	Kerbel Formation	Knox Dolomite	Utica Shale	Cincinnati group	Salina Group	Salina Group	Mahantango Formation
System or series	Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-2,330	-2,114	n/a	-2,212	-1,389	-1,220	-1,505	-2,340
Formation top (relative to GL) (ft)	-2,323	-2,105	-2,128	-2,204	-1,380	-1,207.5	-1,493	-2,330
Formation top (relative to SL) (ft)	-1,657	-1,467	-1,431	-1,204	-373	178	-89	-1,300
Formation 15	Eau Claire Formation[3]	Nolichucky Shale	Kerbel Formation	Trenton Limestone	Cincinnati group[1]	Lockport Dolomite	Lockport Dolomite	Marcellus Shale
System or series	Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-2,395	-2,220	n/a	-2,370	-1,496	-1,473	-1,890	-2,394
Formation top (relative to GL) (ft)	-2,388	-2,211	-2,228	-2,362	-1,487	-1,460.5	-1,878	-2,384
Formation top (relative to SL) (ft)	-1,722	-1,573	-1,531	-1,362	-480	-75	-474	-1,354

[1]Informal marker bed. [2]Unnamed tongue of the Maryville Limestone. [3]Unnamed sandstone member.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
API no.	**34–059–20782**	**34–121–21278**	**47–107–00351**	**47–107–00756**	**47–035–01366**	**47–013–02503**	**47–083–00103**	**47–071–00006**
Lease name	**No. 1 W.R. Marshall**	**No. 1 Robert Ullman**	**No. 9634 Power Oil Co.**	**No. 1 Howard H. Deem**	**No. 1 Walter McCoy**	**No. 1 Gainer-Lee**	**No. 10,228 W. VA.**	**No. 1 Ray Sponaugle**
Permanent datum	**Ground level**	**Ground level**	**Ground level[4]**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**995**	**1,021.7**	**1,039**	**693**	**912**	**1,203**	**2,036**	**2,984.7**
KB elevation (ft)	**1,007**	**1,035**	**1,055.5**	**726**	**940**	**1,230**	**2,050**	**2,998.9**
Measured from	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**8,602**	**11,442**	**13,327**	**13,266**	**17,675**	**20,222**	**13,121**	**13,000**
Formation 11	Angola Shale Member	Huron Member of the Ohio Shale	Rhinestreet Shale Member	Chagrin Shale[5]	Sunbury Shale	Berea Sandstone	Big Mountain Shale[6]	Reedsville Shale (overturned)
System or series	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Mississippian	Upper Devonian	Silurian	Upper Ordovician
Formation top (relative to KB) (ft)	-2,915	-3,650	-3,400	-2,750	-2,508	-2,625	-3,335	-11,045
Formation top (relative to GL) (ft)	-2,903	-3,636.7	-3,383.5	-2,717	-2,480	-2,598	-3,321	-11,030.8
Formation top (relative to SL) (ft)	-1,908	-2,615	-2,344.5	-2,024	-1,568	-1,395	-1,285	-8,046.2
Formation 12	Rhinestreet Shale Member	Java Formation	Sonyea Formation	Huron Member of the Ohio Shale	Berea Sandstone	Greenland Gap (Foreknobs) Formation	Keyser Limestone (lower)	Reedsville Shale (upright)
System or series	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Silurian	Upper Ordovician
Formation top (relative to KB) (ft)	-3,066	-3,975	-3,685	-3,550	-2,520	-2,630	-3,395	-11,270
Formation top (relative to GL) (ft)	-3,054	-3,961.7	-3,668.5	-3,517	-2,492	-2,603	-3,381	-11,255.8
Formation top (relative to SL) (ft)	-2,059	-2,940	-2,629.5	-2,824	-1,580	-1,400	-1,345	-8,271.2
Formation 13	Hamilton Group	Angola Shale Member	Genesee Formation	Java Formation	Greenland Gap (Foreknobs) Formation	Upper Devonian strata, undivided[7]	Tonoloway Limestone[8]	Trenton Group
System or series	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Silurian	Upper Ordovician
Formation top (relative to KB) (ft)	-3,115	-4,148	-3,765	-4,230	-2,537	-2,984	-3,464	-11,470
Formation top (relative to GL) (ft)	-3,103	-4,134.7	-3,748.5	-4,197	-2,509	-2,957	-3,450	-11,455.8
Formation top (relative to SL) (ft)	-2,108	-3,113	-2,709.5	-3,504	-1,597	-1,754	-1,414	-8,471.2
Formation 14	Onondaga Limestone	Rhinestreet Shale Member	Mahantango Formation	Angola Shale Member	Upper Devonian strata, undivided	Upper Devonian strata, undivided[5]	Wills Creek Formation	Black River Group
System or series	Middle Devonian	Upper Devonian	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Silurian	Upper Ordovician
Formation top (relative to KB) (ft)	-3,196	-4,383	-3,846	-4,392	-2,885	-3,257	-4,005	-12,160
Formation top (relative to GL) (ft)	-3,184	-4,369.7	-3,829.5	-4,359	-2,857	-3,230	-3,991	-12,145.8
Formation top (relative to SL) (ft)	-2,189	-3,348	-2,790.5	-3,666	-1,945	-2,027	-1,955	-9,161.2
Formation 15	Oriskany Sandstone	Mahantango Formation	Marcellus Shale	Rhinestreet Shale Member	Huron Member of the Ohio Shale	Huron Member of the Ohio Shale	McKenzie Limestone[9]	
System or series	Lower Devonian	Middle Devonian	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Silurian	
Formation top (relative to KB) (ft)	-3,350	-4,743	-3,970	-4,640	-3,950	-4,525	-4,205	
Formation top (relative to GL) (ft)	-3,338	-4,729.7	-3,953.5	-4,607	-3,922	-4,498	-4,191	
Formation top (relative to SL) (ft)	-2,343	-3,708	-2,914.5	-3,914	-3,010	-3,295	-2,155	

