3. Additional Data Requested by Expert Panel

Geologic Data and Maps

After reading the report by DMRM (2008) and viewing the PowerPoint presentation of E&A (2009), the expert panel concluded that more detailed knowledge of the local geology and the construction details of local water wells were needed to understand the movement of the fugitive gas. To address these needs, the expert panel requested DMRM to document the characteristics of the local geologic units and to make detailed geologic cross sections through the area impacted by subsurface gas invasions. The panel also requested that additional borehole videotapes be taken to evaluate the accuracy of some water well logs and to provide supplemental data for key water wells lacking logs. Figure 3-1 displays the stratigraphic section in the English #1 gas well and shows images of features of the major geologic units as seen in the Bainbridge Township area.

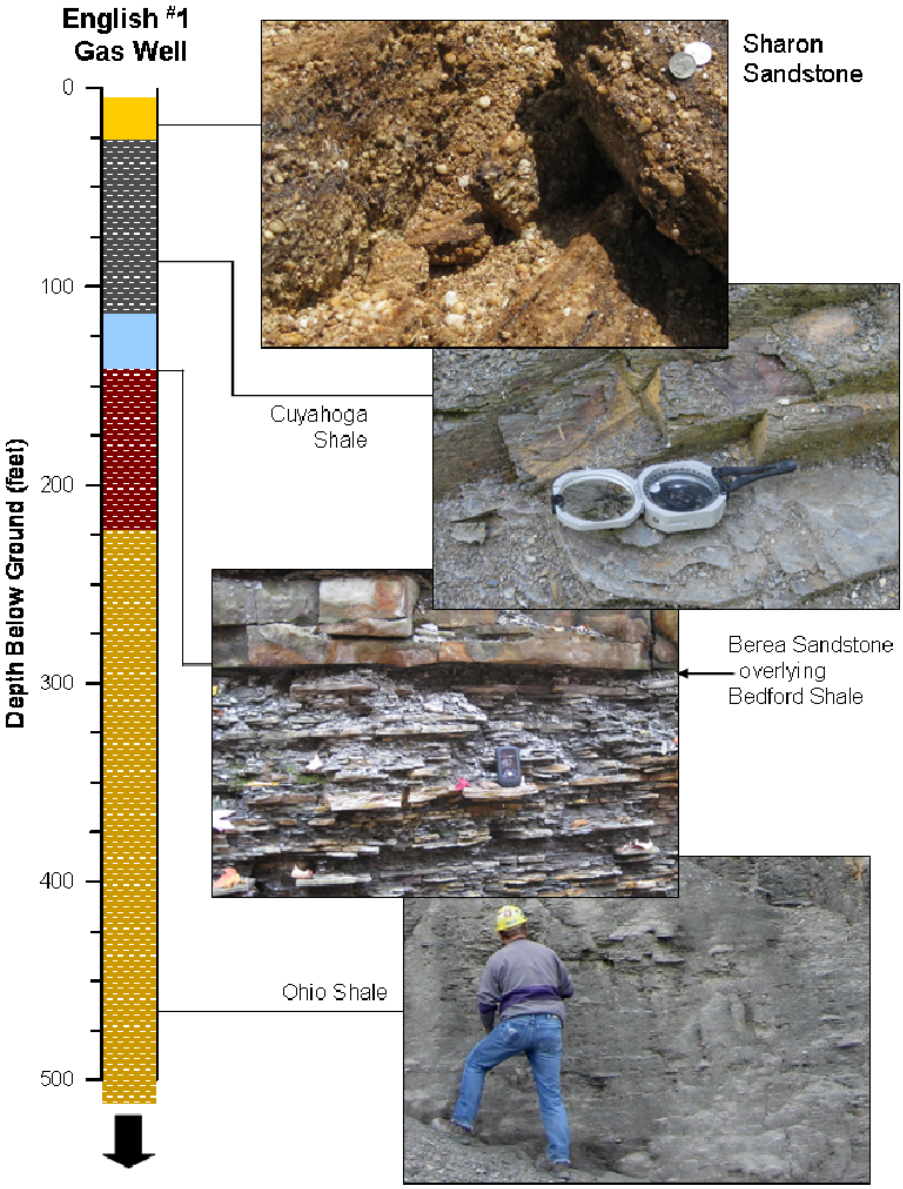

Figure 3-1. Stratigraphic section and images showing near-surface geologic units.

The panel also asked DMRM to measure joint orientations in the each of the near-surface geologic units to help evaluate the role of existing, natural joints in the migration of gas upwards into local water wells.

Figure 3-2 is a regional west-to-east geologic cross section through Geauga County approximately along route 422 in Bainbridge Township. It shows regional variations in the thickness of major geologic units and locations of major rivers and incised bedrock valleys infilled with glacial deposits.

