Subsurface geology for carbon storage in part of the Midwest Regional Carbon Sequestration Partnership region: Southern Michigan to West Virginia

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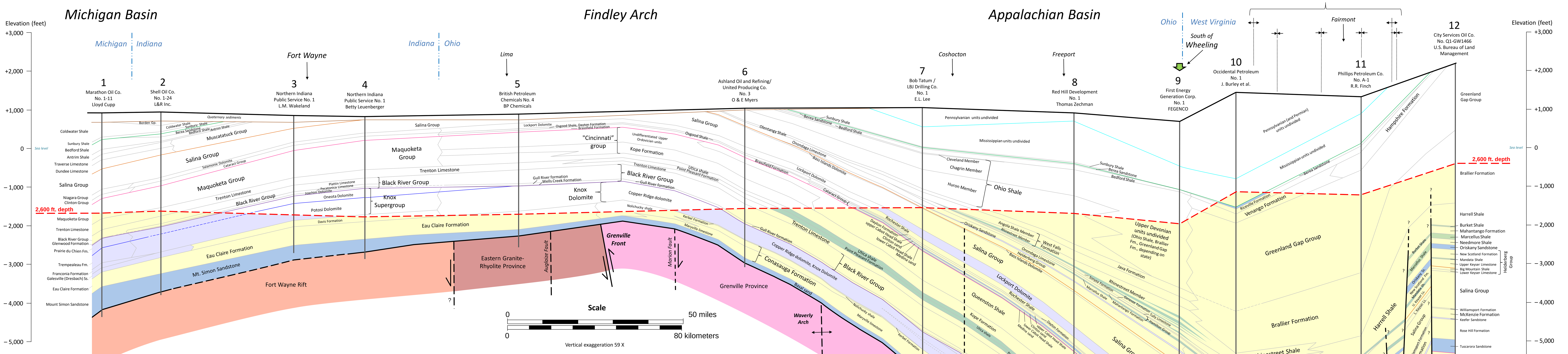
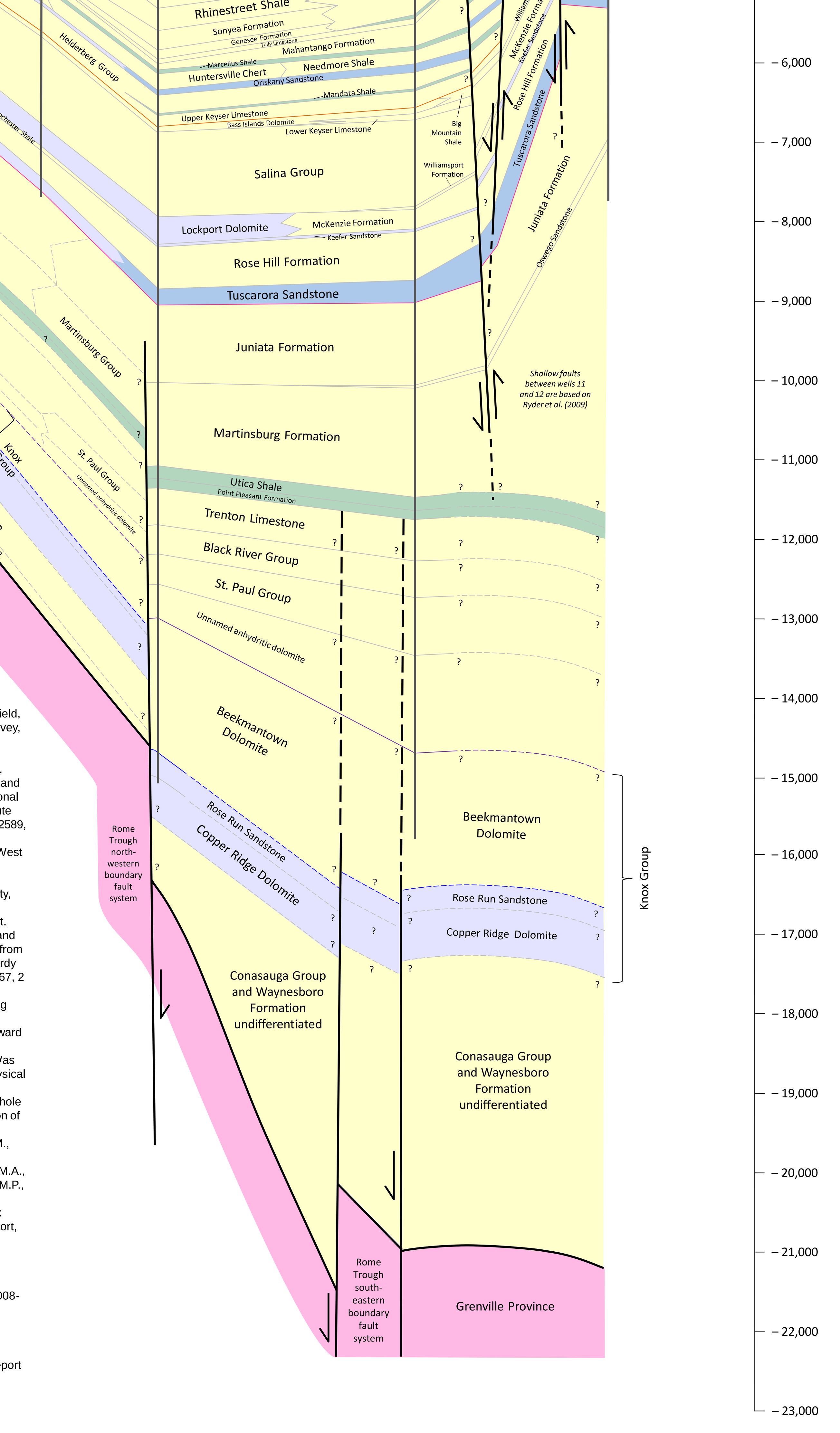
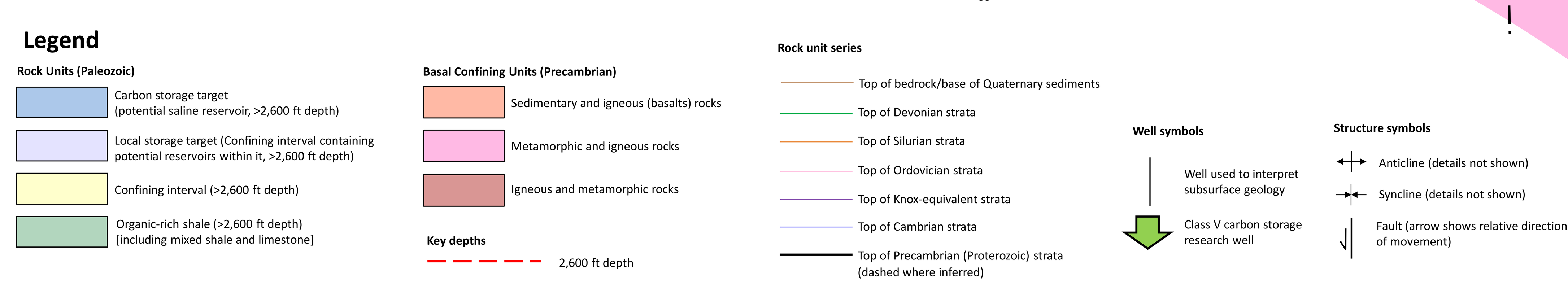
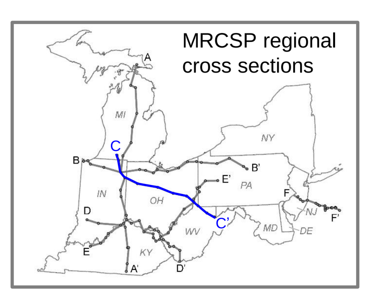
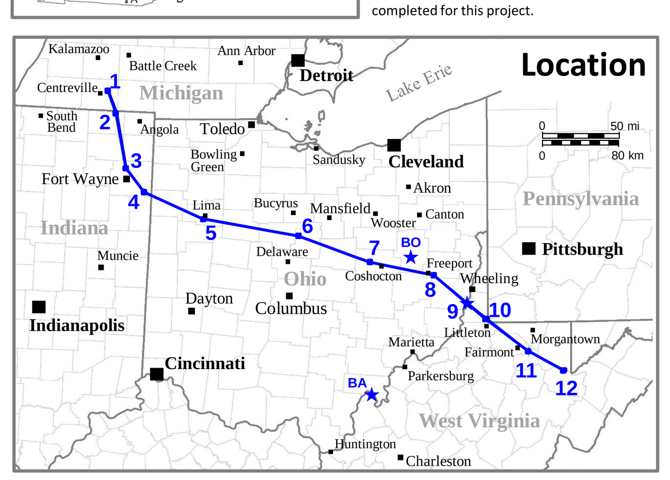