[4]At original well. [5]Shale facies. [6]Bass Islands equivalent. [7]Silty facies. [8]Salina equivalent. [9]Lockport Dolomite equivalent.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
API no.	**34–173–20237**	**34–143–20147**	**34–147–60840**	**34–033–20050**	**34–117–20012**	**34–117–20047**	**34–139–20289**	**34–031–22053**
Lease name	**No. 1 Carter**	**No. 1 Paul Kerbel**	**M and B Asphalt Co.**	**No. 1 V.E. Leonhardt**	**No. 3 Orrie Myers**	**No. 1 A.C. Windbigler**	**No. 1 J. Palmer**	**No. 1 Edwin L. Lee**
Permanent datum	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**666**	**638**	**697**	**1,000**	**1,007**	**1,385.5**	**1,404**	**1,030**
KB elevation (ft)	**673**	**647**	**n/a**	**1,008**	**1,016**	**1,398**	**1,416**	**1,040**
Measured from	**Kelly bushing**	**Kelly bushing**	**Ground level**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**2,821**	**2,785**	**2,870**	**3,772**	**4,100**	**4,890**	**4,775**	**6,970**
Formation 16	Mount Simon Sandstone	Maryville Limestone (upper)	Nolichucky Shale	Black River Group	Utica Shale	Rochester Shale and Lower Silurian carbonates and shales, undivided	Rochester Shale and Lower Silurian carbonates and shales, undivided	Onondaga Limestone
System or series	Middle and Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian	Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-2,550	-2,308	n/a	-2,430	-2,210	-1,952	-2,210	-2,400
Formation top (relative to GL) (ft)	-2,543	-2,299	-2,322	-2,422	-2,201	-1,939.5	-2,198	-2,390
Formation top (relative to SL) (ft)	-1,877	-1,661	-1,625	-1,422	-1,194	-554	-794	-1,360
Formation 17	Metamorphic and igneous rocks	unnamed sandstone in Maryville Limestone	Maryville Limestone (upper)	Wells Creek formation	Trenton Limestone	Clinton sandstone-Cabot Head Shale	Clinton sandstone-Cabot Head Shale	Helderberg Limestone
System or series	Mesoproterozoic	Upper Cambrian	Upper Cambrian	Middle Ordovician	Upper Ordovician	Silurian	Silurian	Lower Devonian
Formation top (relative to KB) (ft)	-2,825	-2,390	n/a	-2,964	-2,385	-2,000	-2,290	-2,535
Formation top (relative to GL) (ft)	-2,818	-2,381	-2,431	-2,956	-2,376	-1,987.5	-2,278	-2,525
Formation top (relative to SL) (ft)	-2,152	-1,743	-1,734	-1,956	-1,369	-602	-874	-1,495
Formation 18		Maryville Limestone (lower)	unnamed sandstone in Maryville Limestone	Knox Dolomite	Black River Group	Brassfield Limestone	Brassfield Limestone	Bass Islands Dolomite
System or series		Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician	Silurian	Silurian	Silurian
Formation top (relative to KB) (ft)		-2,515	n/a	-2,980	-2,440	-2,100	-2,370	-2,595
Formation top (relative to GL) (ft)		-2,506	-2,530	-2,972	-2,431	-2,087.5	-2,358	-2,585
Formation top (relative to SL) (ft)		-1,868	-1,833	-1,972	-1,424	-702	-954	-1,555
Formation 19		Mount Simon Sandstone	Maryville Limestone (lower)	Kerbel Formation	Wells Creek formation	Queenston Shale	Queenston Shale	Salina Group
System or series		Middle and Upper Cambrian	Upper Cambrian	Upper Cambrian	Middle Ordovician	Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)		-2,530	n/a	-3,220	-2,962	-2,135	-2,403	-2,618
Formation top (relative to GL) (ft)		-2,521	-2,578	-3,212	-2,953	-2,122.5	-2,391	-2,608
Formation top (relative to SL) (ft)		-1,883	-1,881	-2,212	-1,946	-737	-987	-1,578
Formation 20		Metamorphic and igneous rocks	Mount Simon Sandstone	Nolichucky Shale	Knox Dolomite (upper)	Cincinnati group	Cincinnati group	Lockport Dolomite
System or series		Mesoproterozoic	Middle and Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)		-2,785	n/a	-3,290	-2,978	-2,230	-2,622	-3,110
Formation top (relative to GL) (ft)		-2,776	-2,650	-3,282	-2,969	-2,217.5	-2,610	-3,100
Formation top (relative to SL) (ft)		-2,138	-1,953	-2,282	-1,962	-832	-1,206	-2,070

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[1]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 16	Helderberg Limestone	Marcellus Shale	Onondaga Limestone	Sonyea Formation	Java Formation	Java Formation	Tonoloway Limestone[2]	
System or series	Lower Devonian	Middle Devonian	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Silurian	
Formation top (relative to KB) (ft)	-3,360	-4,793	-4,025	-4,940	-4,545	-4,900	-4,325	
Formation top (relative to GL) (ft)	-3,348	-4,779.7	-4,008.5	-4,907	-4,517	-4,873	-4,311	
Formation top (relative to SL) (ft)	-2,353	-3,758	-2,969.5	-4,214	-3,605	-3,670	-2,275	
Formation 17	Bass Islands Dolomite	Onondaga Limestone	Oriskany Sandstone	Marcellus Shale	Angola Shale Member	Angola Shale Member	Wills Creek Formation	
System or series	Silurian	Middle Devonian	Lower Devonian	Middle Devonian	Upper Devonian	Upper Devonian	Silurian	
Formation top (relative to KB) (ft)	-3,480	-4,807	-4,316	-4,988	-4,710	-5,100	-4,592	
Formation top (relative to GL) (ft)	-3,468	-4,793.7	-4,299.5	-4,955	-4,682	-5,073	-4,578	
Formation top (relative to SL) (ft)	-2,473	-3,772	-3,260.5	-4,262	-3,770	-3,870	-2,542	
Formation 18	Salina Group	Oriskany Sandstone	Onondaga Limestone	Onondaga Limestone	Rhinestreet Shale Member	Rhinestreet Shale Member	Williamsport Sandstone	
System or series	Silurian	Lower Devonian	Middle Devonian	Middle Devonian	Upper Devonian	Upper Devonian	Silurian	
Formation top (relative to KB) (ft)	-3,512	-4,960	-4,530	-5,010	-4,946	-5,397	-4,705	
Formation top (relative to GL) (ft)	-3,500	-4,946.7	-4,513.5	-4,977	-4,918	-5,370	-4,691	
Formation top (relative to SL) (ft)	-2,505	-3,925	-3,474.5	-4,284	-4,006	-4,167	-2,655	
Formation 19	Lockport Dolomite	Helderberg Limestone	Marcellus Shale	Oriskany Sandstone	Sonyea Formation	Sonyea Formation	McKenzie Limestone[3]	
System or series	Silurian	Lower Devonian	Middle Devonian	Lower Devonian	Upper Devonian	Upper Devonian	Silurian	
Formation top (relative to KB) (ft)	-4,147	-5,010	-4,940	-5,166	-5,078	-5,970	-4,732	
Formation top (relative to GL) (ft)	-4,135	-4,996.7	-4,923.5	-5,133	-5,050	-5,943	-4,718	
Formation top (relative to SL) (ft)	-3,140	-3,975	-3,884.5	-4,440	-4,138	-4,740	-2,682	
Formation 20	Rochester Shale	Bass Islands Dolomite	Onondaga Limestone	Helderberg Limestone	Mahantango Formation	Genesee Formation	Keefer Sandstone	
System or series	Silurian	Silurian	Middle Devonian	Lower Devonian	Middle Devonian	Upper Devonian	Silurian	
Formation top (relative to KB) (ft)	-4,390	-5,227	-4,995	-5,204	-5,170	-6,130	-4,900	
Formation top (relative to GL) (ft)	-4,378	-5,213.7	-4,978.5	-5,171	-5,142	-6,103	-4,886	
Formation top (relative to SL) (ft)	-3,383	-4,192	-3,939.5	-4,478	-4,230	-4,900	-2,850	