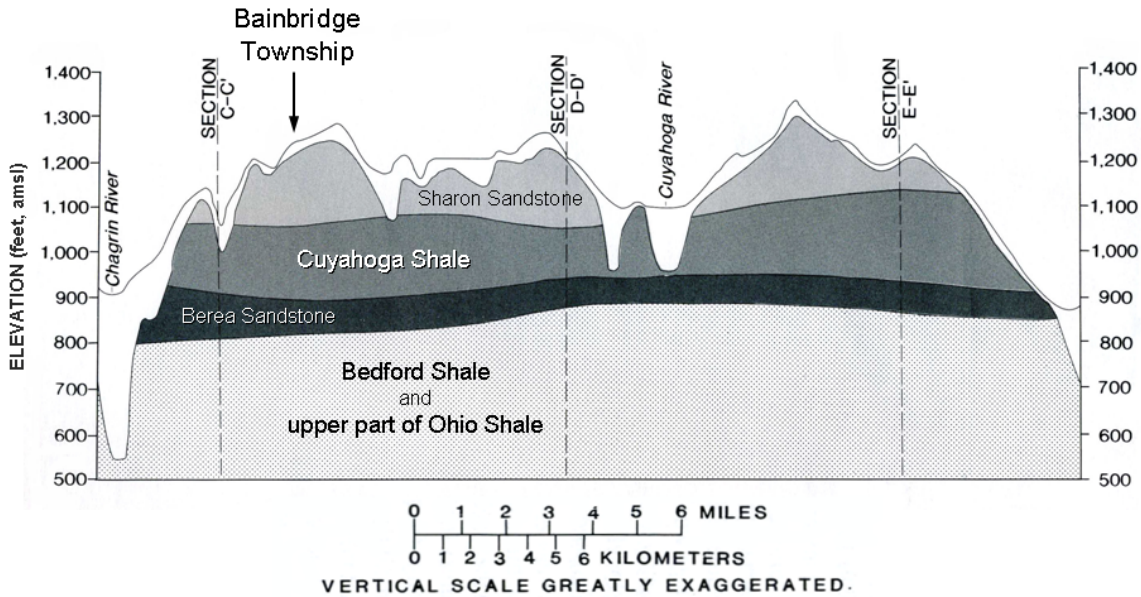

Figure 3-2. West-to-east regional geologic cross section across Bainbridge Township (modified from Eberts and others, 1990).

The Sharon Sandstone underlies most of the elevated areas in Geauga County including the ridge along Bainbridge Road (Figures 1-1 and 3-2). The Sharon Sandstone is coarse-grained, friable, and contains zones of abundant white quartz pebbles (Figure 3-1). Locally, it varies in thickness from 12 to 68 feet. It has both intergranular permeability (pores between sand grains) and fracture permeability along discontinuous vertical joints and bedding planes. Because it is permeable and receives abundant recharge from infiltrating rainfall and snowmelt, the Sharon Sandstone is commonly tapped by residential water wells in Geauga County. It is the source of groundwater for many wells along Scotland Drive and at the bottom of English Drive (Appendix B).

The Cuyahoga Shale underlies the Sharon Sandstone (Figures 3-1 and 3-2) and crops out along the valley of the Chagrin River less than a mile west of English Drive on Geauga Lake Road. The Cuyahoga Shale is thinly bedded and contains thin layers (6 to 12 inches thick) of siltstone, as shown on Figure 3-3. Because of the deeply incised rivers and streams in the Bainbridge Township area, the Cuyahoga Shale locally varies in thickness up to 165 feet. The shale beds contain little to no intergranular permeability, whereas the siltstone beds have negligible intergranular permeability. As a unit, the Cuyahoga Shale has limited fracture permeability along vertical joints and bedding planes, which facilitate seeps in outcrops along the Chagrin River (Figure 3-3) in the springtime. A sample of Cuyahoga Shale collected at the outcrop shown in Figure 3-3 (left side) was sent to Weatherford Laboratories in Houston, Texas, for preparation and lithologic characterization using a scanning electron microscope (SEM).

Figure 3-3. Resistant siltstone bed (left), vertical joints, and bedding planes at a seep (right) in outcrops of Cuyahoga Shale along the Chagrin River, Geauga Lake Road.

SEM images (Figure 3-4) show that the shale sample contains an abundance of grains coated with illitic clay, very fine-grained pyrite, and a distinct lack of pore space. The illite grains are typically about 25 µm (2.5 x 10^{-4} cm) across.