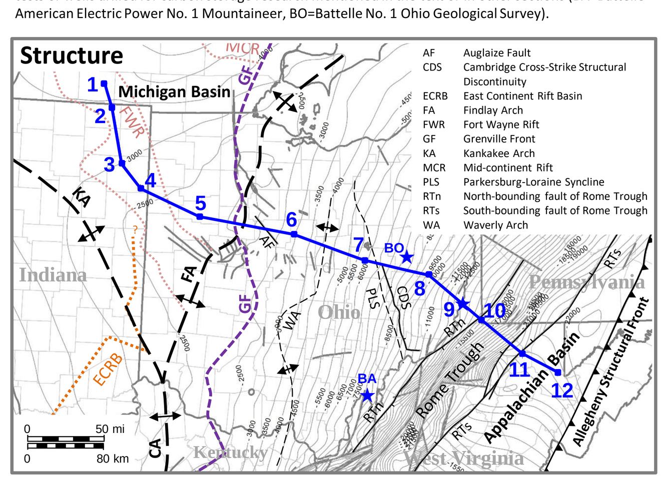




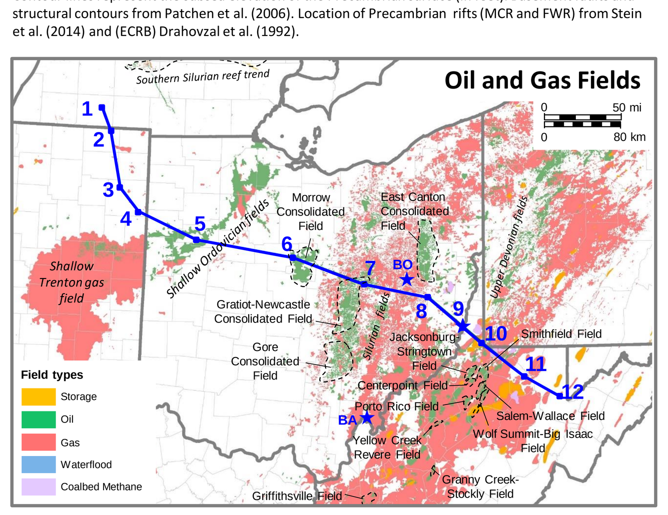
Inset map shows location of other cross sections completed for this project.



Location of wells. Numbers in blue correspond to wells on the cross section. Stars are cored stratigraphic tests or wells drilled for carbon storage research mentioned in the text or in other sections (BA=Battelle-American Electric Power No. 1 Mountaineer, BO=Battelle No. 1 Ohio Geological Survey).