[1]At original well. [2]Salina equivalent. [3]Lockport Dolomite equivalent.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 21			Metamorphic and igneous rocks	Maryville Limestone (upper)	B zone	Cincinnati group[1]	Utica Shale	Rochester Shale
System or series			Mesoproterozoic	Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)			n/a	-3,380	-3,050	-2,358	-3,400	-3,385
Formation top (relative to GL) (ft)			-2,810	-3,372	-3,041	-2,345.5	-3,388	-3,375
Formation top (relative to SL) (ft)			-2,113	-2,372	-2,034	-960	-1,984	-2,345
Formation 22				unnamed sandstone in Maryville Limestone	Knox Dolomite (lower)	Utica Shale	Trenton Limestone	Lower Silurian carbonates and shales, undivided
System or series				Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)				-3,485	-3,168	-3,100	-3,592	-3,475
Formation top (relative to GL) (ft)				-3,477	-3,159	-3,087.5	-3,580	-3,465
Formation top (relative to SL) (ft)				-2,477	-2,152	-1,702	-2,176	-2,435
Formation 23				Maryville Limestone (lower)	Kerbel Formation	Trenton Limestone	Black River Group	Clinton sandstone-Cabot Head Shale-Medina sandstone
System or series				Upper Cambrian	Upper Cambrian	Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)				-3,540	-3,350	-3,280	-3,650	-3,540
Formation top (relative to GL) (ft)				-3,532	-3,341	-3,267.5	-3,638	-3,530
Formation top (relative to SL) (ft)				-2,532	-2,334	-1,882	-2,234	-2,500
Formation 24				Mount Simon Sandstone	Nolichucky Shale	Black River Group	Wells Creek formation	Brassfield Limestone
System or series				Middle and Upper Cambrian	Upper Cambrian	Upper Ordovician	Middle Ordovician	Silurian
Formation top (relative to KB) (ft)				-3,650	-3,393	-3,350	-4,195	-3,675
Formation top (relative to GL) (ft)				-3,642	-3,384	-3,337.5	-4,183	-3,665
Formation top (relative to SL) (ft)				-2,642	-2,377	-1,952	-2,779	-2,635
Formation 25					Maryville Limestone (upper)	Wells Creek formation	Knox Dolomite (upper)	Queenston Shale
System or series					Upper Cambrian	Middle Ordovician	Upper Cambrian	Upper Ordovician
Formation top (relative to KB) (ft)					-3,520	-3,875	-4,220	-3,700
Formation top (relative to GL) (ft)					-3,511	-3,862.5	-4,208	-3,690
Formation top (relative to SL) (ft)					-2,504	-2,477	-2,804	-2,660

[1]Informal marker bed.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[2]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 21	Lower Silurian carbonates and shales, undivided	Salina Group	Oriskany Sandstone	Mandata Shale	Marcellus Shale	Marcellus Shale	Rose Hill Formation	
System or series	Silurian	Silurian	Lower Devonian	Lower Devonian	Middle Devonian	Middle Devonian	Silurian	
Formation top (relative to KB) (ft)	-4,487	-5,282	-5,450	-5,355	-5,191	-6,210	-4,940	
Formation top (relative to GL) (ft)	-4,475	-5,268.7	-5,433.5	-5,322	-5,163	-6,183	-4,926	
Formation top (relative to SL) (ft)	-3,480	-4,247	-4,394.5	-4,629	-4,251	-4,980	-2,890	
Formation 22	Clinton sandstone-Cabot Head Shale-Medina sandstone	Lockport Dolomite	Helderberg Limestone	Keyser Limestone (upper)	Onondaga Limestone	Huntersville Chert	Tuscarora Sandstone	
System or series	Silurian	Silurian	Lower Devonian	Lower Devonian	Middle Devonian	Middle Devonian	Silurian	
Formation top (relative to KB) (ft)	-4,570	-6,050	-5,625	-5,364	-5,209	-6,245	-5,700	
Formation top (relative to GL) (ft)	-4,558	-6,036.7	-5,608.5	-5,331	-5,181	-6,218	-5,686	
Formation top (relative to SL) (ft)	-3,563	-5,015	-4,569.5	-4,638	-4,269	-5,015	-3,650	
Formation 23	Queenston Shale	Keefer Sandstone	Onondaga Limestone	Bass Islands Dolomite	Oriskany Sandstone	Oriskany Sandstone	Juniata Formation	
System or series	Upper Ordovician	Silurian	Middle Devonian	Silurian	Lower Devonian	Lower Devonian	Upper Ordovician	
Formation top (relative to KB) (ft)	-4,740	-6,300	-5,700	-5,433	-5,360	-6,430	-5,950	
Formation top (relative to GL) (ft)	-4,728	-6,286.7	-5,683.5	-5,400	-5,332	-6,403	-5,936	
Formation top (relative to SL) (ft)	-3,733	-5,265	-4,644.5	-4,707	-4,420	-5,200	-3,900	
Formation 24	Cincinnati group	Rochester Shale	Oriskany Sandstone	Salina Group	Helderberg Limestone	Helderberg Limestone	Juniata Formation	
System or series	Upper Ordovician	Silurian	Lower Devonian	Silurian	Lower Devonian	Lower Devonian	Upper Ordovician	
Formation top (relative to KB) (ft)	-5,100	-6,355	-5,870	-5,440	-5,400	-6,520	-6,990	
Formation top (relative to GL) (ft)	-5,088	-6,341.7	-5,853.5	-5,407	-5,372	-6,493	-6,976	
Formation top (relative to SL) (ft)	-4,093	-5,320	-4,814.5	-4,714	-4,460	-5,290	-4,940	
Formation 25	Utica Shale	Lower Silurian carbonates and shales, undivided	Helderberg Limestone	Wills Creek Formation	Mandata Shale	Mandata Shale	Oswego Sandstone	
System or series	Upper Ordovician	Silurian	Lower Devonian	Silurian	Lower Devonian	Lower Devonian	Upper Ordovician	
Formation top (relative to KB) (ft)	-5,943	-6,532	-5,935	-5,990	-5,563	-6,750	-7,290	
Formation top (relative to GL) (ft)	-5,931	-6,518.7	-5,918.5	-5,957	-5,535	-6,723	-7,276	
Formation top (relative to SL) (ft)	-4,936	-5,497	-4,879.5	-5,264	-4,623	-5,520	-5,240	

