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Geologic Cross Section *A*–*A*′ Through the Appalachian Basin From the Southern Margin of the Ontario Lowlands Province, Genesee County, Western New York, to the Valley and Ridge Province, Lycoming County, North-Central Pennsylvania

By Michael H. Trippi, Robert T. Ryder, and Catherine B. Enomoto

Pamphlet to accompany
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Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
meter (m)	3.281	foot (ft)
mile (mi)	1.609	kilometer (km)
kilometer (km)	0.6214	mile (mi)

Geologic Cross Section *A–A′* Through the Appalachian Basin from the Southern Margin of the Ontario Lowlands Province, Genesee County, Western New York, to the Valley and Ridge Province, Lycoming County, North-Central Pennsylvania

By Michael H. Trippi, Robert T. Ryder, and Catherine B. Enomoto

Introduction

Geologic cross section *A–A′* is the fifth in a series of cross sections constructed 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 *A–A′* provides a regional view of the structural and stratigraphic framework of the Appalachian basin from the southern margin of the Ontario Lowlands province in western New York, across the Allegheny Plateau province of central New York and north-central Pennsylvania, to the Valley and Ridge province in north-central Pennsylvania, a distance of approximately 176 miles (mi) (figs. 1 and 2). This cross section is a companion to cross sections *E–E′*, *D–D′*, *C–C′*, and *I–I′* (Ryder and others, 2008; Ryder and others, 2009; Ryder and others, 2012; Ryder and others, 2015) that are located approximately 100 to 500 mi to the southwest (see index map, sheet 2). Cross section *A–A′* complements earlier geologic or stratigraphic cross sections through the central New York and north-central Pennsylvania part of the Appalachian basin by Wagner (1966), Colton (1970), Faill and others (1977), Faill (1979), Berg and others (1980), Harper (1990), de Witt and others (1993), Hettinger (2001), Hickman and others (2006), Riley and others (2006), Smith and Leone (2010), and Mount (2014). Although some of these other cross sections show more structural and stratigraphic detail, they are of more limited extent geographically and stratigraphically.

Cross section *A–A′* contains much information that is useful for evaluating energy resources in the Appalachian basin. Although the Appalachian basin petroleum systems identified by Swezey (2002) and Milici and others (2003) are not shown 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 petroleum migration pathways) may be evaluated by burial history, thermal history, and fluid flow models on the basis of what is shown on the cross section. In addition, cross section *A–A′* 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; Clark and others, 2005) or for the sequestration of carbon dioxide (for example, Smith and others, 2002; Lucier and others, 2006).

Construction of the Cross Section

Cross section *A–A′* is oriented northwest to southeast, approximately normal to the structural grain of the region. Several abrupt bends in the section, however, are required to accommodate key drill holes that penetrate a thick section of Paleozoic sedimentary rocks.

Cross section *A–A′* is based on geological and geophysical data from 10 deep drill holes (table 1), 3 of which penetrate the Paleozoic sedimentary rocks of the basin and bottom in Mesoproterozoic crystalline basement rocks of the Grenville province (Rankin and others, 1993). The locations of the tops of each stratigraphic unit penetrated in the 10 deep drill holes were converted from depth in feet (ft) below the kelly bushing (KB) to depth below ground level (GL), and then were 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 1.

Table 1. Drill holes used to construct cross section *A–A′*.

[Drill-hole locations are shown in figures 1 and 2. Source of all lithologic logs is Geological Sample Log Company (GSLC), Pittsburgh, Pa. Abbreviations are as follows: Co., County; Dept., Department; No., number; N.Y., New York; Pa., Pennsylvania]

Drill-hole number	Name used in text	Location	American Petroleum Institute number	Latitude (decimal degrees)	Longitude (decimal degrees)	Lithologic log	Cored intervals (in feet) and stratigraphic unit	Total depth (in feet)	Age of oldest rocks drilled (stratigraphic unit)
				New York					
1	No. 1 J. Klotzbach	Genesee Co., N.Y. (Akron 7.5-minute quadrangle)	31–037–05117	43.040	-78.390	Yes	Not available	3,950	Mesoproterozoic (granite and (or) gneiss)
2	No. 1 L. Tyler	Genesee Co., N.Y. (Byron 7.5-minute quadrangle)	31–037–04593	43.043	-78.077	Yes	3,520–3,546, Galway Formation	4,000	Mesoproterozoic (granite and (or) gneiss)
3	No. 1 Albert McClurg	Livingston Co., N.Y. (Leicester 7.5-minute quadrangle)	31–051–04552	42.835	-77.937	Yes	Not cored	5,648	Mesoproterozoic (granite and (or) gneiss)
4	No. 1 Arthur N. Kennedy	Livingston Co., N.Y. (Sonyea 7.5-minute quadrangle)	31–051–04630	42.650	-77.756	Yes	5,660–5,690, Galway Formation	6,387	Middle Cambrian (Potsdam Sandstone)
5	No. 1 Hubbard	Steuben Co., N.Y. (Avoca 7.5-minute quadrangle)	31–101–21496	42.405	-77.463	No	Not available	10,061	Middle Cambrian (Potsdam Sandstone)
6	No. 1 Robert Olin	Steuben Co., N.Y. (Woodhull 7.5-minute quadrangle)	31–101–03924	42.063	-77.430	Yes	Not cored	13,508	Middle Cambrian (Potsdam Sandstone)
				Pennsylvania					
7	No. 1 Harry P. Dewey	Tioga Co., Pa. (Marshlands 7.5-minute quadrangle)	37–117–20057	41.689	-77.547	No	Not available	15,082	Upper Cambrian (Gatesburg Formation)
8	No. 1 Pa. Dept. of Forest and Water Tract 129	Potter Co., Pa. (Tamarack 7.5-minute quadrangle)	37–105–20182	41.489	-77.774	Yes	Not cored	18,834	Middle Cambrian (Potsdam Sandstone)
9	No. 1 Pa. State Forest Tract 285–1	Clinton Co., Pa. (Glen Union 7.5-minute quadrangle)	37–035–20276	41.371	-77.567	Yes	15,084–15,143, Black River Group; 15,883–15,943, Beekmantown Group; 17,620–17,650, Gatesburg Formation; 17,965–17,999, Gatesburg Formation	19,365	Middle Cambrian (Warrior Formation)
10	No. 1 W.E. Snyder	Lycoming Co., Pa. (Linden 7.5-minute quadrangle)	37–081–90002	41.142	-77.210	No	Not available	5,808	Middle Cambrian (Warrior Formation)

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, whereas the most commonly used lithologic logs were those produced by the Geological Sample Log Company (table 1). Gamma-ray logs used for correlations were digitized and (or) purchased as Log ASCII files (LAS), converted to graphic images, and then plotted next to their respective drill holes (appendix 2). The lithology assigned to each stratigraphic interval was simplified to just a few rock types and lithologic modifiers.

The data from the drill holes were supplemented by data about bedrock geology and topography. Some details of central New York stratigraphy were obtained from the geologic map of New York (Fisher and others, 1970) and other bedrock geologic maps and reports by Clarke and Luther (1908), Luther (1911), Cooper and Williams (1935), Pepper and de Witt (1950, 1951), Pepper (1954), Pepper and others (1956), Colton (1956), de Witt (1956), Colton and de Witt (1958), de Witt and Colton (1959), Fisher (1959, 1977), Sutton and others (1962), Sutton (1963), Bergin (1964), and Rickard (1975). Similar details of the stratigraphy in north-central Pennsylvania were obtained from the geologic map of Pennsylvania (Berg and others, 1980) and bedrock geologic maps and reports by Colton (1963, 1967), Colton and Luft (1965), Wagner (1966), Faill and others (1977), and Faill (1979). Locations of numerous anticlines and synclines were obtained from the geologic maps of New York (Fisher and others, 1970) and Pennsylvania (Berg and others, 1980) and other previously published maps and reports by Cathcart (1932), Newland and Hartnagel (1932), Wedel (1932), Bradley and Pepper (1938), Bradley and others (1941), Prucha (1968), Frey (1973), Murphy (1981), Geiser (1988), and Harper (1990). Locations of numerous faults and lineaments were obtained from Van Tyne (1975), Fakundiny and Myers (1978), Isachsen (1985), Boyce and Morris (2002), Fakundiny and Pomeroy (2002), Jacobi (2002), Jacobi and Fountain (2002), Ouassaa and Forsyth (2002), Gold and others (2005), and Jacobi and Smith (2006).

The topographic profile for the cross section was created from the USGS National Elevation Dataset (NED) with a one arc-second cell size for parts of New York and Pennsylvania. This topographic profile is approximate and should not be used to determine accurate surface elevations. For example, we noticed errors near drill holes 8 and 9, where the actual surface elevation (as shown on well logs) is more than 100 feet above the topographic profile's elevation. This discrepancy was probably due to the fact that the NED elevation values are average values for numerous points in the one arc-second cells. In locations with highly variable topography (as found near drill holes 8 and 9), the actual elevation of a point location within the cell may differ from the average elevation of the cell. The data can be accessed from the USGS NED website at https://nationalmap.gov/elevation.html.

Although some correlations shown on cross section *A–A′* 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), Berg and others (1980), Patchen and others (1985), Milici and de Witt (1988), and Swezey (2002) for the entire Paleozoic section; Riley and others (2006) for Cambrian and Ordovician rocks; Brett and others (1990) for Silurian rocks; de Witt and others (1993) for Devonian rocks; and Brezinski (1999) and Edmunds and others (1999) for Mississippian and Pennsylvanian rocks. A correlation chart for the stratigraphic units identified along cross section *A–A′* is shown in figure 3.

Only selected unconformities are shown on cross section *A–A′*. Regional unconformities shown on cross section *A–A′* and in figure 3 include (1) the basal Cambrian unconformity (see Read, 1989a), (2) the Middle Ordovician (Knox) unconformity (Mussman and others, 1988), (3) the Upper Ordovician to lower Silurian (Cherokee) unconformity (Dennison and Head, 1975; Brett and others, 1990), (4) the Lower to Middle Devonian (Wallbridge) unconformity (Dennison and Head, 1975), (5) the Upper Devonian unconformity (de Witt and others, 1993), (6) the Middle Mississippian unconformity (modified from Brezinski, 1999), and (7) the Lower Pennsylvanian unconformity (Edmunds and others, 1999). The correlation of these unconformities with North American sequences of Sloss (1988) is shown on figure 3 and shown by Ettensohn (1994) and Swezey (2002).

The locations of most basement-involved faults along cross section *A–A′* are based on features described by Rickard (1973), Van Tyne (1975), Fakundiny and Myers (1978), Beardsley and Cable (1983), Henderson and Timm (1985), Harper (1989), Shumaker and Wilson (1996), Fakundiny and Pomeroy (2002), Jacobi (2002), Jacobi and Fountain (2002), Ouassaa and Forsyth (2002), Jacobi and Smith (2006), and Smith (2006). We also locate a basement fault just north of drill hole 7 based on discussions with J.S. Hnat of Shell Oil (oral commun., 2015).

Prominent thin-skinned structures (Rodgers, 1963) defined by large-scale thrust faults with basal detachment in lower Paleozoic strata and associated ramp anticlines are located at the southeastern end of cross section *A–A′* near drill hole 10. These structures, characteristic of the Valley and Ridge province (fig. 1) are juxtaposed against lesser deformed strata of the Allegheny Plateau (fig. 1) to form the Allegheny structural front (Rodgers, 1970; Faill, 1998; Faill and Nickelsen, 1999) (figs. 1 and 2).

The Allegheny structural front was located by Faill and others (1977) about 8 mi northwest of drill hole 10. Although thin-skinned structures continue northwest of the Allegheny structural front into the Allegheny Plateau of Pennsylvania and New York, they consist of folds with lower amplitudes (such as those shown on geologic maps of Cathcart, 1932; Wedel, 1932; Colton, 1963, 1967; Colton and Luft, 1965; Fisher and others,

1970; Berg and others, 1980; and on fig. 2) and thrust faults with smaller offsets and younger detachment zones. Moreover, all basement-involved faults identified on cross section *A–A′* are located in the Allegheny Plateau and the Ontario Lowlands (fig. 1).

Structural Framework

Basement Rocks and Associated Structures

Basement rocks along cross section *A–A′* consist of igneous and metamorphic rocks of the subsurface extension of the Grenville province (Rankin and others, 1993). Most isotopic ages of these Grenville province rocks range between 1,350 to 950 million years before present (Ma, or mega-annum), and many ages cluster around 1,100 to 1,000 Ma (Rankin and others, 1993) (fig. 3).

Typical of many foreland basins, the crystalline basement of the Appalachians is a homoclinal ramp that dips gently from an interior craton to the external margin of a fold-and-thrust belt. Along cross section *A–A′*, this basement ramp deepens progressively southeastward from about 3,000 ft below mean sea level (MSL) near drill hole 1, to about 26,000 ft below MSL beneath the White Deer syncline near drill hole 10. This gradual southeastward deepening of the basement ramp along cross section *A–A′* is interrupted by the Rome trough (fig. 2), a Middle Cambrian rift system that runs southwest to northeast from central Kentucky through West Virginia and Pennsylvania and possibly into south-central New York (Beardsley and Cable, 1983; Harper, 1989; Shumaker and Wilson, 1996; Harris and others, 2004; Jacobi and Smith, 2006). The northwestern limit of the Rome trough on cross section *A–A′* is shown as the down-to-the-southeast basement-involved fault located 1 mi northwest of drill hole 6, whereas the southeastern limit of the Rome trough on cross section *A–A′* is shown as the down-to-the-northwest basement-involved fault located 1 mi northwest of drill hole 9 (fig. 2). Along cross section *A–A′*, the Rome trough is about 44 mi wide and has a structural relief on the top of basement that ranges from about 100 to 300 ft at its northwestern margin to an estimated 3,800 ft at its deepest location southeast of drill hole 7. The northwest-boundary fault of the Rome trough as recognized in this report was defined by seismic data shown by Beardsley and Cable (1983) and its location was later corroborated by M.S. Cable, University of South Carolina (written commun., 1990). Harper (1989) and Jacobi (2002) also showed this fault just northwest of drill hole 6. The upthrown northwestern side of this basement-involved fault marks the Kane arch of Ryder (1992) (following the Kane gravity high of Diment and others (1980)). The southeast-boundary fault of the Rome trough as recognized by this report was defined by seismic data shown in Henderson and Timm (1985) just northwest of drill hole 9; however, Harper (1989) and Jacobi (2002) place the southeast-boundary fault of the Rome trough (with its northwest side downthrown) to the southeast of drill hole 9, but we show that fault with the southeast side downthrown as described by Shumaker and Wilson (1996), resulting in an uplifted horst block between this fault and the fault described by Henderson and Timm (1985).

On the basis of seismic data and data from an offsetting drill hole in the footwall, Shell Oil staff (J.S. Hnat, Shell Oil, written commun., 2015) propose a major down-to-the-southeast basement-involved fault located less than a mile northwest of drill hole 7 in Tioga County, Pennsylvania. This fault has been interpreted as a syndepositional normal fault active during an extension phase in the Appalachian basin from Neoproterozoic until Late Ordovician, resulting in a thickening of the formations below the Reedsville Shale on the southeastern side of the fault. Starting in the Late Ordovician, there was little to no fault movement, as shown by uniform thickness of formations on opposite sides of the fault from the Reedsville Shale up through the Bloomsburg Formation. Reactivation and reverse fault movement took place during a compression phase in the late Silurian, resulting in uplift of the formations above the Utica (Antes) Shale on the southeast side of the fault (J.S. Hnat, Shell Oil, written commun., 2015).

Three faults shown by Shumaker and Wilson (1996) are not recognized in this report. The first fault is about 3 mi northwest of drill hole 8, the second is 6 mi northwest of drill hole 10, and the third is 2 mi southeast of drill hole 10.

The Rome trough that intersects cross section *A–A′* is a smaller structural feature (with less structural relief on basement) than the trough in Kentucky (Harris and others, 2004), West Virginia (Shumaker and Wilson, 1996), and southern Pennsylvania (Kulander and Ryder, 2005), but its northward trend beyond cross section *A–A′* remains uncertain. The question remains whether the Rome trough continues its northeastward trend into New York as interpreted by Harper (1989) and Jacobi (2002) or changes to an east-northeast trend and remains largely in Pennsylvania as interpreted by Shumaker and Wilson (1996), Faill (1997a), Repetski and others (2008), and Ryder and others (2012).

Harper (1989) proposed that the Rome trough has been displaced along several cross-structural discontinuities (CSDs), including the Lawrenceville-Attica lineament in Steuben County, New York. Jacobi (2002) shows about 18 mi of right-lateral movement of the Rome trough's northwest-boundary fault along the Lawrenceville-Attica lineament (fig. 2). Similar lateral displacement of the southeast-boundary fault of the Rome trough along the Lawrenceville-Attica lineament is also shown in Tioga, Lycoming, and Bradford Counties, Pennsylvania.

Many normal (extensional) basement faults in New York and Pennsylvania were reactivated at least once during the Paleozoic to produce either renewed subsidence or small-scale inversion (Fakundiny and

Myers, 1978; Fakundiny and Pomeroy, 2002; Jacobi, 2002; Jacobi and Fountain, 2002; Ouassaa and Forsyth, 2002; Gold and others, 2005; and Jacobi and Smith, 2006). Small-scale inversion on these faults probably resulted from contraction during the Late Mississippian to Permian Alleghanian orogeny. At least 12 basement faults in New York discussed by Jacobi (2002) intersect cross section *A–A′* including the following (listed from northwest to southeast): (1) an unnamed northwest-trending fault in eastern Genesee County; (2) the western, central, and eastern faults of the Clarendon-Linden fault system (CLFS); (3) the Leroy fault; (4) the Retsof fault; (5) two unnamed east-trending faults in northwestern Steuben County; (6) the Bolivar fault system; (7) the Keuka Lake splay fault; (8) the Lawrenceville-Attica lineament; and (9) the Rome trough northwest-boundary fault.