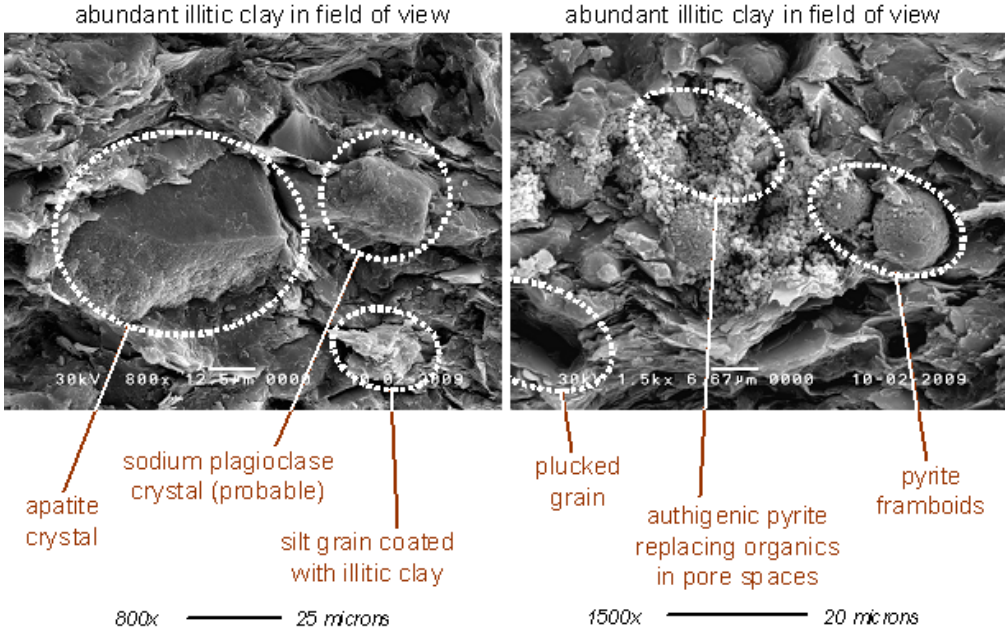

Figure 3-4. SEM images of Cuyahoga Shale showing abundant pyrite and illitic clay.

Szmuc (1970) mapped several local, sandy siltstone beds near the bottom of the Cuyahoga Shale. A sample of one of these resistant siltstone beds (yellow arrow on Figure 3-3) was sent to Weatherford Labs for thin sectioning, and permeability and porosity analyses. Table 3-1 lists the permeability and porosity values measured from this and other bedrock samples sent to Weatherford Labs. The siltstone sample from near the base of the Cuyahoga Shale had low values of intergranular permeability, 0.013 millidarcies (md), and porosity, 0.47 percent.

Table 3-1. Permeability and Porosity Data from Berea Sandstone and Other Samples

Sample	Type	Plug	County	OGS No.	Depth (feet)	Permeability (to air, md)	Porosity (percent)
Berea Sandstone							
sandstone	core	horizontal	Ashtabula	C2720	15	351	15.7
sandstone	outcrop	horizontal	Huron	-----	0	82.7	19.4
sandstone	core	vertical	Ashland	C2837	648	16.5	13.5
sandstone	core	horizontal	Ashland	C2837	648	24.0	19.9
sandstone	core	horizontal	Ashland	C2837	553	40.1	34.2
Cuyahoga Shale							
siltstone	outcrop	horizontal	Geauga	-----	0	0.013	0.47

OGS = Ohio Geological Survey, Collins Lab & Core Repository

The Berea Sandstone underlies the Cuyahoga Shale (Figures 3-1 and 3-4). Many borehole videotapes from water wells in the investigation area show a prominent, highly permeable bedding plane separating the two units. The Berea Sandstone crops out in Independence, Ohio, and locally is quarried for aggregate and building stone. It is a medium to fine-grained, well-sorted sandstone that locally varies in thickness in Bainbridge Township from 13 to 46 feet. It contains far fewer bedding planes and vertical joints than the overlying Cuyahoga Shale or the underlying Bedford and Ohio shales.

Figure 3-5 shows a thin section image of Berea Sandstone taken with a petrographic microscope. The sand-size grains are predominantly quartz (white polygons). The intergranular pore spaces are highlighted by impregnating the sample with blue epoxy. Four Berea Sandstone samples from oil and gas well cores and one outcrop sample were sent to Weatherford Labs for thin sectioning, and porosity and permeability analyses. The measured values of permeability range from 16.5 to 351 md and the porosity ranges from 13.5 to 34.2 percent (Table 3-1).

Because of its excellent porosity, high permeability, large areal extent, and thickness, the Berea Sandstone is a major aquifer throughout northeastern Ohio (Eberts and others, 1999; Jagucki and Darner, 2001). It supplies groundwater to several residential wells on Bainbridge Road and on Scotland, English, and Kingswood drives (Appendix B).