[2]At original well.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
API no.	**34–173–20237**	**34–143–20147**	**34–147–60840**	**34–033–20050**	**34–117–20012**	**34–117–20047**	**34–139–20289**	**34–031–22053**
Lease name	**No. 1 Carter**	**No. 1 Paul Kerbel**	**M and B Asphalt Co.**	**No. 1 V.E. Leonhardt**	**No. 3 Orrie Myers**	**No. 1 A.C. Windbigler**	**No. 1 J. Palmer**	**No. 1 Edwin L. Lee**
Permanent datum	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**666**	**638**	**697**	**1,000**	**1,007**	**1,385.5**	**1,404**	**1,030**
KB elevation (ft)	**673**	**647**	**n/a**	**1,008**	**1,016**	**1,398**	**1,416**	**1,040**
Measured from	**Kelly bushing**	**Kelly bushing**	**Ground level**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**2,821**	**2,785**	**2,870**	**3,772**	**4,100**	**4,890**	**4,775**	**6,970**
Formation 26					unnamed sandstone in Maryville Limestone	Knox Dolomite (upper)	B zone	Cincinnati group
System or series					Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician
Formation top (relative to KB) (ft)					-3,653	-3,884	-4,405	-3,950
Formation top (relative to GL) (ft)					-3,644	-3,871.5	-4,393	-3,940
Formation top (relative to SL) (ft)					-2,637	-2,486	-2,989	-2,910
Formation 27					Maryville Limestone (lower)	B zone	Knox Dolomite (lower)	Utica Shale
System or series					Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician
Formation top (relative to KB) (ft)					-3,690	-3,990	-4,510	-4,840
Formation top (relative to GL) (ft)					-3,681	-3,977.5	-4,498	-4,830
Formation top (relative to SL) (ft)					-2,674	-2,592	-3,094	-3,800
Formation 28					Mount Simon Sandstone	Knox Dolomite (lower)	Kerbel Formation	Trenton Limestone
System or series					Middle and Upper Cambrian	Upper Cambrian	Upper Cambrian	Upper Ordovician
Formation top (relative to KB) (ft)					-3,855	-4,100	-4,615	-5,040
Formation top (relative to GL) (ft)					-3,846	-4,087.5	-4,603	-5,030
Formation top (relative to SL) (ft)					-2,839	-2,702	-3,199	-4,000
Formation 29					Metamorphic and igneous rocks	Kerbel Formation	Nolichucky Shale	Black River Group
System or series					Mesoproterozoic	Upper Cambrian	Upper Cambrian	Upper Ordovician
Formation top (relative to KB) (ft)					-4,000	-4,270	-4,665	-5,135
Formation top (relative to GL) (ft)					-3,991	-4,257.5	-4,653	-5,125
Formation top (relative to SL) (ft)					-2,984	-2,872	-3,249	-4,095
Formation 30						Nolichucky Shale	Maryville Limestone	Wells Creek formation
System or series						Upper Cambrian	Upper Cambrian	Middle Ordovician
Formation top (relative to KB) (ft)						-4,320	-4,740	-5,750
Formation top (relative to GL) (ft)						-4,307.5	-4,728	-5,740
Formation top (relative to SL) (ft)						-2,922	-3,324	-4,710

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[1]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 26	Trenton Limestone	Clinton sandstone-Cabot Head Shale-Medina sandstone	Mandata Shale	McKenzie Limestone	Keyser Limestone (upper)	Keyser Limestone (upper)	Reedsville Shale	
System or series	Upper Ordovician	Silurian	Lower Devonian	Silurian	Lower Devonian	Lower Devonian	Upper Ordovician	
Formation top (relative to KB) (ft)	-6,140	-6,655	-6,085	-6,140	-5,569	-6,760	-7,500	
Formation top (relative to GL) (ft)	-6,128	-6,641.7	-6,068.5	-6,107	-5,541	-6,733	-7,486	
Formation top (relative to SL) (ft)	-5,133	-5,620	-5,029.5	-5,414	-4,629	-5,530	-5,450	
Formation 27	Black River Group	Queenston Shale	Keyser Limestone (upper)	Keefer Sandstone	Bass Islands Dolomite	Bass Islands Dolomite	Reedsville Shale	
System or series	Upper Ordovician	Upper Ordovician	Lower Devonian	Silurian	Silurian	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-6,255	-6,830	-6,098	-6,365	-5,639	-6,870	-8,780	
Formation top (relative to GL) (ft)	-6,243	-6,816.7	-6,081.5	-6,332	-5,611	-6,843	-8,766	
Formation top (relative to SL) (ft)	-5,248	-5,795	-5,042.5	-5,639	-4,699	-5,640	-6,730	
Formation 28	Wells Creek formation	Cincinnati group	Bass Islands Dolomite	Rose Hill Formation	Salina Group	Salina Group (upper)	Reedsville Shale	
System or series	Middle Ordovician	Upper Ordovician	Silurian	Silurian	Silurian	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-6,904	-7,293	-6,172	-6,395	-5,645	-6,906	-9,650	
Formation top (relative to GL) (ft)	-6,892	-7,279.7	-6,155.5	-6,362	-5,617	-6,879	-9,636	
Formation top (relative to SL) (ft)	-5,897	-6,258	-5,116.5	-5,669	-4,705	-5,676	-7,600	
Formation 29	Beekmantown dolomite	Utica Shale	Salina Group	Tuscarora Sandstone	Wills Creek Formation	Salina Group halite bed	Dolly Ridge Formation	
System or series	Lower Ordovician	Upper Ordovician	Silurian	Silurian	Silurian	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-6,950	-8,180	-6,225	-6,788	-6,180	-7,165	-10,046	
Formation top (relative to GL) (ft)	-6,938	-8,166.7	-6,208.5	-6,755	-6,152	-7,138	-10,032	
Formation top (relative to SL) (ft)	-5,943	-7,145	-5,169.5	-6,062	-5,240	-5,935	-7,996	
Formation 30	Rose Run sandstone	Trenton Limestone	Wills Creek Formation	Juniata Formation	McKenzie Limestone	Salina Group (lower)	Nealmont Limestone	
System or series	Upper Cambrian	Upper Ordovician	Silurian	Upper Ordovician	Silurian	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-7,050	-8,410	-6,790	-6,935	-6,290	-7,230	-10,400	
Formation top (relative to GL) (ft)	-7,038	-8,396.7	-6,773.5	-6,902	-6,262	-7,203	-10,386	
Formation top (relative to SL) (ft)	-6,043	-7,375	-5,734.5	-6,209	-5,350	-6,000	-8,350	