The unnamed northwest-trending fault in eastern Genesee County may be related to the northwest-striking Attica-Lockport and Folsomdale faults 13 to 23 mi to the south, respectively, and the similarly oriented Georgian Bay linear zone (fig. 2) in Niagara County (Jacobi, 2002). R.D. Jacobi (written commun., 2016) suggested that this unnamed fault may extend from basement to the surface with negligible vertical movement above the Trenton Group with up to 20 ft of vertical displacement below the Trenton Group.

The most studied fault system in western New York is the CLFS (Van Tyne, 1975; Fakundiny and Pomeroy, 2002; Jacobi, 2002; Jacobi and Fountain, 2002; Jacobi and Smith, 2006), which includes three parallel north-striking faults that extend from Lake Ontario in northwestern Monroe County through Genesee and Wyoming Counties into northwestern Allegany County, and one southwest-striking branch off of the western fault in Genesee, Wyoming, and Erie Counties. Fakundiny and Pomeroy (2002) interpret normal movement for all three main CLFS faults with the western side down. They describe the central CLFS as a broad zone (up to 1.24 mi wide) of complexly fractured strata instead of a single fault (Fakundiny and Pomeroy, 2002). They interpret 164 to 328 ft of vertical displacement at the top of the Trenton Group, whereas the top of basement shows offset in some locations and none in others (Fakundiny and Pomeroy, 2002). They show no offset of the top of the Onondaga Limestone along these faults (Fakundiny and Pomeroy, 2002). Van Tyne (1975) interprets the sense and amount of vertical displacement for the CLFS faults differently. On his *C–D* cross section (located about 5 miles north of cross section *A–A′*) he shows the western fault to be down-to-the-east with approximately 25 ft of vertical displacement (as judged by offset of the tops of the Medina Group and Trenton Group). The central fault is interpreted as down-to-the-west with the amount of vertical displacement varying from about 75 ft (at the top of the Trenton Group) to about 100 ft (at the top of the Medina Group). The eastern fault is shown as down-to-the-east with vertical displacement varying from 25 ft (at the top of the Medina Group) to 50 ft (at the top of the Trenton Group). We used VanTyne's *C–D* cross section as a model for our configuration of the three CLFS faults on cross section *A–A′*. South of the cross section in Allegany County, the Onondaga and Tully Limestones have up to 120 ft of total offset (for all three faults) with the western side down (Jacobi and Fountain, 1996; Jacobi, 2002). Cross section *A–A′* intersects the three main CLFS faults between 0 and 5 mi west of drill hole 2 in Genesee County, New York. Fakundiny and Pomeroy (2002) and Ouassaa and Forsyth (2002) indicate that the CLFS is probably the surface expression of the boundary zone between two deep supercrustal basement megablocks: the Frontenac terrane to the east, and the Elzevir terrane to the west. Jacobi (2002) described varying amounts and directions of slip on these faults at different locations in Allegany County, but all of them appear to have been initiated due to Iapetan rifting activity (late Neoproterozoic [Ediacaran] to Early Cambrian) and also show movement during the Taconic orogeny (Ordovician to early Silurian).

The north-striking Leroy and Retsof faults pass through Monroe, Genesee, Livingston, and Wyoming Counties (Jacobi, 2002). The Leroy fault, which intersects cross section *A–A′* between drill holes 2 and 3, may be an Ordovician growth fault downthrown to the east; the fault may also affect basement rocks similar to the CLFS faults to the west. The Leroy fault may have up to 75 ft of vertical displacement below the Utica Shale (R.D. Jacobi, written commun., 2016). Also, fracture swarms may indicate that the fault extends all the way to the surface (R.D. Jacobi, written commun., 2016). The Retsof fault, which intersects cross section *A–A′* near drill hole 3, is inferred from north-striking fractures, faults, and stream and slope lineaments in a north-striking valley near the towns of Retsof and Greigsville, New York (fig. 1). Jacobi (2002) suggests that the Retsof fault may actually be a 5-mi-wide zone of faulting that extends from a north-striking valley near the towns of Retsof and Griegsville north to Lake Ontario. R.D. Jacobi (written commun., 2016) indicated that the amount of vertical displacement may be up to 40 ft downthrown to the northwest.

In northern Steuben County between drill holes 4 and 5 there are two unnamed, parallel east-striking faults that may be western extensions of the Glodes Corners Road graben faults (Columbia Natural Resources, Inc., 2000; Jacobi, 2002; Smith, 2006) and Muck Farm graben faults, between 10 and 20 miles east of cross section *A–A′*. The Glodes Corners Road graben faults are believed to have been active from the latest Neoproterozoic (Ediacaran) through the Cambrian, but are not parallel to the northeast-striking Rome trough faults to the south; therefore, it is unclear if they are related to the opening of the Rome trough or if they formed independently of that structure (Jacobi, 2002). Reactivation of the faults during the Ordovician resulted in localized dolomitization of the Black River and lower Trenton Group limestones, creation of a graben, and increasing porosity that made conditions favorable for gas accumulation (Columbia Natural

Resources, Inc., 2000; Patchen and others, 2006; Smith, 2006). Smith (2006) believes these faults to be the upward extension of a basement-rooted flower structure.

The Bolivar fault system (Jacobi, 2002), included in the following thin-skinned structures section, may possibly be associated with older basement faults that have been reactivated (R.D. Jacobi, oral commun., 2016). The amount of vertical displacement and vertical extent are unknown.

The Keuka Lake fault splay of Jacobi (2002) intersects the cross section between drill holes 5 and 6. It trends to the northeast and intersects cross section *A–A′* at an angle of about 30 degrees. Magnetic gradient data indicates that the Keuka Lake fault splay may affect basement rocks (Jacobi, 2002). Although we indicate the location of the Keuka Lake fault splay on *A–A′*, we do not show it as a fault because its amount of dip slip and vertical extent were unspecified by Jacobi (2002).

The Lawrenceville-Attica lineament that intersects cross section *A–A′* between drill holes 5 and 6 in Steuben County is interpreted to be the southeastern extension of the Attica-Lockport and Folsomdale faults of Erie, Genesee, and Wyoming Counties and may be a strike-slip fault with right-lateral movement that offsets the Rome trough's northwest-boundary fault by about 18 mi (Jacobi, 2002). The Lawrenceville-Attica lineament may also exhibit normal movement with the southwestern side down, as shown by a monocline with 492 ft of movement at the top of the Onondaga Limestone (Jacobi, 2002). Several other authors (Diment and others, 1980; Gold and Pohn, 1985; Harper, 1989; Boyce and Morris, 2002) have shown the Lawrenceville-Attica lineament as a cross-structural discontinuity (CSD) with possible strike-slip and (or) normal movement. On cross section *A–A′* we indicated the location of the Lawrenceville-Attica lineament, but did not show it as a fault or monocline because the area was already extremely complex with two anticline-syncline pairs superimposed on the regional dip.

Thin-Skinned Structures

Typical Appalachian thin-skinned structures (bedding-plane detachment zones, footwall ramps, ramp anticlines, and imbricate thrust faults) are contractional in origin and probably developed during the Late Mississippian to Permian continental collision (Alleghanian orogeny) between eastern North America and Africa (Rodgers, 1970; Rodgers, 1988; Hatcher and others, 1989; Faill, 1998). Crustal contraction that accompanied this collision caused large horizontal displacements of thick, competent panels of Paleozoic strata along thin, incompetent Paleozoic strata surfaces. In places, compression from the late Silurian through the Alleghanian orogeny reactivated basement faults and locally inverted the Rome trough (Harris, 1978; Shumaker and Wilson, 1996; Hickman and others, 2006; J.S. Hnat, Shell Oil, written commun., 2015).

Thin-skinned structures in the Valley and Ridge province are dominated by a system of foreland-vergent thrust faults (terminology from McClay, 1992) that include the Jersey Shore and Antes thrust faults, an unnamed thrust fault below the Nippenose anticline and White Deer syncline, and a sub-horizontal detachment zone (décollement) at the base of the Silurian Salina Group (Faill and others, 1977). From its junction with the Jersey Shore fault, the basal detachment zone extends northwestward into New York to at least as far as drill hole 4. In addition, minor sub-horizontal detachment zones in the Ordovician Utica (Antes) Shale and Cambrian Waynesboro Formation are interpreted beneath the Allegheny structural front. The unnamed thrust fault below the Nippenose anticline and White Deer syncline and the associated sub-Salina detachment zone were probably the first to form when a thick panel of Cambrian to Devonian (or younger) rocks was decoupled from underlying strata and was thrust northwestward up a major tectonic (footwall) ramp. This ramp connected the basal zone of detachment (footwall flat) in the Cambrian Waynesboro Formation to the upper zone of detachment (hanging-wall flat) at the base of the Silurian Salina Group in Pennsylvania and New York (Scanlin and Engelder, 2003) (upper and lower level décollement of Harris and Milici, 1977; thrust terminology from McClay, 1992). At some later time, the Antes thrust fault probably grew as a splay off the top of the unnamed thrust fault, thereby allowing the fault block above the splay to ride upward rather than travelling to the northwest along the basal Salina detachment zone. Either synchronous with the Antes thrust fault or slightly later, the Jersey Shore fault developed as a forward-breaking imbricate fault block with a lower detachment zone in the Waynesboro Formation and a southeastward-dipping ramp. This ramp cut upsection through strata at least as young as Early Devonian and, in turn, offset the unnamed thrust fault by several thousand feet.

The upper detachment zone extends northwest from the Jersey Shore ramp perhaps for more than 100 mi along the base of the Salina Group before it ends at or near drill hole 4. Multiple anticlines, synclines, and imbricate splay faults formed above this detachment surface as a result of Alleghanian compression. Locations of numerous anticlines and synclines were obtained from the geologic maps of New York (Fisher and others, 1970) and Pennsylvania (Berg and others, 1980) and other previously published maps and reports by Cathcart (1932), Newland and Hartnagel (1932), Wedel (1932), Bradley and Pepper (1938), Bradley and others (1941), Prucha (1968), Frey (1973), Murphy (1981), Geiser (1988), and Harper (1990). Splay faults shown on the cross section were located beneath anticlines. A series of faults similar to these have been interpreted in seismic sections near the crests of folds in this area (J.S. Hnat, Shell Oil, written commun., 2015).

The Bolivar fault system described by Jacobi (2002) is shown as a northeast-striking fault in Steuben and Allegany Counties, New York (fig. 2). The fault intersects cross section *A–A′* about 6 miles southeast of

drill hole 5. This fault may be a splay rising from the Salina Group detachment zone, but it is possible that it may be associated with an older basement faults that have been reactivated. Numerous possible northeast-oriented faults between drill holes 3 and 6 (lineaments and "lineament bundles" of Jacobi (2002)) are shown as dashed lines and green and pink polygons in figure 2 (green polygons are from Jacobi (2002); pink polygons are from R.D. Jacobi, written commun., 2016). The northeast-strike of these features may indicate that they are related to the similarly oriented folds and faults in the Allegheny Plateau created by Alleghanian contraction.

Stratigraphic Framework

The sedimentary rocks shown on cross section *A–A′* span most of the Paleozoic Era, and their thickness ranges from about 4,000 ft at drill hole 1 to about 27,000 ft at the Allegheny structural front at drill hole 10. Lithology, nomenclature, and depositional and tectonic settings of the sedimentary rocks along cross section *A–A′* 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), and Faill (1997a, b, 1998).

Much of the eastward thickening of strata in the Appalachian basin was caused by regional tectonism. During the Neoproterozoic (Ediacaran) to Early Cambrian, as the proto-Atlantic (Iapetus) Ocean opened and formed a rifted continental margin, cooling and thermal contraction of the lithosphere caused subsidence, which provided accommodation or preservation space for sediments to build an eastward-facing passive continental margin (Bond and others, 1988; Read, 1989a). During several later periods in the Paleozoic, subsidence caused by thrust loading during various orogenic events provided additional accommodation or preservation space for sediments to accumulate in Appalachian foreland basins (Quinlan and Beaumont, 1984). Eustatic changes also played a role in the eastward thickening of Appalachian strata (Bond and others, 1988). For example, a rise in sea level can cause load-induced subsidence (by sediments and the overlying water column) and provide accommodation space for additional sediments on the outer continental shelf, whereas a fall in sea level can cause erosion of the inner continental shelf. These eustatic changes were caused by changes in global climate and (or) changes in global tectonic activity.

Lower Cambrian to Upper Ordovician Siliciclastic and Carbonate Strata

Lower Cambrian to Upper Ordovician siliciclastic and carbonate strata are characterized by dolomite, limestone, and lesser amounts of gray shale, red shale, and sandstone (fig. 3). Along cross section *A–A′*, these strata thin dramatically from a thickness of about 11,000 feet beneath the Allegheny structural front in central Pennsylvania to about 3,000 ft in west-central New York. Well 9 penetrates about 8,100 ft of Lower Cambrian to Upper Ordovician strata. In the eastern part of cross section *A–A′* (Allegheny Plateau and Valley and Ridge provinces in north-central Pennsylvania), the Lower Cambrian to Upper Ordovician siliciclastic and carbonate strata consist of the following units (in ascending order): the Antietam Formation (and the equivalent Potsdam Sandstone), Tomstown Formation, Waynesboro Formation, Pleasant Hill Formation, Warrior Formation, Gatesburg Formation, Beekmantown Group (including the Larke, Stonehenge, Nittany, Axemann, and Bellefonte Formations), Black River Group, and Trenton Group (fig. 3). The equivalent Cambrian to Upper Ordovician strata of south-central New York consist of the following units (in ascending order): Potsdam Sandstone, Galway Formation, Little Falls Dolomite, Tribes Hill Dolomite, Bellefonte Formation, Black River Group, and Trenton Group (fig. 3).

The distribution and lithology of Cambrian rocks in the southeastern part of cross section *A–A′* are very speculative because deep drill holes are largely absent. Lithology and thickness data for Cambrian rocks in this area are limited to (1) drill holes 9 and 10, where the upper part of the Warrior Formation is penetrated; (2) drill hole 8, where the upper part of the Potsdam Sandstone is penetrated; and (3) drill hole 7, where the upper sandy member of the Gatesburg Formation is penetrated. Cambrian units between the western boundary of the Rome trough and the northwestern end of cross section *A–A′* are reasonably well documented by drill holes 1 through 6.

The Lower Cambrian Antietam Formation, the Lower Cambrian Tomstown Formation, the Lower and Middle Cambrian Waynesboro Formation, and the Middle Cambrian Pleasant Hill Formation are the oldest stratigraphic units shown on cross section *A–A′*. These units have been projected into the southeastern end of the cross section from known localities 100 mi or more to the south in south-central Pennsylvania (Butts, 1945; Wilson, 1952; Root, 1968; Ryder and others, 2012) and west-central Maryland (Brezinski, 1992). Although Wagner (1966) recognized the Pleasant Hill Formation in drill hole 10, this unit has been reinterpreted in this study as the Middle Cambrian Warrior Formation. The Antietam, Tomstown, Waynesboro, and Pleasant Hill Formations have an estimated combined thickness of as much as 2,200 ft beneath the Allegheny structural front.

The Lower Cambrian Antietam Formation is a basal Cambrian sandstone that rests unconformably on Mesoproterozoic and Neoproterozoic basement rocks of the Grenville province. The Antietam Formation is interpreted as a transgressive marine deposit with a sediment source to the west and northwest. The Antietam Formation is overlain conformably by predominantly dolomite beds of the Lower Cambrian Tomstown Formation. Carbonate strata of the Tomstown Formation

are interpreted as transgressive marine deposits that accumulated on a marine shelf and carbonate ramp after the adjacent craton was submerged by the Iapetus Ocean (Read, 1989a, b).

The Waynesboro Formation in cross section *A–A′* rests conformably on the Tomstown Formation and probably consists of clastic red beds, dolomite, sandstone, and green and gray shale judging from subsurface and outcrop studies in south-central Pennsylvania (Root, 1968; Ryder and others, 2012) and west-central Maryland (Brezinski, 1992). Although an Early Cambrian age is commonly cited for the Waynesboro Formation (Butts, 1945; Palmer, 1971; Brezinski, 1992), fossil evidence is very sparse and a Middle Cambrian age is possible for the upper part of the formation (Stose, 1909; Root, 1968; Read 1989a, b); thus, an Early and Middle Cambrian age is assigned to the Waynesboro Formation in this report. The Waynesboro Formation is interpreted as a shallow-water nearshore marine deposit (Woodward, 1949; Brezinski, 1992).

The Pleasant Hill Formation is predominantly a limestone unit that rests conformably on the Waynesboro Formation. The Middle Cambrian age of the Pleasant Hill Formation is based on trilobite fauna (Wilson, 1952). This limestone probably was deposited in a shallow-marine setting.

Approximately 10 mi southeast of drill hole 9, the Tomstown, Waynesboro, and Pleasant Hill Formations are interpreted to pinch out northwestward (as indicated by a facies change) into the 1,000- to 1,200-ft-thick Middle to Upper Cambrian Potsdam Sandstone. Also at this locality, the Antietam Formation merges with the lower part of the Potsdam Sandstone, another basal Cambrian sandstone. The Potsdam Sandstone extends across most of cross section *A–A′* from near drill hole 9 to between drill holes 2 and 3. In the Rome trough, between the southeast-boundary fault of the trough (Henderson and Timm, 1985) and the unnamed reactivated basement fault just northwest of drill hole 7 (J.S. Hnat, Shell Oil, oral commun., 2015), the Potsdam Sandstone is interpreted to thicken to as much as 2,800 ft and intertongue with the Middle and Upper Cambrian Warrior Formation. Between the unnamed reactivated basement fault and the northwest-boundary fault of the Rome trough (Beardsley and Cable, 1983), the Potsdam Sandstone thickens slightly from about 450 ft to about 500 ft. Northwest of the northwest-boundary fault, the Potsdam Sandstone thins gradually from about 500 ft to a pinch-out edge between drill holes 2 and 3.