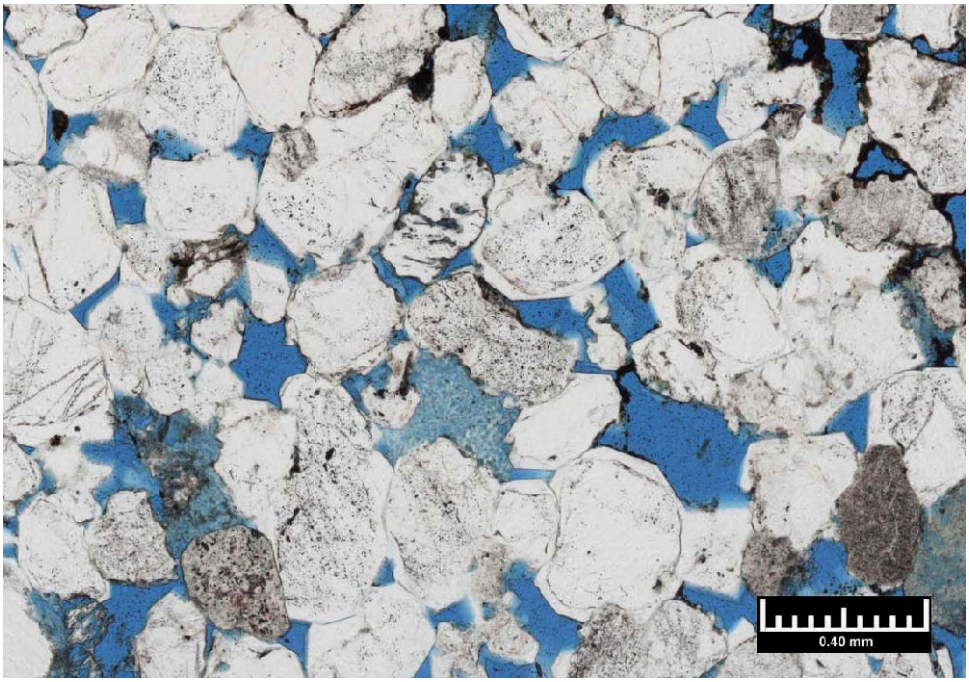

Figure 3-5. Photomicrograph of Berea Sandstone showing abundant pores (blue) and quartz grains (shades of white and light gray).

The Berea Sandstone is underlain by the Bedford Shale, which is typically about 80 feet thick in Bainbridge Township. At outcrops in Independence, Ohio, it consists of thin shale and siltstone beds cut by numerous vertical joints (Figure 3-6). Borehole videotapes show the Bedford Shale in the Adams well (17820 English Dr) and the de Gaetano well (17971 Kingswood Dr).

Figure 3-6. Outcrop of Bedford Shale in Independence, Ohio, showing thin beds of siltstone and shale and numerous vertical joints.

The Ohio Shale underlies the Bedford Shale. At the English #1 gas well, the Ohio Shale is 1,725 feet thick. A 350-foot thick section of Ohio Shale is present in the Haydite Quarry in Cuyahoga County (Figure 3-7). It contains thinly bedded shale and siltstone beds, and abundant joints.

Figure 3-7. Ohio Shale exposed in the Haydite Quarry, showing large sections of thinly bedded shale, resistant thin beds of siltstone (left), and vertical jointing (right).

Figure 8 shows SEM images of an 80-foot deep core sample of Ohio Shale from an oil and gas well (C2720) in Lake County that were sent to Weatherford Labs.