[1]At original well.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
API no.	**34–173–20237**	**34–143–20147**	**34–147–60840**	**34–033–20050**	**34–117–20012**	**34–117–20047**	**34–139–20289**	**34–031–22053**
Lease name	**No. 1 Carter**	**No. 1 Paul Kerbel**	**M and B Asphalt Co.**	**No. 1 V.E. Leonhardt**	**No. 3 Orrie Myers**	**No. 1 A.C. Windbigler**	**No. 1 J. Palmer**	**No. 1 Edwin L. Lee**
Permanent datum	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**666**	**638**	**697**	**1,000**	**1,007**	**1,385.5**	**1,404**	**1,030**
KB elevation (ft)	**673**	**647**	**n/a**	**1,008**	**1,016**	**1,398**	**1,416**	**1,040**
Measured from	**Kelly bushing**	**Kelly bushing**	**Ground level**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**2,821**	**2,785**	**2,870**	**3,772**	**4,100**	**4,890**	**4,775**	**6,970**
Formation 31						Maryville Limestone (upper)		Rose Run sandstone
System or series						Upper Cambrian		Upper Cambrian
Formation top (relative to KB) (ft)						-4,405		-5,798
Formation top (relative to GL) (ft)						-4,392.5		-5,788
Formation top (relative to SL) (ft)						-3,007		-4,758
Formation 32						unnamed sandstone in Maryville Limestone		Copper Ridge dolomite (upper)
System or series						Upper Cambrian		Upper Cambrian
Formation top (relative to KB) (ft)						-4,560		-5,810
Formation top (relative to GL) (ft)						-4,547.5		-5,800
Formation top (relative to SL) (ft)						-3,162		-4,770
Formation 33						Maryville Limestone (lower)		B zone
System or series						Upper Cambrian		Upper Cambrian
Formation top (relative to KB) (ft)						-4,590		-5,927
Formation top (relative to GL) (ft)						-4,577.5		-5,917
Formation top (relative to SL) (ft)						-3,192		-4,887
Formation 34						Mount Simon Sandstone		Copper Ridge dolomite (lower)
System or series						Middle and Upper Cambrian		Upper Cambrian
Formation top (relative to KB) (ft)						-4,750		-6,010
Formation top (relative to GL) (ft)						-4,737.5		-6,000
Formation top (relative to SL) (ft)						-3,352		-4,970
Formation 35						Metamorphic and igneous rocks		Kerbel Formation
System or series						Mesoproterozoic		Upper Cambrian
Formation top (relative to KB) (ft)						-4,870		-6,190
Formation top (relative to GL) (ft)						-4,857.5		-6,180
Formation top (relative to SL) (ft)						-3,472		-5,150

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
API no.	**34–059–20782**	**34–121–21278**	**47–107–00351**	**47–107–00756**	**47–035–01366**	**47–013–02503**	**47–083–00103**	**47–071–00006**
Lease name	**No. 1 W.R. Marshall**	**No. 1 Robert Ullman**	**No. 9634 Power Oil Co.**	**No. 1 Howard H. Deem**	**No. 1 Walter McCoy**	**No. 1 Gainer-Lee**	**No. 10,228 W. VA.**	**No. 1 Ray Sponaugle**
Permanent datum	**Ground level**	**Ground level**	**Ground level[1]**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**995**	**1,021.7**	**1,039**	**693**	**912**	**1,203**	**2,036**	**2,984.7**
KB elevation (ft)	**1,007**	**1,035**	**1,055.5**	**726**	**940**	**1,230**	**2,050**	**2,998.9**
Measured from	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**8,602**	**11,442**	**13,327**	**13,266**	**17,675**	**20,222**	**13,121**	**13,000**
Formation 31	Copper Ridge dolomite (upper)	Black River Group	McKenzie Limestone	Reedsville Shale	Keefer Sandstone	Wills Creek Formation	Black River Group	
System or series	Upper Cambrian	Upper Ordovician	Silurian	Upper Ordovician	Silurian	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-7,110	-8,550	-6,980	-7,468	-6,503	-7,630	-10,690	
Formation top (relative to GL) (ft)	-7,098	-8,536.7	-6,963.5	-7,435	-6,475	-7,603	-10,676	
Formation top (relative to SL) (ft)	-6,103	-7,515	-5,924.5	-6,742	-5,563	-6,400	-8,640	
Formation 32	B zone	Wells Creek formation	Keefer Sandstone	Utica Shale	Rose Hill Formation	McKenzie Limestone	Row Park Limestone(?)	
System or series	Upper Cambrian	Middle Ordovician	Silurian	Upper Ordovician	Silurian	Silurian	Middle Ordovician	
Formation top (relative to KB) (ft)	-7,320	-9,270	-7,208	-8,450	-6,523	-7,810	-11,580	
Formation top (relative to GL) (ft)	-7,308	-9,256.7	-7,191.5	-8,417	-6,495	-7,783	-11,566	
Formation top (relative to SL) (ft)	-6,313	-8,235	-6,152.5	-7,724	-5,583	-6,580	-9,530	
Formation 33	Copper Ridge dolomite (lower)	Beekmantown dolomite	Rose Hill Formation	Trenton Limestone	Tuscarora Sandstone	Keefer Sandstone	Black River Group	
System or series	Upper Cambrian	Lower Ordovician	Silurian	Upper Ordovician	Silurian	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-7,415	-9,372	-7,260	-8,630	-6,975	-8,050	-11,684	
Formation top (relative to GL) (ft)	-7,403	-9,358.7	-7,243.5	-8,597	-6,947	-8,023	-11,670	
Formation top (relative to SL) (ft)	-6,408	-8,337	-6,204.5	-7,904	-6,035	-6,820	-9,634	
Formation 34	Nolichucky Shale	Rose Run sandstone	Tuscarora Sandstone	Black River Limestone	Juniata Formation	Rose Hill Formation	Row Park Limestone(?)	
System or series	Upper Cambrian	Upper Cambrian	Silurian	Upper Ordovician	Upper Ordovician	Silurian	Middle Ordovician	
Formation top (relative to KB) (ft)	-7,593	-10,000	-7,673	-8,766	-7,130	-8,090	-12,052	
Formation top (relative to GL) (ft)	-7,581	-9,986.7	-7,656.5	-8,733	-7,102	-8,063	-12,038	
Formation top (relative to SL) (ft)	-6,586	-8,965	-6,617.5	-8,040	-6,190	-6,860	-10,002	
Formation 35	Maryville Limestone	Copper Ridge dolomite (upper)	Juniata Formation	unnamed anhydritic dolomite	Reedsville Shale	Tuscarora Sandstone	Black River Group	
System or series	Upper Cambrian	Upper Cambrian	Upper Ordovician	Middle Ordovician	Upper Ordovician	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-7,679	-10,152	-7,812	-9,525	-7,650	-8,600	-12,465	
Formation top (relative to GL) (ft)	-7,667	-10,138.7	-7,795.5	-9,492	-7,622	-8,573	-12,451	
Formation top (relative to SL) (ft)	-6,672	-9,117	-6,756.5	-8,799	-6,710	-7,370	-10,415	