The Middle and Upper Cambrian (based on trilobite fauna; Wilson, 1952) Warrior Formation near drill hole 10 is about 2,400 ft thick and consists primarily of sandy dolomite with two limestone units in the upper 900 ft. Wagner (1966) identified the lower limestone in drill hole 10 as the Pleasant Hill Formation, but in this study the lower limestone is reassigned to the Warrior Formation. The additional undrilled part of the Warrior Formation below drill hole 10 is considered to be 600 ft of sandy dolomite, thus suggesting a total thickness of 3,000 ft for the Warrior Formation in this locality. About 10 mi southeast of drill hole 9, the Warrior Formation thickens to about 3,300 ft. In and below drill hole 9, the Warrior Formation thins to about 2,300 ft thick above a horst block adjacent to the southeast-boundary normal basement fault of the Rome trough. The drilled 800 ft of the Warrior Formation in drill hole 9 consists of (in ascending order) sandy dolomite, sandstone, and black shale that appears to replace (by facies change) the limestone and thin dolomite beds of the upper part of the Warrior Formation found in drill hole 10. The undrilled 1,500 ft of proposed sandy dolomite below drill hole 9 is roughly equivalent to the estimated 2,000-ft thickness of the lower sandy dolomite in drill hole 10. Drill hole 8 penetrates a complete 1,000-ft-thick interval of the Warrior Formation that consists of (in ascending order) sandy dolomite, sandstone, black shale, and more dolomite. The interpreted abrupt northwestward thinning of the Warrior Formation between drill holes 8 and 9 resulted mainly from interfingering and overstepping the underlying Potsdam Sandstone. Between drill holes 7 and 8 the shale unit grades into a dolomite, whereas the upper dolomite and middle sandstone units remain the same. The Warrior Formation continues to thin northwestward beyond the Rome trough to the New York border where it is called the following members of the lower Galway Formation (in ascending order): (1) the C sandstone, (2) the B interbedded sandstone and dolomite, and (3) the B dolomite (modified from Smith, 2012).

Complete sections of the Upper Cambrian Gatesburg Formation were penetrated in drill holes 8 through 10, and the upper half of the formation was penetrated in drill hole 7. The Gatesburg Formation includes the following members (in ascending order): (1) the lower sandy member, which is a dolomitic quartzarenite sandstone; (2) the Ore Hill Member, which is a limestone with dolomite interbeds (in drill holes 9 and 10) grading into a limy dolomite (in drill holes 7 and 8); (3) the upper sandy member, which is a dolomitic quartzarenite sandstone; and (4) the Mines Dolomite Member, which is a chert-bearing dolomite. These members of the Gatesburg Formation are consistent with the members reported in outcrops (Wilson, 1952), except for the Stacy Dolomite Member (Wilson, 1952) at the base of the Gatesburg Formation, which is unrecognizable and has been combined with the lower sandy member.

The Upper Cambrian age of the Gatesburg Formation is based on trilobite fauna in the Ore Hill Member (Wilson, 1952). The sandy members of the Gatesburg Formation are interpreted as shallow-marine and peritidal deposits (Wilson, 1952; Riley and others, 1993). Moreover, the quartzarenite composition of the sandstone units suggests that they were derived from the craton (Riley and others, 1993). The Gatesburg Formation continues northwest to the New York border where the name changes to the Little Falls Dolomite and the upper Galway Formation of New York. The Mines Dolomite Member of the Gatesburg Formation is equivalent to the Little Falls Dolomite, whereas the upper sandy member, Ore Hill Member, and lower sandy member of the Gatesburg Formation are equivalent, respectively, to the A sandstone; the A interbedded

sandstone and dolomite, and A dolomite (undivided); and the B sandstone members of the Galway Formation (Smith, 2012). The Galway Formation and Little Falls Dolomite both become thinner to the northwest where erosion that produced the Knox unconformity removed the Little Falls Dolomite between drill holes 3 and 4 and the upper sandstone member of the Galway Formation between drill holes 2 and 3. Two miles northwest of drill hole 6, we chose to combine the members of the Galway Formation below the upper sandstone member into one undivided unit. One unnamed thin sandstone member in the Galway Formation is shown at drill hole 3, and two more unnamed thin sandstone members are shown at drill hole 1. Please note that in some cases (as described above) we have chosen not to represent the separate members of a formation on the cross section or correlation chart (fig. 3). This does not necessarily indicate that the identification of the members is impossible in the field. We may still discuss the separate members in this report and (or) list elevations for the separate members in appendix A. In some locations, we have also chosen to represent multiple formations as one undivided unit. In these locations, we labelled the units with a list of the formations included, followed by "(undivided)" (for example, "Shriver Chert, Mandata Shale, Corriganville Limestone, New Creek Limestone (undivided)"). We still discuss these formations separately in the text and list the formation top elevations separately in appendix A.

The Lower and Middle Ordovician Beekmantown Group consists of dolomite and limestone formations (Wagner, 1966). The Beekmantown Group is about 3,000 ft thick in the Valley and Ridge province (drill hole 10) and beneath the adjoining Allegheny structural front where it consists (in ascending order) of the following formations: Larke Formation (dolomite), Stonehenge Formation (limestone), Nittany Formation (dolomite), Axemann Formation (primarily limestone), and Bellefonte Formation (primarily dolomite) (Wagner, 1966). Farther to the northwest, on the southeast flank of the Rome trough, drill hole 9 penetrated about 1,600 ft of the Beekmantown Group, where two intraformational unconformities are recognized by Wagner (1966). These two unconformities are probably separate tongues of the regional Middle Ordovician Knox unconformity that extend into central Pennsylvania. The lower unconformity (Wagner, 1966) marks the top of the Larke Formation and the Stonehenge Formation. Following Wagner (1966), the Stonehenge Formation is removed by erosion associated with the lower unconformity between drill holes 9 and 10, and the overlying Nittany and Axemann Formations pinch out northwestward by onlap against the lower unconformity. The upper unconformity within the Beekmantown Group in drill hole 9 is located near the top of the Bellefonte Formation. The upper unconformity disappears southeastward of drill hole 9 so that the contact between the lower and upper parts of the Bellefonte Formation becomes gradually conformable (Wagner, 1966; Harris and Repetski, 1982) toward the Allegheny structural front and the Valley and Ridge province.

On the Kane arch (northwest of the fault near drill hole 6) on the northwest flank of the Rome trough, Beekmantown Group-equivalent strata (Tribes Hill Dolomite and the overlying Bellefonte Formation) thin to about 500 ft. Between drill hole 9 and the northern end of cross section *A–A′*, erosion associated with the Knox unconformity removes progressively downsection the following intervals: (1) the Bellefonte Formation (lower part) (between drill holes 6 and 7), (2) the Larke Formation-equivalent Tribes Hill Dolomite (between drill holes 5 and 6), (3) the Little Falls Dolomite (between drill holes 3 and 4), and (4) the upper sandstone member of the Galway Formation (between drill holes 2 and 3). The Bellefonte Formation (upper part) pinches out between drill holes 5 and 6 by onlap.

The Galway Formation, Little Falls Dolomite, and Bellefonte Formation are overlain by a widespread Middle to Upper Ordovician limestone-dominated interval that extends across nearly the entire cross section. This limestone interval varies in thickness from about 1,400 ft in the southeast portion of the Allegheny Plateau (drill hole 9) to about 900 ft in western New York (drill hole 1). On the basis of the nomenclature used in the outcrop belt of central Pennsylvania (Thompson, 1963; Rones, 1969; Laughrey and others, 2003) and in the subsurface near drill hole 10 (Wagner, 1966), the limestone interval is divided into (in ascending order) the Middle to Upper Ordovician Loysburg Formation, the Upper Ordovician Hatter, Snyder, and Linden Hall Formations (all of the Black River Group, as used by Laughrey and others, 2003), and the overlying Upper Ordovician Nealmont, Salona, and Coburn Formations (all of the Trenton Group, as used by Laughrey and others, 2003). The Loysburg Formation grades into the lower portion of the Black River Group in New York State. We chose to follow the Black River and Trenton Group nomenclature of Laughrey and others (2003) because we were not able to identify formation contacts in the subsurface of central Pennsylvania.

The Loysburg Formation includes a lower Milroy (or "Tiger-Striped") Member and an upper Clover Member (Wagner, 1966; Rones, 1969; Berg and others, 1980). The Milroy Member is composed of alternating beds of dolomite and limestone with differential weathering creating a banded or striped appearance. The top of the unit is easily identified by a silty dolomitic limestone or dolomite with high peaks on gamma-ray logs (Wagner, 1966). Siltstone beds (20 to 30 ft thick) were observed at the top of the Milroy Member on lithologic logs created by the Geological Sample Log Company in drill holes 8 and 9. On these logs, the Milroy Member is also described as argillaceous dolomite and limestone. High gamma-ray peaks at the same locations on logs for drill holes 7, 8, and 9 were also observed. A siltstone layer was recognized on the lithologic log for drill hole 6 in Steuben County, New York, marking the top of the argillaceous lower portion of the Black River Group, which is interpreted to be equivalent to the Milroy Member of the Loysburg Formation in Pennsylvania.

The Clover Member of the Loysburg Formation is a microcrystalline to finely crystalline limestone

(Wagner, 1966; Rones, 1969; Berg, 1980). When the underlying and overlying units are less dolomitic, it is difficult to differentiate the Milroy Member from these units (Wagner, 1966). In the Pennsylvania portion of cross section *A–A′*, we grouped the Clover Member of the Loysburg Formation with the overlying Black River Group. The Milroy Member of the Loysburg Formation is shown as a separate recognizable unit between the underlying Bellefonte Formation and the overlying Black River Group.

Across north-central Pennsylvania and central New York, the Black River and Trenton Groups are characterized by a relatively homogeneous lithology (Riley and others, 2006). In cross section *A–A′*, the Black River Group consists mainly of carbonate mudstone and wackestone, whereas the Trenton Group consists mainly of fossiliferous, argillaceous limestone (wackestone, packstone, and grainstone). In New York, the lower 100 to 150 ft of the Black River Group consists of argillaceous and dolomitic limestone that extends across cross section *A–A′* from the Pennsylvania State line to drill hole 1 (fig. 3). This lower unit is considered in this publication to be equivalent to the Milroy Member of the Loysburg Formation in Pennsylvania. We considered the overlying non-argillaceous portion of the Black River Group to be partially equivalent to the Clover member of the Loysburg Formation in Pennsylvania. Two marker beds of unknown lithology, labelled marker X and marker Y on the cross section, are recognized in the upper two-thirds of the Black River Group from the Allegheny structural front to drill hole 1. On the cross section and in figure 3, three widespread bentonite beds are shown in the Trenton Group, a lower unnamed bentonite bed (possibly the Ocoonita or Hockett beds of Kolata and others, 1996), the middle Deicke and upper Millbrig Bentonite beds (Huff and Kolata, 1990; Kolata and others, 1996).

Limestones of the Black River and Trenton Groups are interpreted as subtidal-carbonate-ramp and deeper water carbonate-ramp to shelf-margin deposits, respectively (Laughrey and others, 2003; Riley and others, 2006). The bentonite beds are thought to be derived from extensive volcanic ash falls that occurred during the Late Ordovician part of the Taconic orogeny (Huff and Kolata, 1990; Huff and others, 1992). The southeastward-thickening wedge of carbonate-dominated strata from the base of the Lower and Middle Cambrian Warrior Formation and the equivalent Galway Formation through the Upper Ordovician Trenton Group is interpreted as deposits of a post-rift passive margin sequence (Read, 1989a, b). Middle Ordovician continental-scale erosion of this passive margin forming the Knox unconformity occurred during a drop in eustatic sea level and (or) tectonic uplift that preceded the Taconic orogeny (Harris and Repetski, 1982; Mussman and others, 1988; Read 1989a, b).

Upper Ordovician to Lower Silurian Siliciclastic Strata

The Upper Ordovician to lower Silurian siliciclastic strata are characterized by gray shale, red shale, sandstone, and black shale (fig. 3). As shown on cross section *A–A′*, the combined thickness of the strata ranges from about 4,250 ft in the vicinity of the Allegheny structural front to about 2,000 ft near drill hole 1. In drill hole 9, about 3,500 ft of Upper Ordovician to lower Silurian siliciclastic strata have been penetrated. In the Pennsylvania part of cross section *A–A′*, the Upper Ordovician to lower Silurian siliciclastic strata consist of the following units (in ascending order): the Utica (Antes) Shale, Reedsville Shale, Bald Eagle Formation, Juniata Formation, Tuscarora Formation, Rose Hill Formation, Keefer Formation, and Rochester Member of the Mifflintown Formation (Cotter, 1982; Berg and others, 1983; Ryder, 1992; Hettinger, 2001) (fig. 3). In New York, the Upper Ordovician to lower Silurian siliciclastic strata nomenclature is as follows: (1) Utica Shale is used instead of Utica (Antes) Shale, (2) Lorraine Shale is used instead of Reedsville Shale, (3) Oswego Sandstone is used instead of Bald Eagle Formation, (4) Queenston Shale is used instead of Juniata Formation, (5) Medina Group (including, in ascending order, the Whirlpool sandstone [where present; only identified in the drill hole 4 well logs], Grimsby Sandstone, Thorold Sandstone, and Cambria Shale; Ryder, 2004) is used instead of Tuscarora Formation, and (6) Clinton Group (including, in ascending order, the lower unnamed shale, Reynales Limestone, middle unnamed shale, Irondequoit Limestone, and Rochester Shale; Ryder, 2000) is used instead of Rose Hill Formation, Keefer Formation (equivalent to the Irondequoit Limestone), and Rochester Member of the Mifflintown Formation (Fisher, 1977) (fig. 3).

The Upper Ordovician to lower Silurian siliciclastic strata are interpreted as being derived from an eastern orogenic source and deposited in a rapidly subsiding foreland basin (Castle, 2001). 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; Faill, 1997a).

The Utica (Antes) Shale, a black shale unit that is transitional with the underlying Trenton Group, extends across cross section *A–A′* and ranges in thickness from about 150 ft in drill hole 1 to about 400 ft in the southeastern flank of the Rome trough (drill hole 9). The Utica (Antes) Shale recognized in cross section *A–A′* is approximately equivalent to (in ascending order) the Logana Member of the Lexington Formation, the Point Pleasant Formation, and the Utica Shale proper (Patchen and Carter, 2015). We chose not to use the Point Pleasant Formation nomenclature of Patchen and Carter (2015) because this name was only recently extended to western New York and northeastern Pennsylvania from its original usage in western Ohio (Wickstrom and Gray, 1988; Wickstrom, 1990; Wickstrom and others, 1992). The sums of thicknesses of the Utica Shale and Point Pleasant Formation

shown on isopach maps and data tables in Patchen and Carter (2015) appear to be approximately the same as our thicknesses for the Utica Shale in drill holes 1 through 9. In ascending order, Upper Ordovician strata that overlie the Utica (Antes) Shale consist of the Reedsville and equivalent Lorraine Shales (gray shale, siltstone, and minor sandstone), the Bald Eagle Formation and equivalent Oswego Sandstone (sandstone, siltstone, and gray shale), and the Juniata Formation and equivalent Queenston Shale (silty red shale). The widespread Cherokee unconformity (Dennison and Head, 1975; Brett and others, 1990) is present at the top of the Juniata Formation and equivalent Queenston Shale (Ryder, 2000; Hettinger, 2001). According to Dennison and Head (1975), the Cherokee unconformity resulted from a fall in eustatic sea level that probably was independent of the Taconic orogeny, creating the resultant classic angular unconformity between Upper Ordovician and lower Silurian rocks in eastern Pennsylvania (Pavlides and others, 1968).

The Utica (Antes) Shale is interpreted as an anoxic deposit that accumulated in the distal part of the Taconic foreland basin during initial deepening of the carbonate platform (Castle, 2001), whereas the overlying Reedsville and equivalent Lorraine Shales, Bald Eagle Formation and equivalent Oswego Sandstone, and the Juniata Formation and equivalent Queenston Shale are interpreted as shallow-marine and intertidal deposits that accumulated on a prograding clastic wedge (Diecchio, 1985; Castle, 2001).

The Tuscarora Formation, which is about 400 ft thick (including a 90-ft-thick Castanea Member at the top) in north-central Pennsylvania (near drill hole 9), thins northwestward to about 100 ft in west-central New York (near drill hole 1) where the rocks are assigned to the Medina Group, undivided.

The Rose Hill Formation consists of gray shale, red shale, dolomite, and limestone (Hettinger, 2001; Ryder, 2004; Ryder and others, 2012). On this cross section, the Rose Hill Formation consists of (in ascending order) a lower limestone member, a lower shale member, an upper limestone member, and an upper shale member. The lower limestone member pinches out to the northwest between drill holes 6 and 7, whereas in New York the overlying members correspond, respectively, to the lower unnamed shale, Reynales Limestone, and middle unnamed shale of the Clinton Group. Also, just west of drill hole 7, the Keefer Formation becomes more limy to the northwest and changes across an arbitrary boundary to the equivalent Irondequoit Limestone of the Clinton Group. The Rochester Member of the Mifflintown Formation in Pennsylvania also changes across an arbitrary boundary (just west of drill hole 7) to the Rochester Shale of the Clinton Group.