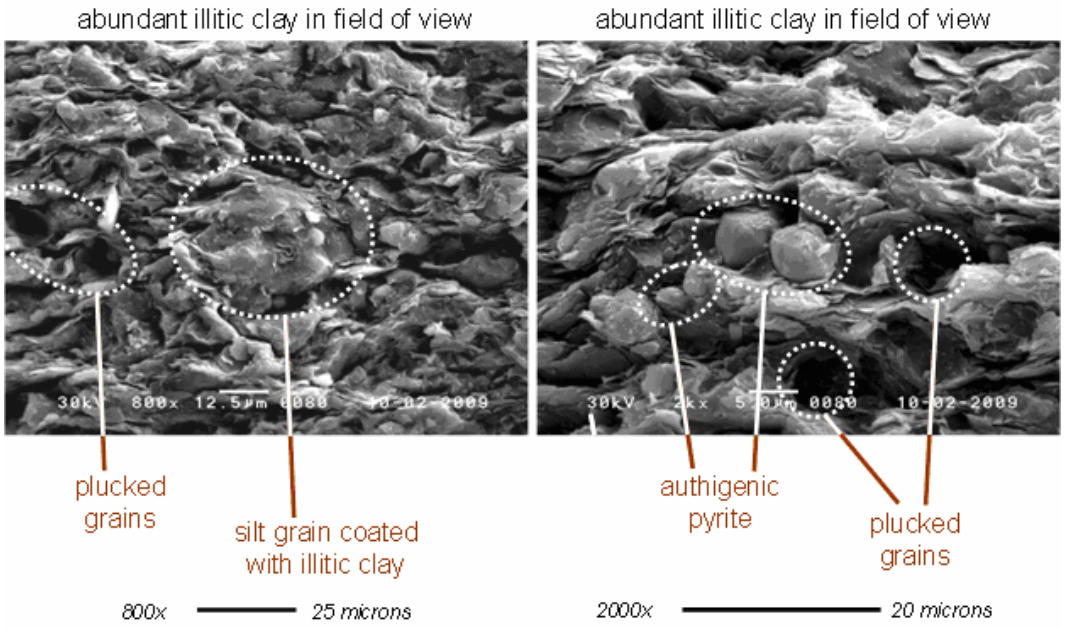

Figure 3-8. SEM images of Ohio Shale samples showing abundant pyrite and illitic clay.

Because of their great thickness and exceedingly low intergranular permeability and porosity, together the Bedford and Ohio shales act a major confining layer inhibiting groundwater flow and groundwater storage. The slow flow of groundwater and gas moving in these units is along the numerous bedding planes and vertical joints, as seen in Figures 3-6 and 3-7.

The expert panel requested that DMRM construct detailed geologic cross sections through the investigation area based on local water well logs, nearby geophysical logs from oil and gas wells, and data from borehole videotapes taken in local water wells. Figure 3-9 is a highly reduced version of Attachment 1 that shows the orientations of the geologic cross sections.

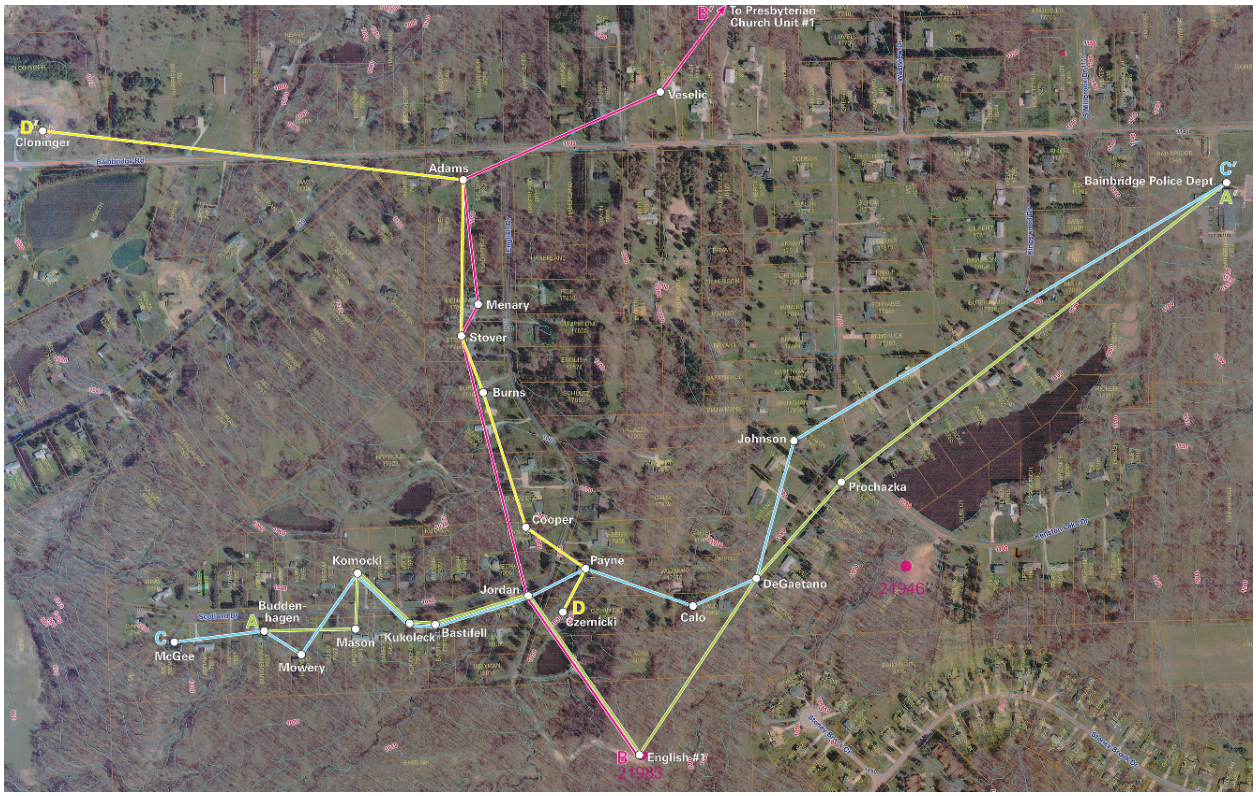

Figure 3-9. Highly reduced version of Attachment 1 – Locations of Cross Sections.