[1]At original well.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 36								Nolichucky Shale
System or series								Upper Cambrian
Formation top (relative to KB) (ft)								-6,212
Formation top (relative to GL) (ft)								-6,202
Formation top (relative to SL) (ft)								-5,172
Formation 37								Maryville Limestone
System or series								Upper Cambrian
Formation top (relative to KB) (ft)								-6,350
Formation top (relative to GL) (ft)								-6,340
Formation top (relative to SL) (ft)								-5,310
Formation 38								Mount Simon Sandstone
System or series								Middle and Upper Cambrian
Formation top (relative to KB) (ft)								-6,850
Formation top (relative to GL) (ft)								-6,840
Formation top (relative to SL) (ft)								-5,810
Formation 39								Metamorphic and igneous rocks
System or series								Mesoproterozoic
Formation top (relative to KB) (ft)								-6,977
Formation top (relative to GL) (ft)								-6,967
Formation top (relative to SL) (ft)								-5,937
Formation 40								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E'*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
API no.	**34–059–20782**	**34–121–21278**	**47–107–00351**	**47–107–00756**	**47–035–01366**	**47–013–02503**	**47–083–00103**	**47–071–00006**
Lease name	**No. 1 W.R. Marshall**	**No. 1 Robert Ullman**	**No. 9634 Power Oil Co.**	**No. 1 Howard H. Deem**	**No. 1 Walter McCoy**	**No. 1 Gainer-Lee**	**No. 10,228 W. VA.**	**No. 1 Ray Sponaugle**
Permanent datum	**Ground level**	**Ground level**	**Ground level[1]**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**995**	**1,021.7**	**1,039**	**693**	**912**	**1,203**	**2,036**	**2,984.7**
KB elevation (ft)	**1,007**	**1,035**	**1,055.5**	**726**	**940**	**1,230**	**2,050**	**2,998.9**
Measured from	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**8,602**	**11,442**	**13,327**	**13,266**	**17,675**	**20,222**	**13,121**	**13,000**
Formation 36	Mount Simon Sandstone	B zone	Reedsville Shale	unnamed sandstone[3]	Trenton Limestone	Juniata Formation	Row Park Limestone(?)	
System or series	Middle and Upper Cambrian	Upper Cambrian	Upper Ordovician	Middle Ordovician	Upper Ordovician	Upper Ordovician	Middle Ordovician	
Formation top (relative to KB) (ft)	-8,245	-10,260	-8,420	-9,796	-8,670	-8,772	-12,785	
Formation top (relative to GL) (ft)	-8,233	-10,246.7	-8,403.5	-9,763	-8,642	-8,745	-12,771	
Formation top (relative to SL) (ft)	-7,238	-9,225	-7,364.5	-9,070	-7,730	-7,542	-10,735	
Formation 37	Metamorphic and igneous rocks	Copper Ridge dolomite (lower)	Utica Shale	Beekmantown Dolomite	Trenton Limestone[4]	Reedsville Shale		
System or series	Mesoproterozoic	Upper Cambrian	Upper Ordovician	Lower Ordovician	Upper Ordovician	Upper Ordovician		
Formation top (relative to KB) (ft)	-8,333	-10,382	-9,415	-9,866	-8,860	-9,470		
Formation top (relative to GL) (ft)	-8,321	-10,368.7	-9,398.5	-9,833	-8,832	-9,443		
Formation top (relative to SL) (ft)	-7,326	-9,347	-8,359.5	-9,140	-7,920	-8,240		
Formation 38		Nolichucky Shale	Trenton Limestone	Rose Run Sandstone	Black River Limestone	Trenton Limestone		
System or series		Upper Cambrian	Upper Ordovician	Upper Cambrian	Upper Ordovician	Upper Ordovician		
Formation top (relative to KB) (ft)		-10,538	-9,590	-10,604	-9,011	-10,600		
Formation top (relative to GL) (ft)		-10,524.7	-9,573.5	-10,571	-8,983	-10,573		
Formation top (relative to SL) (ft)		-9,503	-8,534.5	-9,878	-8,071	-9,370		
Formation 39		Maryville Limestone	Black River Limestone	Copper Ridge Dolomite (upper)	unnamed anhydritic dolomite	Trenton Limestone[4]		
System or series		Upper Cambrian	Upper Ordovician	Upper Cambrian	Middle Ordovician	Upper Ordovician		
Formation top (relative to KB) (ft)		-10,660	-9,741	-10,730	-9,906	-10,800		
Formation top (relative to GL) (ft)		-10,646.7	-9,724.5	-10,697	-9,878	-10,773		
Formation top (relative to SL) (ft)		-9,625	-8,685.5	-10,004	-8,966	-9,570		
Formation 40		Mount Simon Sandstone	unnamed anhydritic dolomite[2]	B zone	unnamed sandstone[3]	Black River Limestone		
System or series		Middle and Upper Cambrian	Middle Ordovician	Upper Cambrian	Middle Ordovician	Upper Ordovician		
Formation top (relative to KB) (ft)		-11,360	-10,525	-10,990	-10,450	-10,990		
Formation top (relative to GL) (ft)		-11,346.7	-10,508.5	-10,957	-10,422	-10,963		
Formation top (relative to SL) (ft)		-10,325	-9,469.5	-10,264	-9,510	-9,760		