Lower Silurian to Middle Devonian Carbonate and Evaporite Strata

Lower Silurian to Middle Devonian strata consist of a lithologically varied interval of limestone, dolomite, sandstone, gray shale, chert, anhydrite, and halite (fig. 3). In the Pennsylvania part of cross section *A–A′* (drill holes 8 and 9), the stratigraphic units in ascending order are as follows: lower and upper Silurian McKenzie Member of the Mifflintown Formation; upper Silurian Bloomsburg Formation; upper Silurian Wills Creek Formation (equivalent to the Vernon Shale of the Salina Group); upper Silurian Salina Group (Vernon Shale, Syracuse Salt, Camillus Shale, and Bertie Dolomite); upper Silurian to Lower Devonian Keyser Formation; Lower Devonian New Creek Limestone, Corriganville Limestone, Mandata Shale, Shriver Chert, and Oriskany Sandstone; and Middle Devonian Onondaga Limestone (Berg and others, 1983) (fig. 3). In the Valley and Ridge province near drill hole 10 (southeast of the Jersey Shore fault), the New Creek Limestone, Corriganville Limestone, Mandata Shale, Shriver Chert, and Oriskany Sandstone are changed to member status of Old Port Formation (with the Oriskany Sandstone renamed the Ridgely Member of the Old Port Formation) (Faill and others, 1977; Berg and others, 1983). Also, in this area, the Salina Group is replaced by the Tonoloway Limestone (Faill and others, 1977; Berg and others, 1983). About 7 miles southeast of drill hole 7, we show an arbitrary boundary between the Vernon Shale of the Salina Group to the northwest and the Wills Creek Formation to the southeast. Also, about 6 miles southeast of drill hole 7, the Middle Devonian uppermost part of the Keyser Formation is absent perhaps because of non-deposition. We show the McKenzie Member of the Mifflintown Formation transitioning into the Lockport Dolomite (equivalent to the Lockport Group of New York) about 8 miles northwest of drill hole 7. At nearly the same location, we show the Bloomsburg Formation grading laterally into the Lockport Dolomite. In New York, the lower Silurian to Middle Devonian strata change nomenclature as follows: (1) the Lockport Dolomite in Pennsylvania is equivalent to the Lockport Group in New York; (2) the Wills Creek Formation in Pennsylvania is equivalent to the Vernon Shale of the Salina Group in New York; and (3) the Keyser Formation, New Creek Limestone, Corriganville Limestone, Mandata Shale, and Shriver Chert in Pennsylvania are equivalent to the Helderberg Group (undivided on cross section *A–A′*) in New York.

The Lockport Dolomite and Lockport Group consists mainly of fine to medium crystalline dolomite, several widespread vuggy rubble zones, and local bioherms (Laughrey, 1987). By comparison, the equivalent McKenzie Member of the Mifflintown Formation consists of carbonate mudstone and fossiliferous wackestone to grainstone interbedded with greenish-gray to black shale (Knowles, 1966; de Witt, 1974). We show the facies change from limestone and shale of the McKenzie Member of the Mifflintown Formation to dolomite of the Lockport Dolomite and Lockport Group approximately 8 miles northwest of drill hole 7.

The upper Silurian Bloomsburg Formation is characterized by grayish-red shale, mudstone, and sandstone (Hoskins, 1961; Knowles, 1966; de Witt, 1974). On cross section *A–A′* the Bloomsburg Formation is interpreted to be about 450 ft thick northwest of the Allegheny structural front and thins to the northwest to about 100 ft between drill holes 6 and 7, before it grades laterally into the upper portion of the Lockport Dolomite.

The upper Silurian Salina Group and the Wills Creek Formation (equivalent to the Vernon Shale of the Salina Group) constitute a well-defined unit that extends across all of cross section *A–A′* and ranges in thickness from about 2,000 to 2,700 ft near the Allegheny structural front where it is over-thickened by flowage and thin-skinned deformation, to about 400 ft in west-central New York (drill hole 1). The portion of the Salina Group above the Vernon Shale overlies an extensive detachment zone that is responsible for multiple Alleghanian folds and imbricate splay faults in upper Silurian and Devonian strata previously described in the thin-skinned structures section. The Salina Group consists mainly of anhydritic dolomite and shale, anhydrite, and halite. The Vernon Shale of the Salina Group consists of anhydritic and dolomitic gray shale or mudstone. Its southeastern equivalent, the upper Silurian Wills Creek Formation, consists of anhydritic and argillaceous dolomite. The halite-bearing part of the Syracuse Salt is concentrated in drill holes 3 through 9. Cross section *A–A′* passes through the Salina salt basin (as defined by Colton, 1970; Frey, 1973; Ege, 1985; Cotter and Inners, 1986; Ryder and others, 2007; and Mount (2014)) from the northwest margin (drill holes 2 through 4) through the thickest portion of the basin (drill holes 5 through 9) in south-central New York and north-central Pennsylvania. Halite-bearing intervals in drill holes 3 through 9 are interpreted from geophysical and lithologic logs and from halite beds previously identified by Heyman (1977). Most halite-bearing intervals shown on section *A–A′*, such as the approximately 1,100-ft-thick interval in drill hole 7, are not composed entirely of halite but instead are intervals of interbedded halite, dolomite, shale, and anhydrite. Non-halite-bearing portions of the Syracuse Salt are composed of dolomite and shale, which totally dominate the formation in drill holes 1 through 3. Overlying the Syracuse Salt is the Camillus Shale composed of anhydritic and dolomitic shale. We interpreted a zone of higher gamma-ray peaks in drill holes 3 through 9 as defining the range of the Camillus Shale. The Bertie Dolomite (anhydritic dolomite and limestone, where present) immediately overlies the Camillus Shale and underlies the Keyser Formation in Pennsylvania, and the Helderberg Group and the Akron Dolomite in New York. We recognized fairly thick sections (100 to 150 ft) of the Bertie Dolomite in Pennsylvania (drill holes 7 through 9), but it was mostly absent in New York except for fairly thin sections (8 to 43 ft) in two drill holes (3 and 4).

Most of the Keyser Formation that overlies the Salina Group is late Silurian in age, based on conodont studies (Denkler and Harris, 1988). In north-central Pennsylvania, the Keyser Formation is limestone that consists of carbonate mudstone and fossiliferous grainstone (Knowles, 1966; de Witt, 1974; Laughrey, 1999). The Keyser Formation of Pennsylvania is equivalent to the lower portion of the Helderberg Group in New York. The Helderberg Group is also equivalent to the upper Silurian Akron Dolomite in New York, an argillaceous dolomite (80-ft-thick or less) that extends from midway between drill holes 4 and 5 to the western end of the cross section between drill holes 2 and 3.

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 seawater where limestone was deposited (Smosna and others, 1977). Dolomites and evaporite beds of the upper Silurian Salina Group that overlie the Lockport Dolomite and Lockport Group signal an abrupt change on the carbonate shelf from normal circulation to greatly restricted circulation caused by a change to a very arid climate (Cecil and others, 2004).

Lower Devonian limestones in cross section *A–A′* constitute a composite unit about 200 ft thick between drill hole 3 and the Allegheny structural front. The New Creek and Corriganville Limestones near the base of the composite unit consist of wackestone, packstone, and skeletal grainstone; the Shriver Chert at the top of the composite unit consists of silty limestone and siliceous shale with abundant chert (Knowles, 1966; de Witt, 1974; Harper, 1999). The Corriganville Limestone is overlain by the thin, dark-gray to black Mandata Shale (Harper, 1999). The Helderberg Group in Steuben County, New York, is generally interpreted as a normal marine deposit that accumulated in an intracratonic basin and on flanking carbonate shelves (Smosna, 1988).

The clean, quartzose Lower Devonian Oriskany Sandstone, also known as the Ridgeley Sandstone in Pennsylvania (Berg and others, 1983; Harper and Patchen, 1996; Harper, 1999), unconformably overlies the Helderberg Group and extends across most of cross section *A–A′*. 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 greater decrease in water depth. This post-Oriskany unconformity probably truncated the Oriskany Sandstone between drill holes 3 and 4 near the pinchout of the Oriskany Sandstone mapped by Opritza (1996) and Harper and Patchen (1996). They show the Oriskany Sandstone to be absent at the locations of drill holes 1 through 5 except for a small area between drill holes 3 and 4. However, a lithologic log of rocks encountered in drill hole 5 from the Geological Sample Log Company clearly identified a white, medium- to coarse-grained sandstone as the Oriskany Sandstone. Therefore, we

chose to show the Oriskany Sandstone as present in drill hole 4 and drill holes 6 through 9. Northwest of drill hole 4 where the Oriskany Sandstone pinches out, the two unconformities merge and cut progressively downsection across the uppermost part of the Akron Dolomite. The Oriskany Sandstone has been interpreted as a shallow-marine deposit (Harper and Patchen, 1996), although Cecil (2004a, b) suggested an earlier eolian provenance for the Oriskany Sandstone and underlying chert beds of the Shriver Chert.

The Oriskany Sandstone is overlain unconformably by a thin, argillaceous, slightly fossiliferous limestone, which is recognized as the Middle Devonian Onondaga Limestone (Flaherty, 1996; Harper and Patchen, 1996). Near drill hole 1, the Onondaga Limestone forms the uppermost bedrock unit below a thin veneer of Quaternary sediments (Fisher and others, 1970). Near drill hole 2, this unit was removed by erosion in the Black Creek valley (fig. 1). Southeast of drill hole 2, the Onondaga Limestone extends across cross section *A–A′* all the way to the Allegheny structural front and is also present in the Jersey Shore fault block southeast of the front. Warters (1972) and Van Tyne (1996) have documented the presence of a trend of pinnacle reefs in the Onondaga in Steuben County, New York.

Middle Devonian to Lower Mississippian Siliciclastic Strata

Middle Devonian to Lower Mississippian siliciclastic strata include black shale, gray shale, sandstone, siltstone, red beds, and minor argillaceous limestones (fig. 3). These Middle Devonian to Lower Mississippian strata shown in cross section *A–A′* thin dramatically northwestward from as much as about 7,900 ft in drill hole 9 in north-central Pennsylvania to an incomplete section about 600 ft thick in drill hole 3 in west-central New York. In Pennsylvania, the Middle Devonian to Lower Mississippian siliciclastic strata include the following units (and their equivalents, in ascending order): (1) the Middle Devonian Hamilton Group (Marcellus Formation and Mahantango Formation), (2) the Middle Devonian Tully Limestone, (3) the Upper Devonian Genesee Formation (including the Geneseo Shale Member, Lodi Limestone Member, Penn Yan Shale Member, Genundewa Limestone Member, and West River Shale Member), (4) Upper Devonian Sonyea Formation (Middlesex Shale Member only), (5) Upper Devonian Brallier Formation, (6) Upper Devonian Lock Haven Formation, (7) Upper Devonian Catskill Formation, (8) Upper Devonian and Lower Mississippian Huntley Mountain Formation, and (9) the Lower Mississippian Burgoon Sandstone. New York equivalents of the Middle Devonian to Lower Mississippian strata in Pennsylvania include the following units (in ascending order): (1) the Middle Devonian Hamilton Group, including the Marcellus Shale, Skaneateles Shale (including the Stafford Limestone Member), Ludlowville Shale (including the Centerfield Limestone Member), and Moscow Shale (including the Tichenor Limestone Member); (2) Middle Devonian Tully Limestone; (3) Upper Devonian Genesee Formation (Geneseo Shale Member, Lodi Limestone Member, Penn Yan Shale Member, Genundewa Limestone Member, and West River Shale Member); (4) Upper Devonian Sonyea Formation (Middlesex Shale Member and Cashaqua Shale Member); (5) the Upper Devonian West Falls Formation (including the Rhinestreet Shale Member, Hatch Shale Member, Grimes Siltstone Member, Gardeau Shale Member, West Hill Member, and Nunda Sandstone Member); (6) Upper Devonian Java Formation (Pipe Creek Shale and Wiscoy Sandstone Members); and (7) Upper Devonian Perrysburg Formation (Dunkirk Shale and unnamed overlying shale members). No Mississippian strata are present in the New York part of cross section *A–A′* due to erosion. The top of the Tully Limestone marks the top of the Middle Devonian on cross section *A–A′* (fig. 3). Also, the Brallier Formation of Pennsylvania is interpreted to be equivalent to the Cashaqua Shale Member of the Sonyea Formation through the Gardeau Shale Member of the West Falls Formation in New York. Furthermore, the Lock Haven Formation of Pennsylvania is interpreted to be equivalent to the West Hill Member of the West Falls Formation through the Perrysburg Formation in New York.

The Upper Devonian to Lower Mississippian siliciclastic strata are interpreted as sediments derived from an eastern orogenic source and deposited in a rapidly subsiding foreland basin. This foreland basin and its sedimentary deposits (the Catskill delta complex of Woodrow and Sevon (1985) and Harper (1999)) are associated with the Acadian orogeny (Colton, 1970; Milici and de Witt, 1988; Osberg and others, 1989; Faill, 1997b).

The stratigraphy of the Middle and Upper Devonian black shales has been studied in great detail because of the role of black shales as hydrocarbon source rocks and reservoirs (Roen and Kepferle, 1993). In the vicinity of the Allegheny structural front and the adjoining Valley and Ridge province, the lowermost of the Devonian black shales is the Middle Devonian Marcellus Formation, which rests conformably on the Middle Devonian Onondaga Limestone. Also, in this region, the widespread Tioga Bentonite Bed (Tioga Bentonite of Dennison and Head, 1975) is often present in either the Marcellus Formation or the Onondaga Limestone (Inners, 1979; Way and others, 1986; Harper and Patchen, 1996). This bentonite bed is shown on cross section *A–A′* and in figure 3 in Pennsylvania only. A metabentonite bed (presumably the Tioga bentonite) was identified on lithologic logs from the Geologic Sample Log Company in drill holes 8 and 9, but was not present in lithologic logs for drill holes 3, 4, and 6 (we did not have lithologic logs for drill holes 5 and 7, and the Marcellus Shale [Formation] and Onondaga Limestone are not present in drill holes 1, 2, and 10). Within the Marcellus Shale two

limestone members are identifiable on well logs for drill holes 7 through 9, which include the lower Cherry Valley Limestone Member and the upper Purcell Limestone Member (as recognized by deWitt and Roen (1993)). We list elevations for these two limestone members and the unnamed shale members (that they separate) in appendix A, but we chose not to show them on cross section *A–A′* or the correlation chart (fig. 3), because they are extremely thin subunits of an already thin formation.

On cross section *A–A′*, we show the Marcellus Formation and the overlying gray shale of the Mahantango Formation of the Hamilton Group near the Allegheny structural front, but in drill holes 7 through 9, we chose to extend the use of the formation names within the Hamilton Group of New York southward into Pennsylvania because the New York formations are easily identifiable on the gamma-ray logs of those three drill holes. The following formations are included in the Hamilton Group in New York, and we recognize them near drill holes 7 through 9 (in ascending order): (1) the Marcellus Shale, (2) the Skaneateles Shale, (3), the Ludlowville Shale, and (4) the Moscow Shale. Basal limestone members of the top three formations (as recognized by deWitt and Roen (1993)) were identifiable on well logs and used to determine formation contacts in drill holes 3 through 5 and 7 through 9 (no well logs were available above the Marcellus Shale in drill hole 6). The basal limestone members include the following (in ascending order): (1) the Stafford Limestone Member of the Skaneateles Shale, (2) the Centerfield Limestone Member of the Ludlowville Shale, (3) and the Tichenor Limestone Member of the Moscow Shale. In drill holes 5, 6, 7, and 9, we were also able to identify the Menteth Limestone Member of the Moscow Shale which separates the upper shale member from the lower Deep Run Shale Member (as recognized by deWitt and Roen (1993)). We listed the elevations of these members in appendix A, but because they are so thin we chose not to represent them on cross section *A–A′* or the correlation chart (fig. 3).

We also chose to extend the use of the following New York names into Pennsylvania in drill holes 7 through 9: (1) Geneseo Shale Member, Lodi Limestone Member, Penn Yan Shale Member, Genundewa Limestone Member, and West River Shale Member of the Genesee Formation; and (2) Middlesex Shale Member of the Sonyea Formation. We chose not to use the name Burket Shale Member of the Harrell Formation (equivalent to Geneseo Shale Member). The black shales of the Marcellus Shale, Geneseo Shale Member of the Genesee Formation, and Middlesex Shale Member of the Sonyea Formation are interpreted as anoxic basin deposits in Pennsylvania (Boswell, 1996; Harper, 1999), whereas the overlying Brallier Formation is interpreted as a marine-basin-slope to turbidite-slope to delta-front deposit (Lundegard and others, 1985; Harper, 1999). In New York, several other black shales (the Rhinestreet Shale Member of the West Falls Formation, Pipe Creek Shale Member of the Java Formation, and Dunkirk Shale Member of the Perrysburg Formation [equivalent to the Huron Member of the Ohio Shale]) are present above the already mentioned Marcellus Shale, Geneseo Shale Member, and the Middlesex Shale Member. Several of these black shales have been of interest for their potential shale-gas deposits (Roen, 1984; de Witt and Roen, 1985; de Witt and others, 1993; Wrightstone, 2015).

A regional Middle to Late Devonian unconformity, described and mapped by de Witt and others (1993), is present throughout all of cross section *A–A′* at the top of the Tully Limestone (base of the Genesee Formation) and at the top of the Hamilton Group where the Tully Limestone is absent (fig. 3). We did not use the unconformity symbol on cross section *A–A′* northwest of well 5 because it would be thicker than the Tully Limestone unit. Cooper and Williams (1935) and de Witt and others (1993) show the Tully Limestone absent north and west of Canandaigua Lake in New York, but the gamma-ray logs for drill hole 3 in Livingston County indicate the presence of a thick limestone at the appropriate stratigraphic position. Thus, we chose to show the Tully Limestone at drill hole 3. However, we suggest that the Tully Limestone is only present locally in erosional remnants in this area, and one of these remnants may have been penetrated by drill hole 3.

Erosion has removed the West Falls, Java, and Perrysburg Formations northwest of drill hole 4, and removed strata of the Hamilton Group, Tully Limestone, Genesee Formation, and Sonyea Formation between drill holes 2 and 3.

The Lock Haven Formation in Pennsylvania and the equivalent West Hill Member and Nunda Sandstone Member of the West Falls Formation, Wiscoy Sandstone Member of the Java Formation, and Perrysburg Formation in New York consist of interbedded sandstone, siltstone and gray shale. Sandstone beds of the Scherr and Foreknobs Formations in central and southern Pennsylvania (equivalent to the Lock Haven Formation) are interpreted as shallow-water marine to shoreline, fluvial-deltaic, delta-front, and tidal-flat deposits (Harper, 1999). Black shale deposits of the Pipe Creek Member of the Java Formation and the Dunkirk Shale Member of the Perrysburg Formation in New York, also equivalents of the Lock Haven Formation in Pennsylvania, are interpreted as anoxic basin deposits (Boswell, 1996; Harper, 1999). The Catskill Formation that overlies the Lock Haven Formation consists of interbedded redbeds of sandstone, siltstone, and shale, and local gray to green shale. The Catskill Formation redbeds are interpreted as exposed alluvial-plain, fluvial, and fluvial-deltaic deposits (Slingerland and Loulé, 1988; Harper, 1999).