Figures 3-10 and 3-11 are highly reduced versions of Attachments 2 and 3, which are west-to-northeast and the north-to-south geologic cross sections along lines A-A′ and B-B′ respectively. The cross sections were constructed by DMRM personnel under the supervision of Dr. Bair. Attachments 2 and 3 are poster-size versions of these figures that can be downloaded from the DMRM website at www.ohiodnr.com/mineral.

Changes in the thickness of the major geologic units can be seen in these diagrams. The cross sections shown on Figures 3-10 and 3-11 (Attachments 2 and 3) were constructed using a convention commonly used in the oil and gas industry. Note that the stratigraphic sections are "hung on" (i.e. normalized to) the top of the Berea Sandstone instead of being plotted relative to surface elevation. This is done to highlight a specific geologic unit, which for our purposes is the Berea Sandstone because it acts a reservoir for the movement and temporary storage of the fugitive gas and because it is tapped by many residential wells.

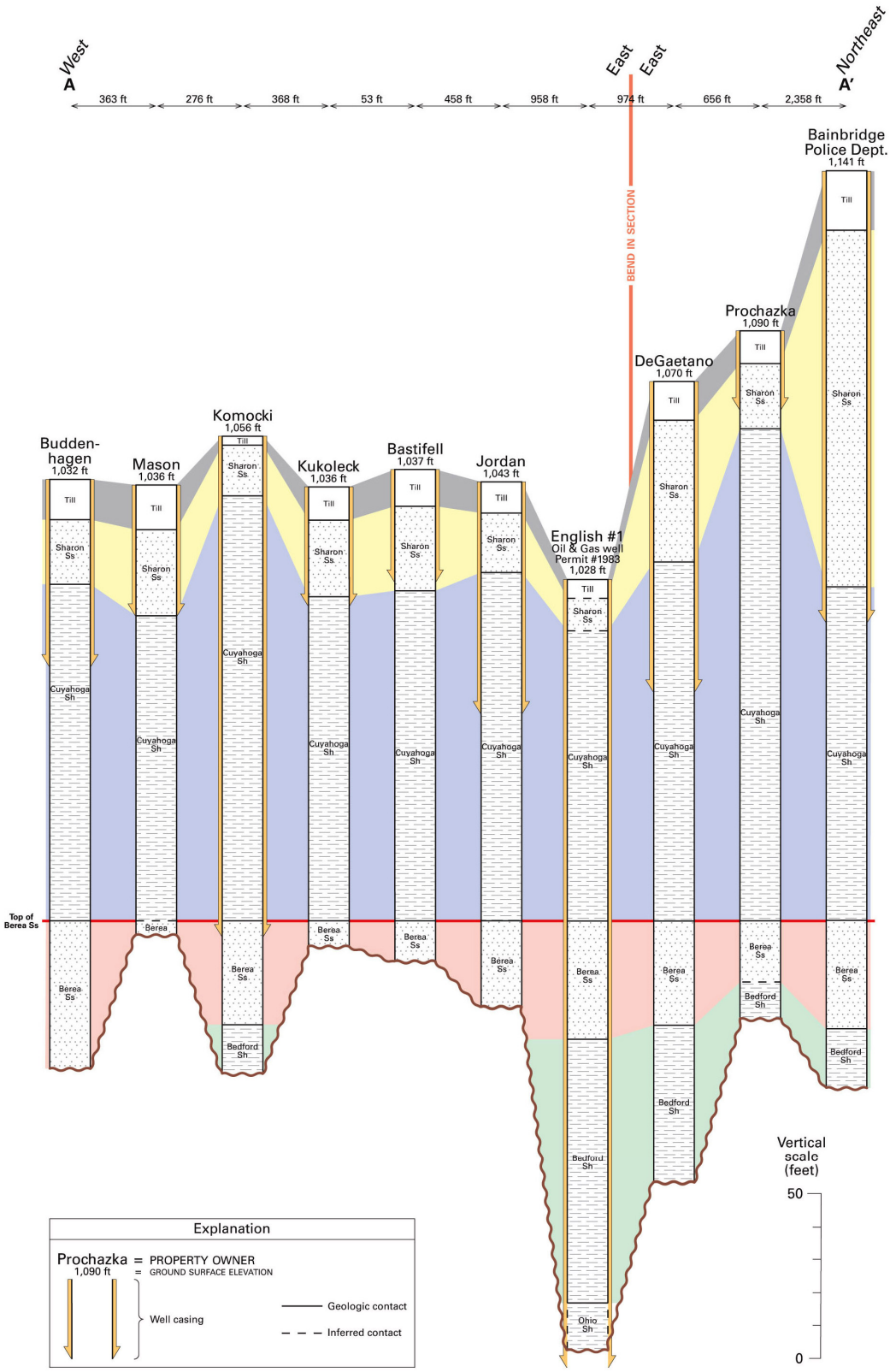

Figure 3-10. Highly reduced version of Attachment 2 – Geologic Cross Section A-A'.