[1]At original well. [2]Wells Creek formation equivalent. [3]St. Peter Sandstone equivalent. [4]Informal marker bed.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 41								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 42								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 43								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 44								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 45								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[1]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 41		Metamorphic and igneous rocks	unnamed sandstone[2]	Copper Ridge Dolomite (lower)	Beekmantown Dolomite	unnamed anhydritic dolomite		
System or series		Mesoproterozoic	Middle Ordovician	Upper Cambrian	Lower Ordovician	Middle Ordovician		
Formation top (relative to KB) (ft)		-11,420	-10,670	-11,100	-10,485	-12,083		
Formation top (relative to GL) (ft)		-11,406.7	-10,653.5	-11,067	-10,457	-12,056		
Formation top (relative to SL) (ft)		-10,385	-9,614.5	-10,374	-9,545	-10,853		
Formation 42			Beekmantown Dolomite	Nolichucky Shale	Rose Run Sandstone	Beekmantown Dolomite		
System or series			Lower Ordovician	Upper Cambrian	Upper Cambrian	Lower Ordovician		
Formation top (relative to KB) (ft)			-10,708	-11,310	-11,658	-12,850		
Formation top (relative to GL) (ft)			-10,691.5	-11,277	-11,630	-12,823		
Formation top (relative to SL) (ft)			-9,652.5	-10,584	-10,718	-11,620		
Formation 43			Rose Run Sandstone	Maryville Limestone	Copper Ridge Dolomite (upper)	Rose Run Sandstone		
System or series			Upper Cambrian	Middle and Upper Cambrian	Upper Cambrian	Upper Cambrian		
Formation top (relative to KB) (ft)			-11,635	-11,580	-11,825	-14,330		
Formation top (relative to GL) (ft)			-11,618.5	-11,547	-11,797	-14,303		
Formation top (relative to SL) (ft)			-10,579.5	-10,854	-10,885	-13,100		
Formation 44			Copper Ridge Dolomite (upper)	Waynesboro Formation	B zone equivalent	Copper Ridge Dolomite (upper)		
System or series			Upper Cambrian	Middle and Upper Cambrian	Upper Cambrian	Upper Cambrian		
Formation top (relative to KB) (ft)			-11,740	-12,155	-12,202	-14,670		
Formation top (relative to GL) (ft)			-11,723.5	-12,122	-12,174	-14,643		
Formation top (relative to SL) (ft)			-10,684.5	-11,429	-11,262	-13,440		
Formation 45			B zone	Metamorphic and igneous rocks	Copper Ridge Dolomite (lower)	B zone equivalent		
System or series			Upper Cambrian	Mesoproterozoic	Upper Cambrian	Upper Cambrian		
Formation top (relative to KB) (ft)			-11,970	-13,255	-12,310	-14,925		
Formation top (relative to GL) (ft)			-11,953.5	-13,222	-12,282	-14,898		
Formation top (relative to SL) (ft)			-10,914.5	-12,529	-11,370	-13,695		

[1]At original well. [2]St. Peter Sandstone equivalent.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 46								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 47								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 48								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 49								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 50								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[1]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 46			Copper Ridge Dolomite (lower)		basal sandstone member[2]	Copper Ridge Dolomite (lower)		
System or series			Upper Cambrian		Upper Cambrian	Upper Cambrian		
Formation top (relative to KB) (ft)			-12,090		-12,745	-15,040		
Formation top (relative to GL) (ft)			-12,073.5		-12,717	-15,013		
Formation top (relative to SL) (ft)			-11,034.5		-11,805	-13,810		
Formation 47			Nolichucky Shale		Nolichucky Shale	basal sandstone member[2]		
System or series			Upper Cambrian		Upper Cambrian	Upper Cambrian		
Formation top (relative to KB) (ft)			-12,257		-12,872	-15,700		
Formation top (relative to GL) (ft)			-12,240.5		-12,844	-15,673		
Formation top (relative to SL) (ft)			-11,201.5		-11,932	-14,470		
Formation 48			Maryville Limestone		unnamed dolomite member[3]	Nolichucky Shale		
System or series			Middle and Upper Cambrian		Middle and Upper Cambrian	Upper Cambrian		
Formation top (relative to KB) (ft)			-12,455		-13,200	-15,855		
Formation top (relative to GL) (ft)			-12,438.5		-13,172	-15,828		
Formation top (relative to SL) (ft)			-11,399.5		-12,260	-14,625		
Formation 49			Waynesboro Formation		unnamed sandstone member[3]	unnamed dolomite member[3]		
System or series			Middle and Upper Cambrian		Middle and Upper Cambrian	Middle and Upper Cambrian		
Formation top (relative to KB) (ft)			-12,950		-13,930	-15,955		
Formation top (relative to GL) (ft)			-12,933.5		-13,902	-15,928		
Formation top (relative to SL) (ft)			-11,894.5		-12,990	-14,725		
Formation 50			Metamorphic and igneous rocks		unnamed limestone member[3]	unnamed sandstone member[3]		
System or series			Mesoproterozoic		Middle and Upper Cambrian	Middle and Upper Cambrian		
Formation top (relative to KB) (ft)			-13,290		-14,390	-16,743		
Formation top (relative to GL) (ft)			-13,273.5		-14,362	-16,716		
Formation top (relative to SL) (ft)			-12,234.5		-13,450	-15,513		

[1]At original well. [2]Member of the Copper Ridge Dolomite. [3]Member of the Maryville Limestone.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 51								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 52								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 53								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 54								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 55								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	**34–059–20782**	**34–121–21278**	**47–107–00351**	**47–107–00756**	**47–035–01366**	**47–013–02503**	**47–083–00103**	**47–071–00006**
Lease name	**No. 1 W.R. Marshall**	**No. 1 Robert Ullman**	**No. 9634 Power Oil Co.**	**No. 1 Howard H. Deem**	**No. 1 Walter McCoy**	**No. 1 Gainer-Lee**	**No. 10,228 W. VA.**	**No. 1 Ray Sponaugle**
Permanent datum	**Ground level**	**Ground level**	**Ground level[1]**	**Ground level**	**Ground level**	**Ground level**	**Ground level**	**Ground level**
GL elevation (ft)	**995**	**1,021.7**	**1,039**	**693**	**912**	**1,203**	**2,036**	**2,984.7**
KB elevation (ft)	**1,007**	**1,035**	**1,055.5**	**726**	**940**	**1,230**	**2,050**	**2,998.9**
Measured from	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**	**Kelly bushing**
Drill depth (ft)	**8,602**	**11,442**	**13,327**	**13,266**	**17,675**	**20,222**	**13,121**	**13,000**
Formation 51					Rogersville Shale	unnamed limestone member[3]		
System or series					Middle Cambrian	Middle and Upper Cambrian		
Formation top (relative to KB) (ft)					-14,795	-16,900		
Formation top (relative to GL) (ft)					-14,767	-16,873		
Formation top (relative to SL) (ft)					-13,855	-15,670		
Formation 52					Rutledge Limestone	Rogersville Shale		
System or series					Middle Cambrian	Middle Cambrian		
Formation top (relative to KB) (ft)					-15,500	-17,450		
Formation top (relative to GL) (ft)					-15,472	-17,423		
Formation top (relative to SL) (ft)					-14,560	-16,220		
Formation 53					Pumpkin Valley Shale	Rutledge Limestone		
System or series					Middle Cambrian	Middle Cambrian		
Formation top (relative to KB) (ft)					-15,825	-18,042		
Formation top (relative to GL) (ft)					-15,797	-18,015		
Formation top (relative to SL) (ft)					-14,885	-16,812		
Formation 54					unnamed limestone member[2]	Pumpkin Valley Shale		
System or series					Lower and Middle Cambrian	Middle Cambrian		
Formation top (relative to KB) (ft)					-15,940	-18,215		
Formation top (relative to GL) (ft)					-15,912	-18,188		
Formation top (relative to SL) (ft)					-15,000	-16,985		
Formation 55					unnamed sandstone and shale members[2]	unnamed limestone member[2]		
System or series					Lower and Middle Cambrian	Lower and Middle Cambrian		
Formation top (relative to KB) (ft)					-16,270	-18,311		
Formation top (relative to GL) (ft)					-16,242	-18,284		
Formation top (relative to SL) (ft)					-15,330	-17,081		

[1]At original well. [2]Members of the Waynesboro Formation. [3]Member of the Maryville Limestone.