Major structural features of the study area. Basement faults near the cross section are highlighted in black, otherwise they are shown in gray. Major regional structural arches and synclines are shown by dashed lines. More local arches and synclines in eastern Pennsylvania and West Virginia are not shown. Contour lines represent the subsea elevation of the Precambrian surface (in feet). Basement faults and structural contours from Patchen et al. (2006). Location of Precambrian rifts (MCR and FWR) from Stein et al. (2014) and (ECRB) Drahovzal et al. (1992).



Oil and gas fields of the study region. Text in italics identifies general interval in which fields produce. Enhanced oil and gas recovery with CO_2 may be possible in some areas (e.g., Riley et al., 2010). Specific fields mentioned in MRCSP Phase 3 reports relative to potential enhanced gas and oil recovery are labeled and outlined with dashed lines. For more information, see phase 1, 2, and 3 MRCSP reports.

Explanation

This cross section extends from the southern margin of the Michigan Basin, across the arches province of eastern Ohio, and southeastward into the Appalachian Basin in West Virginia. The section crosses through, or near, several large cities, power plants, and industrial areas with significant CO_2 emissions. Future regulations may limit carbon emissions, so it is important to understand the potential for safe geologic storage of CO_2 in the subsurface and for CO_2 use in enhanced oil and gas recovery. Geologic storage involves the capture of carbon emissions and the injection of captured CO_2 under pressure into reservoirs with sufficient seals and confining zones deep underground to prevent migration of injected CO_2 into shallower strata (e.g., NETL, 2015).

This cross section was constructed to help industry, policy makers, and the general public visualize the geology of rock units relative to subsurface carbon storage as part of the research efforts of the Midwest Regional Carbon Sequestration Partnership (MRCSP). Subsurface units in the cross section are color-coded at depths greater than 2,600 ft based on a unit's potential as a (1) storage interval (regional saline reservoir), (2) confining interval with local potential reservoirs, (3) confining zone, or (4) organic-rich shale. Units are color-coded at depths greater than 2,600 ft, which is a conservative estimate of the depth needed for CO_2 to be in a dense super-critical phase (with variation). Below this depth, natural pressures beneath the surface should be great enough to cause CO_2 to dramatically decrease in volume allowing for maximum storage capacity. This depth should also allow CO_2 to be miscible in oil, for efficient use in enhanced oil recovery.

The cross section is based on 12 deep wells, one in Michigan, three in Indiana, five in Ohio, and three in West Virginia. Deep wells with the best down-hole geophysical logs available were chosen for correlations in order to illustrate the relationship between depth and potential future carbon storage units along the section. The eastern end of the section follows part of cross section D–D' of Ryder et al. (2009), which highlighted Cambrian and Ordovician rocks in the subsurface. The current cross section shows all strata from the surface to depth. Well data used in the section are from the Indiana, Kentucky, Ohio, and West Virginia geological surveys. The FEGENCO No. 1 well (no. 9 on the cross section) was drilled by the MRCSP for CO_2-storage research. Additional CO_2 research wells in the region near the cross section are shown on the location map.

Potential carbon storage reservoirs are examined below 2,600 ft depth and above the Precambrian surface. The depth to the Precambrian surface is influenced by geologic structures, including regional basins, arches, and faults (see structure map). Fault locations and vertical extent through the Paleozoic rocks are based on regional studies by Patchen et al. (2006). Rock units shallow to the south out of the Michigan Basin above the Findlay Arch and along the Grenville Front, before deepening southeastward into the Appalachian Basin. In West Virginia, the section traverses the Rome Trough, in which thick accumulations of Cambrian sediments were deposited (Harris et al., 2004; Ryder et al., 2008, 2009).

The Cambrian Mount Simon Sandstone is thick and permeable on the western end of the cross section. It is used for industrial waste disposal near Gary, Indiana (west of South Bend on location map), and is one of the primary potential carbon storage intervals in the region (Barnes et al., 2009; Medina and Rupp, 2012; Sminchak, 2012; NETL, 2015), The Mount Simon Sandstone thins as it shallows toward the Grenville Front in western Ohio, and is correlative to the thinner basal sand in Ohio east of the Grenville Front.