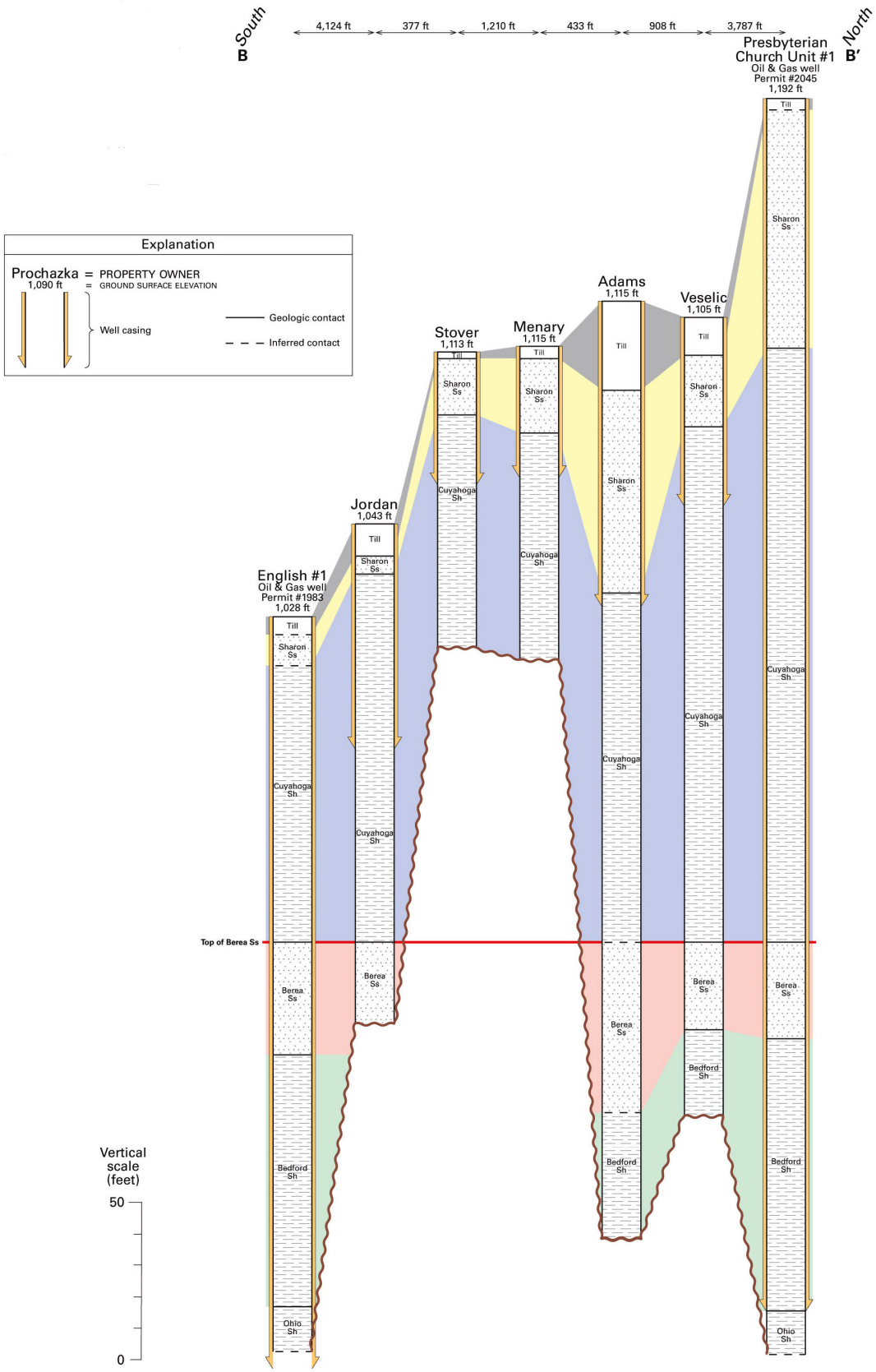

Figure 3-11. Highly reduced version of Attachment 3 – Geologic Cross Section B-B′.