The Upper Devonian to Lower Mississippian Huntley Mountain Formation is present in several Allegheny Plateau highland areas on cross section *A–A′* between drill holes 6 and 10 and is completely eroded in New York. The Huntley Mountain Formation consists mainly of argillaceous sandstone and is interpreted as fluvial and estuarine deposits (Berg, 1999).

The Lower Mississippian Burgoon Sandstone is present on several Allegheny Plateau highland areas on cross section *A–A′* between drill holes 8 and 10, where

the sandstone is locally truncated by the Middle Mississippian unconformity and the overlying Middle and Upper Mississippian Mauch Chunk Formation (fig. 3). The location of the truncated margin of the Burgoon Sandstone is consistent with the northeast-trending truncated margin of the Burgoon shown by Brezinski (1999). The Burgoon Sandstone is interpreted as a braided-fluvial deposit (Berg, 1999; Brezinski, 1999).

Middle and Upper Mississippian and Pennsylvanian Siliciclastic Strata

The Middle and Upper Mississippian and Pennsylvanian siliciclastic strata on cross section *A–A′* consist of sandstone, red and gray shale, and coal (fig. 3). These strata are only a few hundred feet thick because they are deeply eroded. These Mississippian and Pennsylvanian strata include the following units (in ascending order): the Middle and Upper Mississippian Mauch Chunk Formation; the Lower and Middle Pennsylvanian Pottsville Formation, and the Middle Pennsylvanian Allegheny Formation (fig. 3).

The Middle and Upper Mississippian and Pennsylvanian siliciclastic strata are 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; Faill, 1997b, 1998).

The Middle and Upper Mississippian Mauch Chunk Formation rests conformably on the Lower Mississippian Burgoon Sandstone at a few Allegheny Plateau uplands 8 to 10 mi southeast of drill hole 9. The Mauch Chunk Formation consists of red and gray shale and local sandstone deposited in an alluvial environment.

The Lower and Middle Pennsylvanian Pottsville Formation (which consists of red sandstone; red conglomeratic sandstone; sandy gray shale; gray shale; and minor coal) unconformably overlies the Mauch Chunk Formation in Pennsylvania. The widespread unconformity at the base of the Pottsville Formation is known by various names that include the basal Pennsylvanian unconformity (Brezinski, 1999), the sub-Pennsylvanian unconformity (Beuthin, 1994), the Mississippian-Pennsylvanian unconformity (Rice and Schwietering, 1988), and the Lower Pennsylvanian unconformity (this report and Edmunds and others, 1999). The Pottsville Formation is only several hundred feet thick on cross section *A–A′* in Pennsylvania where it crops out on three mountaintops in the Jersey Mills syncline southeast of drill hole 9, and on a mountaintop in the Pine Creek syncline between drill holes 6 and 7.

The Middle Pennsylvanian Allegheny Formation (which consists of gray shale, sandstone, coal, and local thin limestone) comformably overlies the Pottsville Formation. Along cross section *A–A′*, the Allegheny Formation is only present on a mountaintop in the Pine Creek syncline northwest of drill hole 7. Strata of the Allegheny Formation are interpreted as alluvial-plain, delta-plain, marginal-marine, and peat-swamp deposits (Edmunds and others, 1999).

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Appendix 1. Table Summarizing Stratigraphic Units and Depths of Stratigraphic Units for Drill Holes 1–10 in Cross Section *A*–*A′*

Blank cells indicate no formation was encountered in the drill hole.

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 1	Onondaga Limestone and Bois Blanc Formation	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Cashaqua Shale Member of the Sonyea Formation	Cashaqua Shale Member of the Sonyea Formation	Wiscoy Sandstone Member of the Java Formation
System or series:	Middle Devonian	upper Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-8	-13	-14	-13	-15
Formation top (relative to GL) (ft)	0	0	0	0	0
Formation top (relative to SL) (ft)	862	703	989	599	1,760
Formation 2	Akron Dolomite (unconformity)	Salina Group (Vernon Shale) (green shale and anhydritic dolomite)	Middlesex Shale Member of the Sonyea Formation	Middlesex Shale Member of the Sonyea Formation	Pipe Creek Shale Member of the Java Formation
System or series:	upper Silurian	upper Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-46	-173	-60	-136	-153
Formation top (relative to GL) (ft)	-38	-160	-46	-123	-138
Formation top (relative to SL) (ft)	824	543	943	476	1,622
Formation 3	Salina Group (Camillus Shale)	Lockport Group (dolomite)	West River Shale Member of the Genesee Formation[1]	West River Shale Member of the Genesee Formation[1]	Nunda Sandstone Member of the West Falls Formation
System or series:	upper Silurian	lower and upper Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-70	-293	-76	-172	-226
Formation top (relative to GL) (ft)	-62	-280	-62	-159	-211
Formation top (relative to SL) (ft)	800	423	927	440	1,549

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 1	Wiscoy Sandstone Member of the Java Formation	Catskill Formation (red sandstone, siltstone, and shale) and Lock Haven Formation (sandstone)	Huntley Mountain Formation	Mauch Chunk Formation (red and gray shale)	Beekmantown Group (Bellefonte Formation) (upper part)
System or series:	Upper Devonian	Upper Devonian	Lower Mississippian	Mississippian	Middle Ordovician
Formation top (relative to KB) (ft)	-13	-18	-24	-33	0
Formation top (relative to GL) (ft)	0	0	-1	0	0
Formation top (relative to SL) (ft)	1,645	1,569	1,846	2,004	726
Formation 2	Pipe Creek Shale Member of the Java Formation	Lock Haven Formation (shale and siltstone)	Catskill Formation (red sandstone, siltstone, and shale)	Burgoon Sandstone	Beekmantown Group (Bellefonte Formation) (lower part)
System or series:	Upper Devonian	Upper Devonian	Upper Devonian	Lower Mississippian	Middle Ordovician
Formation top (relative to KB) (ft)	-815	-694	-140	-150	-300
Formation top (relative to GL) (ft)	-802	-676	-117	-117	-300
Formation top (relative to SL) (ft)	843	893	1,730	1,887	426
Formation 3	West Falls, Sonyea, and Genesee Formations (undivided)	Lock Haven Formation (sandstone, siltstone, and shale)	Lock Haven Formation (sandstone, siltstone, and shale)	Huntley Mountain Formation (argillaceous sandstone)	Beekmantown Group (Axemann Formation) (limestone)
System or series:	Upper Devonian	Upper Devonian	Upper Devonian	Lower Mississippian	Middle Ordovician
Formation top (relative to KB) (ft)	-865	-1,100	-1,142	-442	-1,320
Formation top (relative to GL) (ft)	-852	-1,082	-1,119	-409	-1,320
Formation top (relative to SL) (ft)	793	487	728	1,595	-594

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 4	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Clinton Group (Rochester Shale)	Genundewa Limestone Member of the Genesee Formation[1]	Genundewa Limestone Member of the Genesee Formation[1]	West Hill Member of the West Falls Formation (shale and siltstone)
System or series:	upper Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-140	-484	-106	-265	-439
Formation top (relative to GL) (ft)	-132	-471	-92	-252	-424
Formation top (relative to SL) (ft)	730	232	897	347	1,336
Formation 5	Salina Group (Vernon Shale) (green shale and anhydritic dolomite)	Clinton Group (Irondequoit Limestone)	Penn Yan Shale Member of the Genesee Formation[1]	Penn Yan Shale Member of the Genesee Formation[1]	West Falls Formation (undivided members below West Hill Member; shale and siltstone)
System or series:	upper Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-278	-595	-108	-270	-658
Formation top (relative to GL) (ft)	-270	-582	-94	-257	-643
Formation top (relative to SL) (ft)	592	121	895	342	1,117
Formation 6	Lockport Group (dolomite)	Clinton Group (middle unnamed shale)	Lodi Limestone Member of the Genesee Formation[1]	Lodi Limestone Member of the Genesee Formation[1]	Rhinestreet Shale Member of the West Falls Formation
System or series:	lower and upper Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-510	-610	-126	-332	-1,830
Formation top (relative to GL) (ft)	-502	-597	-112	-319	-1,815
Formation top (relative to SL) (ft)	360	106	877	280	-55

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 4	Tully Limestone (unconformity)	Barllier Formation (shale and siltstone)	Lock Haven Formation (siltstone)	Catskill Formation (red sandstone, siltstone, and shale)	Beekmantown Group (Nittany Formation)
System or series:	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Lower Ordovician
Formation top (relative to KB) (ft)	-3,275	-2,510	2,600	-813	-2,234
Formation top (relative to GL) (ft)	-3,262	-2,492	2,624	-780	-2,234
Formation top (relative to SL) (ft)	-1,617	-923	4,470	1,224	-1,508
Formation 5	Hamilton Group (undivided formations above Marcellus Shale)	Middlesex Shale Member of the Sonyea Formation	Brallier Formation (shale and siltstone)	Lock Haven Formation (sandstone, siltstone, and shale)	Beekmantown Group (Stonehenge Formation) (limestone) (Knox unconformity)
System or series:	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Middle Ordovician
Formation top (relative to KB) (ft)	-3,330	-3,702	-3,970	-2,138	-2,640
Formation top (relative to GL) (ft)	-3,317	-3,684	-3,947	-2,105	-2,640
Formation top (relative to SL) (ft)	-1,672	-2,115	-2,100	-101	-1,914
Formation 6	Hamilton Group (Marcellus Shale)	West River Shale and Genundewa Limestone Members (undivided) of the Genesee Formation[1]	Middlesex Shale Member of the Sonyea Formation	Lock Haven Formation (siltstone)	Beekmantown Group (Larke Formation)
System or series:	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Lower Ordovician
Formation top (relative to KB) (ft)	-3,970	-4,002	-4,589	-3,354	-2,670
Formation top (relative to GL) (ft)	-3,957	-3,984	-4,566	-3,321	-2,670
Formation top (relative to SL) (ft)	-2,312	-2,415	-2,719	-1,317	-1,944

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A*′.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 7	Clinton Group (Rochester Shale)	Clinton Group (Reynales Limestone)	Geneseo Shale Member of the Genesee Formation	Geneseo Shale Member of the Genesee Formation	Cashaqua Shale Member of the Sonyea Formation
System or series:	Silurian	Silurian	Upper Devonian	Upper Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-675	-614	-128	-342	-1,845
Formation top (relative to GL) (ft)	-667	-601	-114	-329	-1,830
Formation top (relative to SL) (ft)	195	102	875	270	-70
Formation 8	Clinton Group (Irondequoit Limestone)	Clinton Group (lower unnamed shale)	Tully Limestone (unconformity)	Tully Limestone (unconformity)	Middlesex Shale Member of the Sonyea Formation
System or series:	Silurian	Silurian	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-788	-626	-167	-373	-2,002
Formation top (relative to GL) (ft)	-780	-613	-153	-360	-1,987
Formation top (relative to SL) (ft)	82	90	836	239	-227
Formation 9	Clinton Group (middle unnamed shale)	Medina Group (sandstone)	Hamilton Group (Moscow Shale)	Hamilton Group (Moscow Shale)	West River Shale Member of the Genesee Formation[1]
System or series:	Silurian	Silurian	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-798	-630	-185	-377	-172
Formation top (relative to GL) (ft)	-790	-617	-171	-364	-157
Formation top (relative to SL) (ft)	72	86	818	235	1,603

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 7	Onondaga Limestone	Penn Yan Shale and Lodi Limestone Members (undivided) of the Genesee Formation[1]	West River Shale and Genundewa Limestone Members (undivided) of the Genesee Formation[1]	Brallier Formation (shale and siltstone)	Gatesburg Formation (Mines Dolomite Member)
System or series:	Middle Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-4,045	-4,474	-4,860	-4,787	-3,060
Formation top (relative to GL) (ft)	-4,032	-4,456	-4,837	-4,754	-3,060
Formation top (relative to SL) (ft)	-2,387	-2,887	-2,990	-2,750	-2,334
Formation 8	Oriskany Sandstone (unconformity)	Geneseo Shale Member of the Genesee Formation	Penn Yan Shale and Lodi Limestone Members (undivided) of the Genesee Formation[1]	Middlesex Shale Member of the Sonyea Formation	Gatesburg Formation (upper sandy member)
System or series:	Lower Devonian	Upper Devonian	Upper Devonian	Upper Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-4,080	-4,642	-5,290	-6,250	-3,300
Formation top (relative to GL) (ft)	-4,067	-4,624	-5,267	-6,217	-3,300
Formation top (relative to SL) (ft)	-2,422	-3,055	-3,420	-4,213	-2,574
Formation 9	Helderberg Group (limestone) (unconformity)	Tully Limestone (unconformity)	Geneseo Shale Member of the Genesee Formation	West River Shale and Genundewa Limestone Members (undivided) of the Genesee Formation[1]	Gatesburg Formation (Ore Hill Member) (limestone)
System or series:	Lower Devonian	Middle Devonian	Upper Devonian	Upper Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-4,140	-4,764	-5,480	-6,492	-3,810
Formation top (relative to GL) (ft)	-4,127	-4,746	-5,457	-6,459	-3,810
Formation top (relative to SL) (ft)	-2,482	-3,177	-3,610	-4,455	-3,084

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 10	Clinton Group (Reynales Limestone)	Queenston Shale (Cherokee unconformity)	Hamilton Group (Tichenor Limestone Member of Moscow Shale)[2]	Hamilton Group (Tichenor Limestone Member of Moscow Shale)[2]	Genundewa Limestone Member of the Genesee Formation[1]
System or series:	Silurian	Upper Ordovician	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-802	-722	-306	-512	-2,340
Formation top (relative to GL) (ft)	-794	-709	-292	-499	-2,325
Formation top (relative to SL) (ft)	68	-6	697	100	-565
Formation 11	Clinton Group (lower unnamed shale)	Oswego Sandstone	Hamilton Group (Ludlowville Shale)	Hamilton Group (Ludlowville Shale)	Penn Yan Shale Member of the Genesee Formation[1]
System or series:	Silurian	Upper Ordovician	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-811	-1,715	-314	-523	-2,347
Formation top (relative to GL) (ft)	-803	-1,702	-300	-510	-2,332
Formation top (relative to SL) (ft)	59	-999	689	89	-572
Formation 12	Medina Group (sandstone)	Lorraine Shale	Hamilton Group (Centerfield Limestone Member of Ludlowville Shale)[2]	Hamilton Group (Centerfield Limestone Member of Ludlowville Shale)[2]	Lodi Limestone Member of the Genesee Formation[1]
System or series:	Silurian	Upper Ordovician	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-820	-1,797	-429	-632	-2,500
Formation top (relative to GL) (ft)	-812	-1,784	-415	-619	-2,485
Formation top (relative to SL) (ft)	50	-1,081	574	-20	-725

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 10	Salina Group (Camillus Shale)	Hamilton Group (Moscow Shale)	Tully Limestone (unconformity)	Penn Yan Shale and Lodi Limestone Members (undivided) of the Genesee Formation[1]	Gatesburg Formation (lower sandy member)
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Upper Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-4,368	-4,840	-5,550	-6,906	-3,950
Formation top (relative to GL) (ft)	-4,355	-4,822	-5,527	-6,873	-3,950
Formation top (relative to SL) (ft)	-2,710	-3,253	-3,680	-4,869	-3,224
Formation 11	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Hamilton Group (Menteth Limestone Member of Moscow Shale)[2]	Hamilton Group (Moscow Shale)	Geneseo Shale Member of the Genesee Formation	Warrior Formation (limestone)
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Upper Devonian	Upper Cambrian
Formation top (relative to KB) (ft)	-4,447	-4,940	-5,640	-7,066	-4,300
Formation top (relative to GL) (ft)	-4,434	-4,922	-5,617	-7,033	-4,300
Formation top (relative to SL) (ft)	-2,789	-3,353	-3,770	-5,029	-3,574
Formation 12	Salina Group (Syracuse Salt) (upper halite)	Hamilton Group (Deep Run Shale Member of Moscow Shale)[2]	Hamilton Group (Menteth Limestone Member of Moscow Shale)[2]	Tully Limestone (unconformity)	Warrior Formation (sandy dolomite)
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	Middle Cambrian
Formation top (relative to KB) (ft)	-4,500	-4,952	-5,764	-7,150	-4,500
Formation top (relative to GL) (ft)	-4,487	-4,934	-5,741	-7,117	-4,500
Formation top (relative to SL) (ft)	-2,842	-3,365	-3,894	-5,113	-3,774

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 13	Queenston Shale (Cherokee unconformity)	Utica Shale	Hamilton Group (Skaneateles Shale)	Hamilton Group (Skaneateles Shale)	Geneseo Shale Member of the Genesee Formation
System or series:	Upper Ordovician	Upper Ordovician	Middle Devonian	Middle Devonian	Upper Devonian
Formation top (relative to KB) (ft)	-920	-2,300	-437	-641	-2,520
Formation top (relative to GL) (ft)	-912	-2,287	-423	-628	-2,505
Formation top (relative to SL) (ft)	-50	-1,584	566	-29	-745
Formation 14	Oswego Sandstone	Trenton Group (undivided)	Hamilton Group (Stafford Limestone Member of the Skaneateles Shale)[2]	Hamilton Group (Stafford Limestone Member of the Skaneateles Shale)[2]	Tully Limestone (unconformity)
System or series:	Upper Ordovician	Upper Ordovician	Middle Devonian	Middle Devonian	Middle Devonian
Formation top (relative to KB) (ft)	-1,990	-2,458	-668	-894	-2,588
Formation top (relative to GL) (ft)	-1,982	-2,445	-654	-881	-2,573
Formation top (relative to SL) (ft)	-1,120	-1,742	335	-282	-813
Formation 15	Lorraine Shale	Trenton Group (Millbrig Bentonite Bed)	Hamilton Group (Marcellus Shale)	Hamilton Group (Marcellus Shale)	Hamilton Group (Moscow Shale)
System or series:	Upper Ordovician	Upper Ordovician	Middle Devonian	Middle Devonian	Middle Devonian
Formation top (relative to KB) (ft)	-2,076	-3,023	-673	-900	-2,620
Formation top (relative to GL) (ft)	-2,068	-3,010	-659	-887	-2,605
Formation top (relative to SL) (ft)	-1,206	-2,307	330	-288	-845