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E'*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	1	2	3	4	5	6	7	8
API no.	34–173–20237	34–143–20147	34–147–60840	34–033–20050	34–117–20012	34–117–20047	34–139–20289	34–031–22053
Lease name	No. 1 Carter	No. 1 Paul Kerbel	M and B Asphalt Co.	No. 1 V.E. Leonhardt	No. 3 Orrie Myers	No. 1 A.C. Windbigler	No. 1 J. Palmer	No. 1 Edwin L. Lee
Permanent datum	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	666	638	697	1,000	1,007	1,385.5	1,404	1,030
KB elevation (ft)	673	647	n/a	1,008	1,016	1,398	1,416	1,040
Measured from	Kelly bushing	Kelly bushing	Ground level	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	2,821	2,785	2,870	3,772	4,100	4,890	4,775	6,970
Formation 56								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 57								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 58								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								
Formation 59								
System or series								
Formation top (relative to KB) (ft)								
Formation top (relative to GL) (ft)								
Formation top (relative to SL) (ft)								

Appendix A. Wells, stratigraphic units, and depths of stratigraphic units in cross section *E–E′*—Continued.

[API, American Petroleum Institute; GL, ground level; KB, kelly bushing; n/a, not available; SL, sea level]

Drill-hole no.	9	10	11	12	13	14	15	16
API no.	34–059–20782	34–121–21278	47–107–00351	47–107–00756	47–035–01366	47–013–02503	47–083–00103	47–071–00006
Lease name	No. 1 W.R. Marshall	No. 1 Robert Ullman	No. 9634 Power Oil Co.	No. 1 Howard H. Deem	No. 1 Walter McCoy	No. 1 Gainer-Lee	No. 10,228 W. VA.	No. 1 Ray Sponaugle
Permanent datum	Ground level	Ground level	Ground level[1]	Ground level	Ground level	Ground level	Ground level	Ground level
GL elevation (ft)	995	1,021.7	1,039	693	912	1,203	2,036	2,984.7
KB elevation (ft)	1,007	1,035	1,055.5	726	940	1,230	2,050	2,998.9
Measured from	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing	Kelly bushing
Drill depth (ft)	8,602	11,442	13,327	13,266	17,675	20,222	13,121	13,000
Formation 56					Tomstown Dolomite	unnamed sandstone and shale members[2]		
System or series					Lower Cambrian	Lower and Middle Cambrian		
Formation top (relative to KB) (ft)					-17,240	-18,588		
Formation top (relative to GL) (ft)					-17,212	-18,561		
Formation top (relative to SL) (ft)					-16,300	-17,358		
Formation 57					Chilhowee Group	Tomstown Dolomite		
System or series					Lower Cambrian	Lower Cambrian		
Formation top (relative to KB) (ft)					-17,510	-19,705		
Formation top (relative to GL) (ft)					-17,482	-19,678		
Formation top (relative to SL) (ft)					-16,570	-18,475		
Formation 58					Metamorphic and igneous rocks	Chilhowee Group		
System or series					Mesoproterozoic	Lower Cambrian		
Formation top (relative to KB) (ft)					-17,626	-19,950		
Formation top (relative to GL) (ft)					-17,598	-19,923		
Formation top (relative to SL) (ft)					-16,686	-18,720		
Formation 59						Metamorphic and igneous rocks		
System or series						Mesoproterozoic		
Formation top (relative to KB) (ft)						-20,050		
Formation top (relative to GL) (ft)						-20,023		
Formation top (relative to SL) (ft)						-18,820		

[1]At original well. [2]Members of the Waynesboro Formation.

Appendix B. Scale, units, and depths for gamma-ray logging runs.

[API, American Petroleum Institute; KB, Kelly bushing; TD, total depth; µgm Ra-eq/ton, micrograms of radium equivalent per metric ton]

Drill hole no.	Scale and units	Depths of selected logged intervals	Casing shoe location(s)	Notes
1	0–200 API units 200–400 API units (backup scale)	About 7 ft below KB to TD		
2	0–200 API units 200–400 API units (backup scale)	100 ft below KB to TD		
3	0–200 API units	Ground level to TD		
4	0–200 API units 200–400 API units (backup scale)	100 ft below KB to TD		
5	0–10 (no units, probably µgm Ra-eq/ton) 10–20 (no units, probably µgm Ra-eq/ton) (backup scale)	About 9 ft below KB to TD	1,245 ft below KB	
6	0–200 API units 200–400 API units (backup scale)	About 12 ft below KB to TD	75 ft below KB	
7	0–200 API units 200–400 API units (backup scale)	100 ft below KB to TD	810 ft below KB	
8	0–200 API units 200–400 API units (backup scale)	100 ft below KB to TD	520 ft below KB	
9	0–10 µgm Ra-eq/ton(?) 10–20 µgm Ra-eq/ton(?) (backup scale)	100 ft below KB to 4,790 ft	1,395 ft below KB	
	0–8 µgm Ra-eq/ton(?) 8–16 µgm Ra-eq/ton(?) (backup scale)	4,790 ft to TD	4,790 ft below KB	
10	0–200 API units 200–400 API units (backup scale)	About 13 ft below KB to TD	116 ft below KB 2,006 ft below KB 6,891 ft below KB	
11	0–10 µgm Ra-eq/ton	About 65 ft below KB to 12,330 ft		
		12,330 ft to TD (spontaneous potential log only)		Spontaneous potential log (millivolts) not shown on the cross section.
12	0–200 API units 200–400 API units (backup scale) (no scale change noted between logging runs)	Logging run 2: 2,390 to 8,710 ft Logging run 3: 8,710 to 12,810 ft Logging run 4: 12,810 ft to TD		
13	0–150 API units 150–300 API units (backup scale)	About 28 ft below KB to TD		
14	0–120 API units 0–250 API units 0–200 API units 0–250 API units 0–150 API units	About 27 ft below KB to 2,643 ft 2,670 to 8,190 ft 8,190 to 10,850 ft 10,850 to 11,020 ft 11,020 ft to TD		
15	0–15 µgm Ra-eq/ton(?) 0–16 µgm Ra-eq/ton(?)	About 14 ft below KB to 6,300 ft 6,300 ft to TD		
16	0–12.5 µgm Ra-eq/ton(?)	100 ft below KB to TD		

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