The top of the Berea Sandstone is identified on Figures 3-10 and 3-11 (Attachments 2 and 3) by the thick red line. The thickness of the Berea Sandstone is highlighted by the light red background coloring. The light blue background color highlights the thickness of the Cuyahoga Shale, whereas the light green background color highlights the thickness of the Bedford and Ohio shales. The light yellow background at the top of each stratigraphic section highlights the thickness of the Sharon Sandstone, whereas the overlying light gray background shows the thickness of soil and glacial deposits. The name of each homeowner and the elevation of the wellhead are shown at the top of each well. The distance between wells is given at the top of the diagrams because the horizontal scale varies, which is typical of this manner of portraying geologic information. Figures 3-10 and 3-11 (Attachments 2 and 3) also show the length of casing in each well and the depth of the well.

Because the Berea Sandstone is the major aquifer tapped by the deeper, highly productive residential wells in the investigation area and because many of these wells experienced elevated wellhead LEL values for many, many months, the expert panel requested DMRM to construct a more detailed structure contour map of the top of the Berea Sandstone than the one in its Bainbridge investigation file, which was based solely on gamma ray logs from nearby oil and gas wells. The new map, Attachment 4, was constructed by DMRM personnel under the supervision of Dr. Bair using drillers' logs from local water wells, geophysical logs from oil and gas wells, and information from several borehole videotapes taken in water wells lacking well logs. The structure contour map shows the elevation, in feet above mean sea level, of the top of the Berea Sandstone and, by stratigraphic correspondence, the bottom of the Cuyahoga Shale. Figure 3-12 is a highly reduced version of Attachment 4, which can be downloaded from the DMRM website at www.ohiodnr.com/mineral. The contour surface is similar in character but

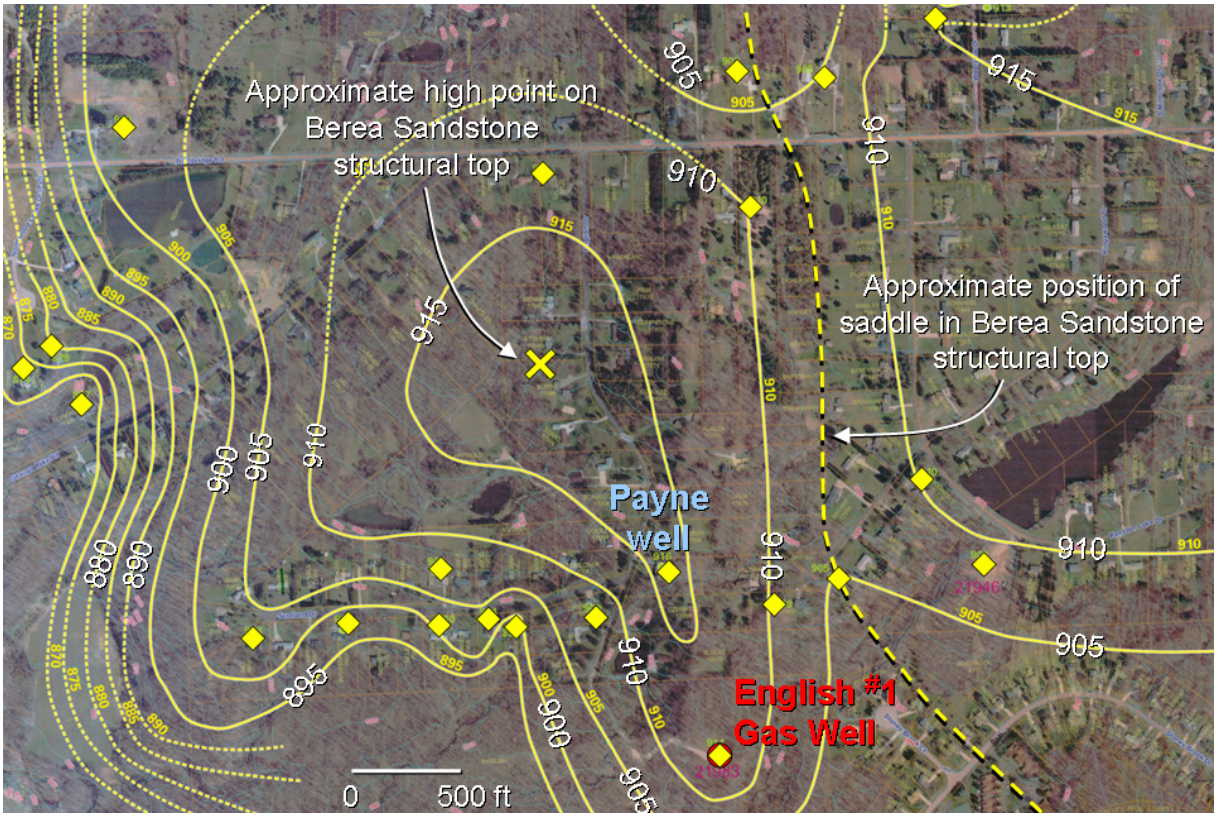

Figure 3-12. Reduced and annotated version of Attachment 4 – Structure Contour Map on Top of Berea Sandstone.