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 13	Salina Group (Syracuse Salt) (upper anhydritic dolomite)	Hamilton Group (Tichenor Limestone Member of Moscow Shale)[2]	Hamilton Group (Deep Run Shale Member of Moscow Shale)[2]	Hamilton Group (Moscow Shale)	Warrior Formation (argillaceous limestone)
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	Middle Cambrian
Formation top (relative to KB) (ft)	-4,990	-4,998	-5,773	-7,310	-4,800
Formation top (relative to GL) (ft)	-4,977	-4,980	-5,750	-7,277	-4,800
Formation top (relative to SL) (ft)	-3,332	-3,411	-3,903	-5,273	-4,074
Formation 14	Salina Group (Syracuse Salt) (middle halite)	Hamilton Group (Ludlowville Shale)	Hamilton Group (Tichenor Limestone Member of Moscow Shale)[2]	Hamilton Group (Menteth Limestone Member of Moscow Shale)[2]	Warrior Formation (sandy dolomite)
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	Middle Cambrian
Formation top (relative to KB) (ft)	-5,130	-5,004	-5,780	-7,460	-5,200
Formation top (relative to GL) (ft)	-5,117	-4,986	-5,757	-7,427	-5,200
Formation top (relative to SL) (ft)	-3,472	-3,417	-3,910	-5,423	-4,474
Formation 15	Salina Group (Syracuse Salt) (lower anhydritic dolomite)	Hamilton Group (Centerfield Limestone Member of Ludlowville Shale)[2]	Hamilton Group (Ludlowville Shale)	Hamilton Group (Deep Run Shale Member of Moscow Shale)[2]	
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-5,160	-5,268	-5,800	-7,469	
Formation top (relative to GL) (ft)	-5,147	-5,250	-5,777	-7,436	
Formation top (relative to SL) (ft)	-3,502	-3,681	-3,930	-5,432	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 16	Utica Shale	Trenton Group (Deicke Bentonite Bed)	Onondaga Limestone	Onondaga Limestone	Hamilton Group (Menteth Limestone Member of Moscow Shale)[2]
System or series:	Upper Ordovician	Upper Ordovician	Middle Devonian	Middle Devonian	Middle Devonian
Formation top (relative to KB) (ft)	-2,563	-3,048	-699	-940	-2,713
Formation top (relative to GL) (ft)	-2,555	-3,035	-685	-927	-2,698
Formation top (relative to SL) (ft)	-1,693	-2,332	304	-328	-938
Formation 17	Trenton Group (undivided)	Black River Group (undivided)	Akron Dolomite (unconformity)	Oriskany Sandstone (unconformity)	Hamilton Group (Deep Run Shale Member of Moscow Shale)[2]
System or series:	Upper Ordovician	Middle and Upper Ordovician	upper Silurian	Lower Devonian	Middle Devonian
Formation top (relative to KB) (ft)	-2,712	-3,122	-838	-1,040	-2,720
Formation top (relative to GL) (ft)	-2,704	-3,109	-824	-1,027	-2,705
Formation top (relative to SL) (ft)	-1,842	-2,406	165	-428	-945
Formation 18	Trenton Group (Millbrig Bentonite Bed)	Black River Group (marker x)	Salina Group (Bertie Dolomite) (anhydritic)	Akron Dolomite (unconformity)	Hamilton Group (Tichenor Limestone Member of Moscow Shale)[2]
System or series:	Upper Ordovician	Middle and Upper Ordovician	upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,141	-3,300	-905	-1,055	-2,778
Formation top (relative to GL) (ft)	-3,133	-3,287	-891	-1,042	-2,763
Formation top (relative to SL) (ft)	-2,271	-2,584	98	-443	-1,003

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 16	Salina Group (Syracuse Salt) (lower halite)	Hamilton Group (Skaneateles Shale)	Hamilton Group (Centerfield Limestone Member of Ludlowville Shale)[2]	Hamilton Group (Tichenor Limestone Member of Moscow Shale)[2]	
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-5,380	-5,280	-6,070	-7,490	
Formation top (relative to GL) (ft)	-5,367	-5,262	-6,047	-7,457	
Formation top (relative to SL) (ft)	-3,722	-3,693	-4,200	-5,453	
Formation 17	Salina Group (Vernon Shale) (green shale and anhydritic dolomite)	Hamilton Group (Stafford Limestone Member of the Skaneateles Shale)[2]	Hamilton Group (Skaneateles Shale)	Hamilton Group (Ludlowville Shale)	
System or series:	upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-5,462	-5,504	-6,076	-7,510	
Formation top (relative to GL) (ft)	-5,449	-5,486	-6,053	-7,477	
Formation top (relative to SL) (ft)	-3,804	-3,917	-4,206	-5,473	
Formation 18	Lockport Group (dolomite)	Hamilton Group (upper unnamed shale member of the Marcellus Shale)[2]	Hamilton Group (Stafford Limestone Member of the Skaneateles Shale)[2]	Hamilton Group (Centerfield Limestone Member of Ludlowville Shale)[2]	
System or series:	lower and upper Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,378	-5,520	-6,203	-7,740	
Formation top (relative to GL) (ft)	-6,365	-5,502	-6,180	-7,707	
Formation top (relative to SL) (ft)	-4,720	-3,933	-4,333	-5,703	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 19	Trenton Group (Deicke Bentonite Bed)	Black River Group (marker y)	Salina Group (Camillus Shale)	Salina Group (Bertie Dolomite) (anhydritic)	Hamilton Group (Ludlowville Shale)
System or series:	Upper Ordovician	Middle and Upper Ordovician	upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,174	-3,376	-913	-1,152	-2,800
Formation top (relative to GL) (ft)	-3,166	-3,363	-899	-1,139	-2,785
Formation top (relative to SL) (ft)	-2,304	-2,660	90	-540	-1,025
Formation 20	Black River Group (undivided)	Black River Group (argillaceous limestone and dolomite)	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Salina Group (Camillus Shale)	Hamilton Group (Centerfield Limestone Member of Ludlowville Shale)[2]
System or series:	Middle and Upper Ordovician	Middle and Upper Ordovician	upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,240	-3,426	-974	-1,195	-2,922
Formation top (relative to GL) (ft)	-3,232	-3,413	-960	-1,182	-2,907
Formation top (relative to SL) (ft)	-2,370	-2,710	29	-583	-1,147
Formation 21	Black River Group (marker x)	Galway Formation (upper dolomite) (Knox unconformity)	Salina Group (Syracuse Salt) (anhydritic shale and dolomite)	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Hamilton Group (Skaneateles Shale)
System or series:	Middle and Upper Ordovician	Upper Cambrian	upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,355	-3,520	-1,155	-1,260	-2,930
Formation top (relative to GL) (ft)	-3,347	-3,507	-1,141	-1,247	-2,915
Formation top (relative to SL) (ft)	-2,485	-2,804	-153	-648	-1,155

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 19	Clinton Group (Rochester Shale)	Hamilton Group (Purcell Limestone Member of the Marcellus Shale)[2]	Hamilton Group (upper unnamed shale member of the Marcellus Shale)[2]	Hamilton Group (Skaneateles Shale)	
System or series:	Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,535	-5,544	-6,238	-7,748	
Formation top (relative to GL) (ft)	-6,522	-5,526	-6,215	-7,715	
Formation top (relative to SL) (ft)	-4,877	-3,957	-4,368	-5,711	
Formation 20	Clinton Group (Irondequoit Limestone)	Hamilton Group (middle unnamed shale member of the Marcellus Shale)[2]	Hamilton Group (Purcell Limestone Member of the Marcellus Shale)[2]	Hamilton Group (Stafford Limestone Member of the Skaneateles Shale)[2]	
System or series:	Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,710	-5,550	-6,259	-7,940	
Formation top (relative to GL) (ft)	-6,697	-5,532	-6,236	-7,907	
Formation top (relative to SL) (ft)	-5,052	-3,963	-4,389	-5,903	
Formation 21	Clinton Group (middle unnamed shale)	Hamilton Group (Cherry Valley Limestone Member of the Marcellus Shale)[2]	Hamilton Group (middle unnamed shale member of the Marcellus Shale)[2]	Hamilton Group (upper unnamed shale member of the Marcellus Shale)[2]	
System or series:	Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,735	-5,560	-6,267	-8,000	
Formation top (relative to GL) (ft)	-6,722	-5,542	-6,244	-7,967	
Formation top (relative to SL) (ft)	-5,077	-3,973	-4,397	-5,963	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 22	Black River Group (marker y)	granite and (or) gneiss	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Salina Group (Syracuse Salt) (upper halite)	Hamilton Group (Stafford Limestone Member of the Skaneateles Shale)[2]
System or series:	Middle and Upper Ordovician	Mesoproterozoic	upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,419	-3,812	-1,278	-1,565	-3,192
Formation top (relative to GL) (ft)	-3,411	-3,799	-1,264	-1,552	-3,177
Formation top (relative to SL) (ft)	-2,549	-3,096	-276	-953	-1,417
Formation 23	Black River Group (argillaceous limestone and dolomite)		Salina Group (Syracuse Salt) (halite)	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	Hamilton Group (Marcellus Shale)
System or series:	Middle and Upper Ordovician		upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,470		-1,355	-1,635	-3,210
Formation top (relative to GL) (ft)	-3,462		-1,341	-1,622	-3,195
Formation top (relative to SL) (ft)	-2,600		-353	-1,023	-1,435
Formation 24	Galway Formation (upper dolomite) (Knox unconformity)		Salina Group (Syracuse Salt) (lower halite)	Salina Group (Syracuse Salt) (lower halite)	Onondaga Limestone
System or series:	Upper Cambrian		upper Silurian	upper Silurian	Middle Devonian
Formation top (relative to KB) (ft)	-3,555		-1,825	-1,825	-3,260
Formation top (relative to GL) (ft)	-3,547		-1,812	-1,812	-3,245
Formation top (relative to SL) (ft)	-2,685		-1,213	-1,213	-1,485

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 22	Clinton Group (Reynales Limestone)	Hamilton Group (lower unnamed shale member of the Marcellus Shale)[2]	Hamilton Group (Cherry Valley Limestone Member of the Marcellus Shale)[2]	Hamilton Group (Purcell Limestone Member of the Marcellus Shale)[2]	
System or series:	Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,865	-5,564	-6,293	-8,020	
Formation top (relative to GL) (ft)	-6,852	-5,546	-6,270	-7,987	
Formation top (relative to SL) (ft)	-5,207	-3,977	-4,423	-5,983	
Formation 23	Clinton Group (lower unnamed shale)	Onondaga Limestone	Hamilton Group (lower unnamed shale member of the Marcellus Shale)[2]	Hamilton Group (middle unnamed shale member of the Marcellus Shale)[2]	
System or series:	Silurian	Middle Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,900	-5,626	-6,300	-8,050	
Formation top (relative to GL) (ft)	-6,887	-5,608	-6,277	-8,017	
Formation top (relative to SL) (ft)	-5,242	-4,039	-4,430	-6,013	
Formation 24	Medina Group (Cambria Shale and Thorold Sandstone) (undivided)	Oriskany Sandstone (unconformity)	Tioga bentonite bed	Hamilton Group (Cherry Valley Limestone Member of the Marcellus Shale)[2]	
System or series:	Silurian	Lower Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-6,972	-5,646	-6,355	-8,089	
Formation top (relative to GL) (ft)	-6,959	-5,628	-6,332	-8,056	
Formation top (relative to SL) (ft)	-5,314	-4,059	-4,485	-6,052	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 25	Galway Formation (upper sandstone)		Salina Group (Vernon Shale) (green shale and anhydritic dolomite)	Salina Group (Vernon Shale) (green shale and anhydritic dolomite)	Helderberg Group (limestone) (unconformity)
System or series:	Upper Cambrian		upper Silurian	upper Silurian	Lower Devonian
Formation top (relative to KB) (ft)	-3,700		-1,418	-1,900	-3,300
Formation top (relative to GL) (ft)	-3,692		-1,404	-1,887	-3,285
Formation top (relative to SL) (ft)	-2,830		-416	-1,288	-1,525
Formation 26	Galway Formation (middle dolomite)		Lockport Group (dolomite)	Lockport Group (dolomite)	Salina Group (Camillus Shale)
System or series:	Upper Cambrian		lower and upper Silurian	lower and upper Silurian	upper Silurian
Formation top (relative to KB) (ft)	-3,740		-1,548	-2,058	-3,468
Formation top (relative to GL) (ft)	-3,732		-1,534	-2,045	-3,453
Formation top (relative to SL) (ft)	-2,870		-546	-1,446	-1,693
Formation 27	Galway Formation (lower sandstone)		Clinton Group (Rochester Shale)	Clinton Group (Rochester Shale)	Salina Group (Syracuse Salt) (halite)
System or series:	Upper Cambrian		Silurian	Silurian	upper Silurian
Formation top (relative to KB) (ft)	-3,810		-1,680	-2,255	-3,542
Formation top (relative to GL) (ft)	-3,802		-1,666	-2,242	-3,527
Formation top (relative to SL) (ft)	-2,940		-678	-1,643	-1,767

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 25	Medina Group (Grimsby Sandstone and Whirlpool Sandstone) (undivided)	Shriver Chert, Mandata Sh., Corriganville Ls., New Creek Ls., and Keyser Fm. (undivided) (unconformity)	Onondaga Limestone	Hamilton Group (lower unnamed shale member of the Marcellus Shale)[2]	
System or series:	Silurian	Lower Devonian	Middle Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-7,107	-5,672	-6,365	-8,092	
Formation top (relative to GL) (ft)	-7,094	-5,654	-6,342	-8,059	
Formation top (relative to SL) (ft)	-5,449	-4,085	-4,495	-6,055	
Formation 26	Queenston Shale (Cherokee unconformity)	Salina Group (Bertie Limestone) (anhydritic dolomite)	Oriskany Sandstone (unconformity)	Tioga bentonite bed	
System or series:	Upper Ordovician	upper Silurian	Lower Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-7,175	-5,840	-6,380	-8,179	
Formation top (relative to GL) (ft)	-7,162	-5,822	-6,357	-8,146	
Formation top (relative to SL) (ft)	-5,517	-4,253	-4,510	-6,142	
Formation 27	Oswego Sandstone	Salina Group (Camillus Shale)	Shriver Chert, Mandata Sh., Corriganville Ls., New Creek Ls., and Keyser Fm. (uppermost part) (undivided) (unconformity)	Onondaga Limestone	
System or series:	Upper Ordovician	upper Silurian	Lower Devonian	Middle Devonian	
Formation top (relative to KB) (ft)	-8,130	-6,028	-6,410	-8,181	
Formation top (relative to GL) (ft)	-8,117	-6,010	-6,387	-8,148	
Formation top (relative to SL) (ft)	-6,472	-4,441	-4,540	-6,144	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A*′.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 28	Galway Formation (lower dolomite)		Clinton Group (Irondequoit Limestone)	Clinton Group (Irondequoit Limestone)	Salina Group (Vernon Shale) (green shale and anhydritic dolomite)
System or series:	Upper Cambrian		Silurian	Silurian	upper Silurian
Formation top (relative to KB) (ft)	-3,855		-1,868	-2,400	-4,404
Formation top (relative to GL) (ft)	-3,847		-1,854	-2,387	-4,389
Formation top (relative to SL) (ft)	-2,985		-866	-1,788	-2,629
Formation 29	granite and (or) gneiss		Clinton Group (middle unnamed shale)	Clinton Group (middle unnamed shale)	Lockport Group (dolomite)
System or series:	Mesoproterozoic		Silurian	Silurian	lower and upper Silurian
Formation top (relative to KB) (ft)	-3,895		-1,874	-2,408	-4,744
Formation top (relative to GL) (ft)	-3,887		-1,860	-2,395	-4,729
Formation top (relative to SL) (ft)	-3,025		-872	-1,796	-2,969
Formation 30			Clinton Group (Reynales Limestone and lower unnamed shale) (undivided)	Clinton Group (Reynales Limestone and lower unnamed shale) (undivided)	Clinton Group (Rochester Shale)
System or series:			Silurian	Silurian	Silurian
Formation top (relative to KB) (ft)			-1,895	-2,439	-4,957
Formation top (relative to GL) (ft)			-1,881	-2,426	-4,942
Formation top (relative to SL) (ft)			-893	-1,827	-3,182

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 28	Lorraine Shale	Salina Group (Syracuse Salt) (halite)	Keyser Formation (limestone)	Oriskany Sandstone (unconformity)	
System or series:	Upper Ordovician	upper Silurian	Lower Devonian	Lower Devonian	
Formation top (relative to KB) (ft)	-8,778	-6,104	-6,572	-8,231	
Formation top (relative to GL) (ft)	-8,765	-6,086	-6,549	-8,198	
Formation top (relative to SL) (ft)	-7,120	-4,517	-4,702	-6,194	
Formation 29	Utica Shale	Salina Group (Vernon Shale) (green shale and anhydritic dolomite)	Salina Group (Bertie Dolomite) (dolomite and shale)	Shriver Chert, Mandata Sh., Corriganville Ls., New Creek Ls., and Keyser Fm. (uppermost part) (undivided) (unconformity)	
System or series:	Upper Ordovician	upper Silurian	upper Silurian	Lower Devonian	
Formation top (relative to KB) (ft)	-9,573	-7,220	-6,650	-8,280	
Formation top (relative to GL) (ft)	-9,560	-7,202	-6,627	-8,247	
Formation top (relative to SL) (ft)	-7,915	-5,633	-4,780	-6,243	
Formation 30	Trenton Group (undivided)	Bloomsburg Formation (red shale)	Salina Group (Camillus Shale)	Keyser Formation	
System or series:	Upper Ordovician	upper Silurian	upper Silurian	Lower Devonian	
Formation top (relative to KB) (ft)	-9,672	-7,638	-6,772	-8,430	
Formation top (relative to GL) (ft)	-9,659	-7,620	-6,749	-8,397	
Formation top (relative to SL) (ft)	-8,014	-6,051	-4,902	-6,393	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 31			Medina Group (Cambria Shale and Thorold Sandstone) (undivided)	Medina Group (Cambria Shale and Thorold Sandstone) (undivided)	Clinton Group (Irondequoit Limestone)
System or series:			Silurian	Silurian	Silurian
Formation top (relative to KB) (ft)			-1,900	-2,450	-5,048
Formation top (relative to GL) (ft)			-1,886	-2,437	-5,033
Formation top (relative to SL) (ft)			-898	-1,838	-3,273
Formation 32			Medina Group (Grimsby Sandstone)	Medina Group (Grimsby Sandstone)	Clinton Group (middle unnamed shale)
System or series:			Silurian	Silurian	Silurian
Formation top (relative to KB) (ft)			-1,940	-2,500	-5,068
Formation top (relative to GL) (ft)			-1,926	-2,487	-5,053
Formation top (relative to SL) (ft)			-938	-1,888	-3,293
Formation 33			Queenston Shale (Cherokee unconformity)	Medina Group (Whirlpool Sandstone)	Clinton Group (Reynales Limestone and lower unnamed shale) (undivided)
System or series:			Upper Ordovician	Silurian	Silurian
Formation top (relative to KB) (ft)			-2,003	-2,560	-5,116
Formation top (relative to GL) (ft)			-1,989	-2,547	-5,101
Formation top (relative to SL) (ft)			-1,001	-1,948	-3,341

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 31	Trenton Group (Millbrig Bentonite Bed)	Mifflintown Formation (McKenzie Member)	Salina Group (Syracuse Salt) (upper halite)	Salina Group (Bertie Limestone) (anhydritic dolomite)	
System or series:	Upper Ordovician	Silurian	upper Silurian	upper Silurian	
Formation top (relative to KB) (ft)	-10,165	-7,922	-6,835	-8,520	
Formation top (relative to GL) (ft)	-10,152	-7,904	-6,812	-8,487	
Formation top (relative to SL) (ft)	-8,507	-6,335	-4,965	-6,483	
Formation 32	Trenton Group (Deicke Bentonite Bed)	Clinton Group (Rochester Shale)	Salina Group (Syracuse Salt) (upper anhydritic dolomite)	Salina Group (Camillus Shale)	
System or series:	Upper Ordovician	Silurian	upper Silurian	upper Silurian	
Formation top (relative to KB) (ft)	-10,214	-8,170	-7,837	-8,663	
Formation top (relative to GL) (ft)	-10,201	-8,152	-7,814	-8,630	
Formation top (relative to SL) (ft)	-8,556	-6,583	-5,967	-6,626	
Formation 33	Trenton Group (unnamed bentonite bed)	Clinton Group (Irondequoit Limestone) (equivalent to Keefer Formation of Pa.)	Salina Group (Syracuse Salt) (middle halite)	Salina Group (Syracuse Salt) (anhydritic dolomite and shale)	
System or series:	Upper Ordovician	Silurian	upper Silurian	upper Silurian	
Formation top (relative to KB) (ft)	-10,230	-8,234	-8,041	-8,726	
Formation top (relative to GL) (ft)	-10,217	-8,216	-8,018	-8,693	
Formation top (relative to SL) (ft)	-8,572	-6,647	-6,171	-6,689	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 34			Oswego Sandstone	Queenston Shale (Cherokee unconformity)	Medina Group (Cambria Shale and Thorold Sandstone) (undivided)
System or series:			Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)			-3,040	-2,572	-5,158
Formation top (relative to GL) (ft)			-3,026	-2,559	-5,143
Formation top (relative to SL) (ft)			-2,038	-1,960	-3,383
Formation 35			Lorraine Shale	Oswego Sandstone	Medina Group (Grimsby Sandstone and Whirlpool Sandstone) (undivided)
System or series:			Upper Ordovician	Upper Ordovician	Silurian
Formation top (relative to KB) (ft)			-3,133	-3,570	-5,219
Formation top (relative to GL) (ft)			-3,119	-3,557	-5,204
Formation top (relative to SL) (ft)			-2,131	-2,958	-3,444
Formation 36			Utica Shale	Lorraine Shale	Queenston Shale (Cherokee unconformity)
System or series:			Upper Ordovician	Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-3,675	-3,770	-5,290
Formation top (relative to GL) (ft)			-3,661	-3,757	-5,275
Formation top (relative to SL) (ft)			-2,673	-3,158	-3,515

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 34	Black River Group (undivided)	Rose Hill Formation (upper shale member)	Salina Group (Syracuse Salt) (lower anhydritic dolomite)	Salina Group (Syracuse Salt) (halite)	
System or series:	Middle and Upper Ordovician	lower Silurian	upper Silurian	upper Silurian	
Formation top (relative to KB) (ft)	-10,255	-8,250	-8,145	-8,942	
Formation top (relative to GL) (ft)	-10,242	-8,232	-8,122	-8,909	
Formation top (relative to SL) (ft)	-8,597	-6,663	-6,275	-6,905	
Formation 35	Black River Group (marker x)	Rose Hill Formation (upper limestone member) (equivalent to Reynales Limestone)	Salina Group (Syracuse Salt) (lower halite)	Wills Creek Formation (argillaceous dolomite with anhydrite)	
System or series:	Middle and Upper Ordovician	lower Silurian	upper Silurian	lower and upper Silurian	
Formation top (relative to KB) (ft)	-10,542	-8,424	-8,340	-9,543	
Formation top (relative to GL) (ft)	-10,529	-8,406	-8,317	-9,510	
Formation top (relative to SL) (ft)	-8,884	-6,837	-6,470	-7,506	
Formation 36	Black River Group (marker y)	Rose Hill Formation (lower shale member)	Wills Creek Formation (argillaceous dolomite with anhydrite)	Bloomsburg Formation (red shale)	
System or series:	Middle and Upper Ordovician	lower Silurian	lower and upper Silurian	upper Silurian	
Formation top (relative to KB) (ft)	-10,640	-8,433	-8,516	-10,005	
Formation top (relative to GL) (ft)	-10,627	-8,415	-8,493	-9,972	
Formation top (relative to SL) (ft)	-8,982	-6,846	-6,646	-7,968	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A*′.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	1	2	3	4	5
American Petroleum Institute well number	31–037–05117	31–037–04593	31–051–04552	31–051–04630	31–101–21496
Lease name	No. 1 J. Klotzbach	No. 1 L. Tyler	No. 1 Albert McClurg	No. 1 Arthur N. Kennedy	No. 1 Hubbard
Permanent datum	GL	GL	GL	GL	GL
Ground level elevation (ft)	862	703	988.5	599	1,760
Kelly bushing elevation (ft)	870	716	1,003	612	1,775
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	3,950	4,000	5,648	6,387	10,061
Formation 37			Trenton Group (undivided)	Utica Shale	Oswego Sandstone
System or series:			Upper Ordovician	Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-3,855	-4,303	-6,070
Formation top (relative to GL) (ft)			-3,841	-4,290	-6,055
Formation top (relative to SL) (ft)			-2,853	-3,691	-4,295
Formation 38			Trenton Group (Millbrig Bentonite Bed)	Trenton Group (undivided)	Lorraine Shale
System or series:			Upper Ordovician	Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-4,431	-4,480	-6,262
Formation top (relative to GL) (ft)			-4,417	-4,467	-6,247
Formation top (relative to SL) (ft)			-3,429	-3,868	-4,487
Formation 39			Trenton Group (Deicke Bentonite Bed)	Trenton Group (Millbrig Bentonite Bed)	Utica Shale
System or series:			Upper Ordovician	Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-4,457	-5,033	-6,900
Formation top (relative to GL) (ft)			-4,443	-5,020	-6,885
Formation top (relative to SL) (ft)			-3,455	-4,421	-5,125
Formation 40			Black River Group (unnamed bentonite bed)	Trenton Group (Deicke Bentonite Bed)	Trenton Group (undivided)
System or series:			Middle and Upper Ordovician	Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-4,479	-5,054	-7,330
Formation top (relative to GL) (ft)			-4,465	-5,041	-7,315
Formation top (relative to SL) (ft)			-3,477	-4,442	-5,555

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 37	Black River Group (argillaceous limestone and dolomite)	Rose Hill Formation (lower limestone member)	Bloomsburg Formation (red shale)	Mifflintown Formation (McKenzie Member)	
System or series:	Middle and Upper Ordovician	lower Silurian	upper Silurian	Silurian	
Formation top (relative to KB) (ft)	-10,707	-8,520	-8,956	-10,212	
Formation top (relative to GL) (ft)	-10,694	-8,502	-8,933	-10,179	
Formation top (relative to SL) (ft)	-9,049	-6,933	-7,086	-8,175	
Formation 38	Beekmantown Group (Bellefonte Formation) (upper part)	Tuscarora Formation (Castanea Member) (sandstone)	Mifflintown Formation (McKenzie Member)	Mifflintown Formation (Rochester Member)	
System or series:	Middle Ordovician	Silurian	Silurian	Silurian	
Formation top (relative to KB) (ft)	-10,850	-8,530	-9,068	-10,408	
Formation top (relative to GL) (ft)	-10,837	-8,512	-9,045	-10,375	
Formation top (relative to SL) (ft)	-9,192	-6,943	-7,198	-8,371	
Formation 39	Tribes Hill Dolomite (Knox unconformity)	Tuscarora Formation (main body) (sandstone)	Mifflintown Formation (Rochester Member)	Keefer Formation	
System or series:	Lower Ordovician	Silurian	Silurian	Upper Devonian	
Formation top (relative to KB) (ft)	-10,970	-8,668	-9,388	-10,481	
Formation top (relative to GL) (ft)	-10,957	-8,650	-9,365	-10,448	
Formation top (relative to SL) (ft)	-9,312	-7,081	-7,518	-8,444	
Formation 40	Little Falls Dolomite	Juniata Formation (red shale) (Cherokee unconformity)	Keefer Formation (equiv. to Irondequoit Ls. of N.Y.)	Rose Hill Formation (upper shale member)	
System or series:	Upper Cambrian	Upper Ordovician	Upper Devonian	lower Silurian	
Formation top (relative to KB) (ft)	-11,360	-8,816	-9,458	-10,528	
Formation top (relative to GL) (ft)	-11,347	-8,798	-9,435	-10,495	
Formation top (relative to SL) (ft)	-9,702	-7,229	-7,588	-8,491	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A*–*A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 41			Black River Group (marker x)	Black River Group (unnamed bentonite bed)	Trenton Group (Millbrig Bentonite Bed)
System or series:			Middle and Upper Ordovician	Middle and Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-4,660	-5,082	-7,942
Formation top (relative to GL) (ft)			-4,646	-5,069	-7,927
Formation top (relative to SL) (ft)			-3,658	-4,470	-6,167
Formation 42			Black River Group (marker y)	Black River Group (marker x)	Trenton Group (Deicke Bentonite Bed)
System or series:			Middle and Upper Ordovician	Middle and Upper Ordovician	Upper Ordovician
Formation top (relative to KB) (ft)			-4,723	-5,278	-7,968
Formation top (relative to GL) (ft)			-4,709	-5,265	-7,953
Formation top (relative to SL) (ft)			-3,721	-4,666	-6,193
Formation 43			Black River Group (argillaceous limestone and dolomite)	Black River Group (marker y)	Black River Group (unnamed bentonite bed)
System or series:			Middle and Upper Ordovician	Middle and Upper Ordovician	Middle and Upper Ordovician
Formation top (relative to KB) (ft)			-4,778	-5,358	-7,983
Formation top (relative to GL) (ft)			-4,764	-5,345	-7,968
Formation top (relative to SL) (ft)			-3,776	-4,746	-6,208

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 41	Galway Formation (A sandstone)	Bald Eagle Formation (sandstone)	Rose Hill Formation (upper shale member)	Rose Hill Formation (upper limestone member)	
System or series:	Upper Cambrian	Upper Ordovician	lower Silurian	lower Silurian	
Formation top (relative to KB) (ft)	-11,750	-9,478	-9,516	-10,853	
Formation top (relative to GL) (ft)	-11,737	-9,460	-9,493	-10,820	
Formation top (relative to SL) (ft)	-10,092	-7,891	-7,646	-8,816	
Formation 42	Galway Formation (A interbedded sandstone and dolomite, and A dolomite) (undivided)	Reedsville Shale	Rose Hill Formation (upper limestone member)	Rose Hill Formation (lower shale member)	
System or series:	Upper Cambrian	Upper Ordovician	lower Silurian	lower Silurian	
Formation top (relative to KB) (ft)	-12,044	-10,664	-9,800	-10,890	
Formation top (relative to GL) (ft)	-12,031	-10,646	-9,777	-10,857	
Formation top (relative to SL) (ft)	-10,386	-9,077	-7,930	-8,853	
Formation 43	Galway Formation (B sandstone)	Utica (Antes) Shale	Rose Hill Formation (lower shale member)	Rose Hill Formation (lower limestone member)	
System or series:	Upper Cambrian	Upper Ordovician	lower Silurian	lower Silurian	
Formation top (relative to KB) (ft)	-12,410	-11,262	-9,818	-10,988	
Formation top (relative to GL) (ft)	-12,397	-11,244	-9,795	-10,955	
Formation top (relative to SL) (ft)	-10,752	-9,675	-7,948	-8,951	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 44			Galway Formation (sandstone) (Knox unconformity)	Black River Group (argillaceous limestone and dolomite)	Black River Group (marker x)
System or series:			Upper Cambrian	Middle and Upper Ordovician	Middle and Upper Ordovician
Formation top (relative to KB) (ft)			-4,880	-5,420	-8,268
Formation top (relative to GL) (ft)			-4,866	-5,407	-8,253
Formation top (relative to SL) (ft)			-3,878	-4,808	-6,493
Formation 45			Galway Formation (dolomite)	Little Falls Dolomite (Knox unconformity)	Black River Group (marker y)
System or series:			Upper Cambrian	Upper Cambrian	Middle and Upper Ordovician
Formation top (relative to KB) (ft)			-4,950	-5,530	-8,332
Formation top (relative to GL) (ft)			-4,936	-5,517	-8,317
Formation top (relative to SL) (ft)			-3,948	-4,918	-6,557
Formation 46			Galway Formation (sandstone)	Galway Formation (upper sandstone member)	Black River Group (argillaceous limestone and dolomite)
System or series:			Upper Cambrian	Upper Cambrian	Middle and Upper Ordovician
Formation top (relative to KB) (ft)			-5,192	-5,620	-8,402
Formation top (relative to GL) (ft)			-5,178	-5,607	-8,387
Formation top (relative to SL) (ft)			-4,190	-5,008	-6,627

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 44	Galway Formation (B dolomite)	Trenton Group (limestone)	Rose Hill Formation (lower limestone member)	Tuscarora Formation (Castanea Member) (sandstone)	
System or series:	Upper Cambrian	Upper Ordovician	lower Silurian	Silurian	
Formation top (relative to KB) (ft)	-12,600	-11,494	-9,905	-10,995	
Formation top (relative to GL) (ft)	-12,587	-11,476	-9,882	-10,962	
Formation top (relative to SL) (ft)	-10,942	-9,907	-8,035	-8,958	
Formation 45	Galway Formation (B interbedded sandstone and dolomite)	Trenton Group (Millbrig Bentonite Bed)	Tuscarora Formation (Castanea Member) (sandstone)	Tuscarora Formation (main body)	
System or series:	Upper Cambrian	Upper Ordovician	Silurian	Silurian	
Formation top (relative to KB) (ft)	-12,750	-12,360	-9,914	-11,087	
Formation top (relative to GL) (ft)	-12,737	-12,342	-9,891	-11,054	
Formation top (relative to SL) (ft)	-11,092	-10,773	-8,044	-9,050	
Formation 46	Galway Formation (C sandstone)	Trenton Group (Deicke Bentonite Bed)	Tuscarora Formation (main body) (sandstone)	Juniata Formation (red shale) (Cherokee unconformity)	
System or series:	Upper Cambrian	Upper Ordovician	Silurian	Upper Ordovician	
Formation top (relative to KB) (ft)	-12,900	-12,380	-9,985	-11,407	
Formation top (relative to GL) (ft)	-12,887	-12,362	-9,962	-11,374	
Formation top (relative to SL) (ft)	-11,242	-10,793	-8,115	-9,370	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
Formation 47			Galway Formation (sandy dolomite)	Galway Formation (dolomite)	Little Falls Dolomite (Knox unconformity)
System or series:			Upper Cambrian	Upper Cambrian	Upper Cambrian
Formation top (relative to KB) (ft)			-5,253	-5,770	-8,530
Formation top (relative to GL) (ft)			-5,239	-5,757	-8,515
Formation top (relative to SL) (ft)			-4,251	-5,158	-6,755
Formation 48			Potsdam Sandstone (or lowermost Galway)	Potsdam Sandstone	Galway Formation (upper sandstone member)
System or series:			Upper Cambrian	Middle Cambrian	Upper Cambrian
Formation top (relative to KB) (ft)			-5,440	-6,387	-8,928
Formation top (relative to GL) (ft)			-5,426	-6,374	-8,913
Formation top (relative to SL) (ft)			-4,438	-5,775	-7,153
Formation 49			granite and (or) gneiss		Galway Formation (dolomite)
System or series:			Mesoproterozoic		Upper Cambrian
Formation top (relative to KB) (ft)			-5,557		-9,168
Formation top (relative to GL) (ft)			-5,543		-9,153
Formation top (relative to SL) (ft)			-4,555		-7,393
Formation 50					Potsdam Sandstone
System or series:					Middle Cambrian
Formation top (relative to KB) (ft)					-9,843
Formation top (relative to GL) (ft)					-9,828
Formation top (relative to SL) (ft)					-8,068

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 47	Potsdam Sandstone	Trenton Group (unnamed bentonite bed)	Juniata Formation (red shale) (Cherokee unconformity)	Bald Eagle Formation (sandstone)	
System or series:	Middle Cambrian	Upper Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)	-13,100	-12,400	-10,297	-12,243	
Formation top (relative to GL) (ft)	-13,087	-12,382	-10,274	-12,210	
Formation top (relative to SL) (ft)	-11,442	-10,813	-8,427	-10,206	
Formation 48		Black River Group (limestone)	Bald Eagle Formation (sandstone)	Reedsville Shale	
System or series:		Middle and Upper Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)		-12,403	-11,200	-13,453	
Formation top (relative to GL) (ft)		-12,385	-11,177	-13,420	
Formation top (relative to SL) (ft)		-10,816	-9,330	-11,416	
Formation 49		Black River Group (marker x)	Reedsville Shale	Utica (Antes) Shale	
System or series:		Middle and Upper Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)		-12,914	-12,350	-14,060	
Formation top (relative to GL) (ft)		-12,896	-12,327	-14,027	
Formation top (relative to SL) (ft)		-11,327	-10,480	-12,023	
Formation 50		Black River Group (marker y)	Utica (Antes) Shale	Trenton Group (limestone)	
System or series:		Middle and Upper Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)		-13,024	-12,930	-14,390	
Formation top (relative to GL) (ft)		-13,006	-12,907	-14,357	
Formation top (relative to SL) (ft)		-11,437	-11,060	-12,353	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	1	2	3	4	5
American Petroleum Institute well number	31–037–05117	31–037–04593	31–051–04552	31–051–04630	31–101–21496
Lease name	No. 1 J. Klotzbach	No. 1 L. Tyler	No. 1 Albert McClurg	No. 1 Arthur N. Kennedy	No. 1 Hubbard
Permanent datum	GL	GL	GL	GL	GL
Ground level elevation (ft)	862	703	988.5	599	1,760
Kelly bushing elevation (ft)	870	716	1,003	612	1,775
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	3,950	4,000	5,648	6,387	10,061
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)					

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 51		Loysburg Formation (argillaceous limestone and dolomite)	Trenton Group (limestone)	Trenton Group (Millbrig Bentonite Bed)	
System or series:		Middle and Upper Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)		-13,095	-13,180	-14,703	
Formation top (relative to GL) (ft)		-13,077	-13,157	-14,670	
Formation top (relative to SL) (ft)		-11,508	-11,310	-12,666	
Formation 52		Beekmantown Group (Bellefonte Formation) (upper part)	Trenton Group (Millbrig Bentonite Bed)	Trenton Group (Deicke Bentonite Bed)	
System or series:		Middle Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)		-13,194	-13,870	-14,728	
Formation top (relative to GL) (ft)		-13,176	-13,847	-14,695	
Formation top (relative to SL) (ft)		-11,607	-12,000	-12,691	
Formation 53		Beekmantown Group (Bellefonte Formation) (lower part) (unconformity)	Trenton Group (Deicke Bentonite Bed)	Trenton Group (unnamed bentonite bed)	
System or series:		Middle Ordovician	Upper Ordovician	Upper Ordovician	
Formation top (relative to KB) (ft)		-13,700	-13,888	-14,756	
Formation top (relative to GL) (ft)		-13,682	-13,865	-14,723	
Formation top (relative to SL) (ft)		-12,113	-12,018	-12,719	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	1	2	3	4	5
American Petroleum Institute well number	31–037–05117	31–037–04593	31–051–04552	31–051–04630	31–101–21496
Lease name	No. 1 J. Klotzbach	No. 1 L. Tyler	No. 1 Albert McClurg	No. 1 Arthur N. Kennedy	No. 1 Hubbard
Permanent datum	GL	GL	GL	GL	GL
Ground level elevation (ft)	862	703	988.5	599	1,760
Kelly bushing elevation (ft)	870	716	1,003	612	1,775
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	3,950	4,000	5,648	6,387	10,061
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)					
Formation 56					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 54		Beekmantown Group (Larke Formation) (Knox unconformity)	Trenton Group (unnamed bentonite bed)	Black River Group (limestone)	
System or series:		Lower Ordovician	Upper Ordovician	Middle and Upper Ordovician	
Formation top (relative to KB) (ft)		-13,992	-13,908	-14,910	
Formation top (relative to GL) (ft)		-13,974	-13,885	-14,877	
Formation top (relative to SL) (ft)		-12,405	-12,038	-12,873	
Formation 55		Gatesburg Formation (Mines Dolomite Member)	Black River Group (limestone)	Black River Group (marker x)	
System or series:		Upper Cambrian	Middle and Upper Ordovician	Middle and Upper Ordovician	
Formation top (relative to KB) (ft)		-14,445	-13,986	-15,030	
Formation top (relative to GL) (ft)		-14,427	-13,963	-14,997	
Formation top (relative to SL) (ft)		-12,858	-12,116	-12,993	
Formation 56		Gatesburg Formation (upper sandy member)	Black River Group (marker x)	Black River Group (marker y)	
System or series:		Upper Cambrian	Middle and Upper Ordovician	Middle and Upper Ordovician	
Formation top (relative to KB) (ft)		-14,840	-14,310	-15,158	
Formation top (relative to GL) (ft)		-14,822	-14,287	-15,125	
Formation top (relative to SL) (ft)		-13,253	-12,440	-13,121	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**1**	**2**	**3**	**4**	**5**
American Petroleum Institute well number	**31–037–05117**	**31–037–04593**	**31–051–04552**	**31–051–04630**	**31–101–21496**
Lease name	**No. 1 J. Klotzbach**	**No. 1 L. Tyler**	**No. 1 Albert McClurg**	**No. 1 Arthur N. Kennedy**	**No. 1 Hubbard**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**GL**
Ground level elevation (ft)	**862**	**703**	**988.5**	**599**	**1,760**
Kelly bushing elevation (ft)	**870**	**716**	**1,003**	**612**	**1,775**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**3,950**	**4,000**	**5,648**	**6,387**	**10,061**
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 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	6	7	8	9	10
American Petroleum Institute well number	31–101–03924	37–117–20057	37–105–20182	37–035–20276	37–081–90002
Lease name	No. 1 Robert Olin	No. 1 Harry P. Dewey	No. 1 Pa. Dept. of Forest and Water Tract 129	No. 1 Pa. State Forest, Tract 285–1	No. 1 W.E. Snyder
Permanent datum	GL	GL	GL	GL	DF
Ground level elevation (ft)	1,645	1,569	1,847	2,004	726
Kelly bushing elevation (ft)	1,658	1,587	1,870	2,037	726
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	13,508	15,082	18,834	19,360	5,808
Formation 57			Black River Group (marker y)	Loysburg Formation (argillaceous limestone and dolomite)	
System or series:			Middle and Upper Ordovician	Middle and Upper Ordovician	
Formation top (relative to KB) (ft)			-14,436	-15,228	
Formation top (relative to GL) (ft)			-14,413	-15,195	
Formation top (relative to SL) (ft)			-12,566	-13,191	
Formation 58			Loysburg Formation (argillaceous limestone and dolomite)	Beekmantown Group (Bellefonte Formation) (upper part)	
System or series:			Middle and Upper Ordovician	Middle Ordovician	
Formation top (relative to KB) (ft)			-14,503	-15,417	
Formation top (relative to GL) (ft)			-14,480	-15,384	
Formation top (relative to SL) (ft)			-12,633	-13,380	
Formation 59			Beekmantown Group (Bellefonte Formation) (upper part)	Beekmantown Group (Bellefonte Formation) (lower part) (unconformity)	
System or series:			Middle Ordovician	Middle Ordovician	
Formation top (relative to KB) (ft)			-14,710	-15,599	
Formation top (relative to GL) (ft)			-14,687	-15,566	
Formation top (relative to SL) (ft)			-12,840	-13,562	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	1	2	3	4	5
American Petroleum Institute well number	31–037–05117	31–037–04593	31–051–04552	31–051–04630	31–101–21496
Lease name	No. 1 J. Klotzbach	No. 1 L. Tyler	No. 1 Albert McClurg	No. 1 Arthur N. Kennedy	No. 1 Hubbard
Permanent datum	GL	GL	GL	GL	GL
Ground level elevation (ft)	862	703	988.5	599	1,760
Kelly bushing elevation (ft)	870	716	1,003	612	1,775
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	3,950	4,000	5,648	6,387	10,061
Formation 60					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 61					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 62					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 60			Beekmantown Group (Bellefonte Formation) (lower part) (unconformity)	Beekmantown Group (Larke Formation) (Knox unconformity)	
System or series:			Middle Ordovician	Lower Ordovician	
Formation top (relative to KB) (ft)			-14,950	-16,625	
Formation top (relative to GL) (ft)			-14,927	-16,592	
Formation top (relative to SL) (ft)			-13,080	-14,588	
Formation 61			Beekmantown Group (Larke Formation) (Knox unconformity)	Gatesburg Formation (Mines Dolomite Member)	
System or series:			Lower Ordovician	Upper Cambrian	
Formation top (relative to KB) (ft)			-15,520	-17,065	
Formation top (relative to GL) (ft)			-15,497	-17,032	
Formation top (relative to SL) (ft)			-13,650	-15,028	
Formation 62			Gatesburg Formation (Mines Dolomite Member)	Gatesburg Formation (upper sandy member)	
System or series:			Upper Cambrian	Upper Cambrian	
Formation top (relative to KB) (ft)			-15,956	-17,400	
Formation top (relative to GL) (ft)			-15,933	-17,367	
Formation top (relative to SL) (ft)			-14,086	-15,363	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	1	2	3	4	5
American Petroleum Institute well number	31–037–05117	31–037–04593	31–051–04552	31–051–04630	31–101–21496
Lease name	No. 1 J. Klotzbach	No. 1 L. Tyler	No. 1 Albert McClurg	No. 1 Arthur N. Kennedy	No. 1 Hubbard
Permanent datum	GL	GL	GL	GL	GL
Ground level elevation (ft)	862	703	988.5	599	1,760
Kelly bushing elevation (ft)	870	716	1,003	612	1,775
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	3,950	4,000	5,648	6,387	10,061
Formation 63					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 64					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 65					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 66					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 63			Gatesburg Formation (upper sandy member)	Gatesburg Formation (Ore Hill Member) (limestone)	
System or series:			Upper Cambrian	Upper Cambrian	
Formation top (relative to KB) (ft)			-16,384	-17,815	
Formation top (relative to GL) (ft)			-16,361	-17,782	
Formation top (relative to SL) (ft)			-14,514	-15,778	
Formation 64			Gatesburg Formation (Ore Hill Member) (dolomite)	Gatesburg Formation (lower sandy member)	
System or series:			Upper Cambrian	Upper Cambrian	
Formation top (relative to KB) (ft)			-16,790	-18,398	
Formation top (relative to GL) (ft)			-16,767	-18,365	
Formation top (relative to SL) (ft)			-14,920	-16,361	
Formation 65			Gatesburg Formation (lower sandy member)	Warrior Formation (shale and dolomite)	
System or series:			Upper Cambrian	Upper Cambrian	
Formation top (relative to KB) (ft)			-17,590	-18,696	
Formation top (relative to GL) (ft)			-17,567	-18,663	
Formation top (relative to SL) (ft)			-15,720	-16,659	
Formation 66			Warrior Formation (upper oolitic dolomite	Warrior Formation (sandstone)	
System or series:			Upper Cambrian	Middle Cambrian	
Formation top (relative to KB) (ft)			-17,776	-18,950	
Formation top (relative to GL) (ft)			-17,753	-18,917	
Formation top (relative to SL) (ft)			-15,906	-16,913	

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	1	2	3	4	5
American Petroleum Institute well number	31–037–05117	31–037–04593	31–051–04552	31–051–04630	31–101–21496
Lease name	No. 1 J. Klotzbach	No. 1 L. Tyler	No. 1 Albert McClurg	No. 1 Arthur N. Kennedy	No. 1 Hubbard
Permanent datum	GL	GL	GL	GL	GL
Ground level elevation (ft)	862	703	988.5	599	1,760
Kelly bushing elevation (ft)	870	716	1,003	612	1,775
Measured from	KB	KB	KB	KB	KB
Drill depth (ft)	3,950	4,000	5,648	6,387	10,061
Formation 67					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 68					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 69					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					
Formation 70					
System or series:					
Formation top (relative to KB) (ft)					
Formation top (relative to GL) (ft)					
Formation top (relative to SL) (ft)					

[1]West River Shale, Genundewa Limestone, Penn Yan Shale, and Lodi Limestone Members of the Genesee Formation are shown as undivided on cross section *A–A′* and correlation chart (fig. 3). On cross section *A–A′*, they may also be shown as West River Shale and Genundewa Limestone Members, undivided; and Penn Yan Shale and Lodi Limestone Members, undivided.

[2]Not shown on cross section *A–A′* or correlation chart (fig. 3) because unit is to thin.

Appendix 1. Table summarizing stratigraphic units and depths of stratigraphic units for drill holes 1–10 in cross section *A–A′*.—Continued

[Abbreviations: Dept., Department; DF, drill floor; equiv., equivalent; Fm., Formation; ft, feet; GL, ground level; KB, kelly bushing; Ls., Limestone; No., number; N.Y., New York; Pa., Pennsylvania; Sh., Shale; SL, sea level]

Drill-hole number	**6**	**7**	**8**	**9**	**10**
American Petroleum Institute well number	**31–101–03924**	**37–117–20057**	**37–105–20182**	**37–035–20276**	**37–081–90002**
Lease name	**No. 1 Robert Olin**	**No. 1 Harry P. Dewey**	**No. 1 Pa. Dept. of Forest and Water Tract 129**	**No. 1 Pa. State Forest, Tract 285–1**	**No. 1 W.E. Snyder**
Permanent datum	**GL**	**GL**	**GL**	**GL**	**DF**
Ground level elevation (ft)	**1,645**	**1,569**	**1,847**	**2,004**	**726**
Kelly bushing elevation (ft)	**1,658**	**1,587**	**1,870**	**2,037**	**726**
Measured from	**KB**	**KB**	**KB**	**KB**	**KB**
Drill depth (ft)	**13,508**	**15,082**	**18,834**	**19,360**	**5,808**
Formation 67			Warrior Formation (shale and dolomite)	Warrior Formation (sandy dolomite)	
System or series:			Upper Cambrian	Middle Cambrian	
Formation top (relative to KB) (ft)			-17,850	-19,267	
Formation top (relative to GL) (ft)			-17,827	-19,234	
Formation top (relative to SL) (ft)			-15,980	-17,230	
Formation 68			Warrior Formation (sandstone)		
System or series:			Middle Cambrian		
Formation top (relative to KB) (ft)			-18,100		
Formation top (relative to GL) (ft)			-18,077		
Formation top (relative to SL) (ft)			-16,230		
Formation 69			Warrior Formation (sandy dolomite)		
System or series:			Middle Cambrian		
Formation top (relative to KB) (ft)			-18,590		
Formation top (relative to GL) (ft)			-18,567		
Formation top (relative to SL) (ft)			-16,720		
Formation 70			Potsdam Sandstone		
System or series:			Middle Cambrian		
Formation top (relative to KB) (ft)			-18,700		
Formation top (relative to GL) (ft)			-18,677		
Formation top (relative to SL) (ft)			-16,830		

Appendix 2. Scale, Units, and Depths for Gamma-Ray Logging Runs

Appendix 2. Scale, units, and depths for gamma-ray logging runs.

[Abbreviations: API, American Petroleum Institute; ft, feet; KB, kelly bushing; na, not applicable; nd, no data; TD, total depth; µgm Ra-eq/ton, micrograms of radium equivalent per metric ton; µR/hr, micro-Roentgens per hour]

Drill-hole number	Scale and units	Depth of selected logged intervals	Notes
1	0–200 API units	83 ft below KB to 3,899 ft	TD is 3,950 ft below KB
2	0–200 API units 200–400 API units (backup scale)	KB to TD	TD is 4,000 ft below KB
3	0–200 API units 200–400 API units (backup scale) 400–600 API units (second backup scale) 600–800 API units (third backup scale)	KB to TD	TD is 5,648 ft below KB
4	0–200 API units 200–400 API units (backup scale) 400–600 API units (second backup scale)	29.5 ft below KB to TD	TD is 6,388 ft below KB
5	0–200 API units 200–400 API units (backup scale) 400–600 API units (second backup scale)	KB to TD	TD is 10,051 ft below KB
6	0–13.5 µR/hr 13.5–26 µR/hr (backup scale)	4,000.5 ft below KB to 6,292.5 ft	Birdwell log
	0–7.5 µgm Ra-eq/ton 7.5–15 µgm Ra-eq/ton (backup scale)	6,292.5 ft below KB to 12,646.5 ft	Schlumberger log
	0–10.5 µgm Ra-eq/ton 10.5–21 µgm Ra-eq/ton (backup scale)	12,646.5 ft below KB to TD	Schlumberger log; TD is 13,508 ft below KB
7	0–200 API units 200–400 API units (backup scale)	100 ft below KB to 13,400.5 ft	na
	0–200 API units 200–400 API units (backup scale)	13,400.5 ft below KB to 14,982 ft	TD is 15,082 ft below KB
8	0–110 API units	KB to 6,486 ft	Birdwell log (curve extends beyond scale maximum)
	0–150 API units 150–300 API units (backup scale)	6,486 ft below KB to 18,796.5 ft	Schlumberger log; TD is 18,834 ft below KB
9	0–200 API units 200–400 API units (backup scale)	200 ft below KB to 19,357 ft	TD is 19,365 ft below KB
10	nd	nd	na

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