East of the Findlay Arch, the section approximately parallels the dip of strata into the Appalachian Basin (see structure map), with units gradually deepening and some thickening to the east. Potential saline reservoirs for CO_2 storage in the eastern part of the section include parts of the (1) Upper Cambrian Copper Ridge Dolomite, and Rose Run Sandstone, (2) Silurian Tuscarora Sandstone, (3) Keefer Sandstone, and (4) Cataract-Medina Group (including the "Clinton" and "Medina" sand of drillers), and (5) Devonian Oriskany and (6) Berea sandstones. Information about the reservoir characteristics and carbon storage potential of these units can be found in MRCSP and other reports (Roen and Walker, 1996; Wickstrom et al., 2005; Carter et al., 2010; 2012; Riley et al., 2010; Battelle Memorial Institute, 2011a, b; Greb et al., 2012; Medina et al., 2012).

A large amount of data was collected from the Cambrian basal sandstone, Rose Run Sandstone, and overlying strata in a well drilled by the Ohio Division of the Geological Survey between wells 7 and 8 on the section (BO on location map, Wickstrom et al., 2011). Carbon storage tests in the Copper Ridge B zone and Rose Run Sandstone were conducted at the Mountaineer power plant (BA on map), south of the section (Bacon et al., 2007; 2009; Gupta et al., 2013). Deeper downdip, the FEGENCO No 1 well (no. 9 on the section) was a Class V CO_2 injection test well and one of the first wells in the region to test the potential for CO_2 storage at a coal-fired power plant (Wickstrom et al., 2008). The well found insufficient permeability for injection at depth in the Silurian-aged Clinton Sandstone, Salina Group dolomites, and Devonian-aged Oriskany Sandstone, but collected significant data on these units and their caprocks (Battelle, 2011a; Gupta et al., 2011).

In the east, the cross section is near numerous oil and gas fields. CO_2 can be used for enhanced oil recovery (EOR) in conventional reservoirs, enhanced gas recovery (EGR) in unconventional reservoirs, as well as for repressurizing depleted reservoirs (e.g., NETL, 2015), especially in hydrocarbon accumulations encountered at depths greater than approximately 2,600 ft. Although many of the fields shown on the oil and gas map produce at depths shallower than 2,600 ft, some of these fields may exhibit unique pressure and temperature conditions that promote near-miscible conditions, and several deeper fields have potential for EOR or EGR via miscible CO_2 floods. Outlined and named fields on the oil and gas map are discussed in MRCSP Phase 3 reports. The East Canton, Gratiot-Newcastle, and Gore fields have significant EOR potential (e.g., Mishra et al., 2014) from reservoirs in the Silurian Clinton-Medina interval. Small-scale field tests of CO_2 injectivity and modeling of the Silurian Clinton sands in in the East Canton Field have had positive results (Riley et al., 2009) Eastward, Devonian "Gordon sands" of the Hampshire Formation in the Salem-Wallace and Wolf Summit-Big Isaac fields, and the Mississippian "Big Injun" sand in the Centerpoint and Granny Creek fields (in undivided Mississippian units on the cross section and labeled on the inset oil and gas map) may have near-miscible CO_2 EOR potential. The Big Injun sand has safely been used for natural gas storage at relatively shallow depths in West Virginia.

Organic-rich shales (green on cross section) such as the Upper Ordovician Utica Shale, and the Devonian Mandata, Marcellus, and Burket shales may have potential for enhanced gas recovery with CO_2 (Nuttall, 2010; Patchen and Carter, 2015), but more research is needed. More information regarding CO_2 storage and enhanced oil and gas recovery opportunities in the region are available at the MRCSP website (mrcsp.org), and in published reports summarizing research (Wickstrom et al., 2005; Riley et al., 2010; Battelle, 2011b; see Phase 3 reports).

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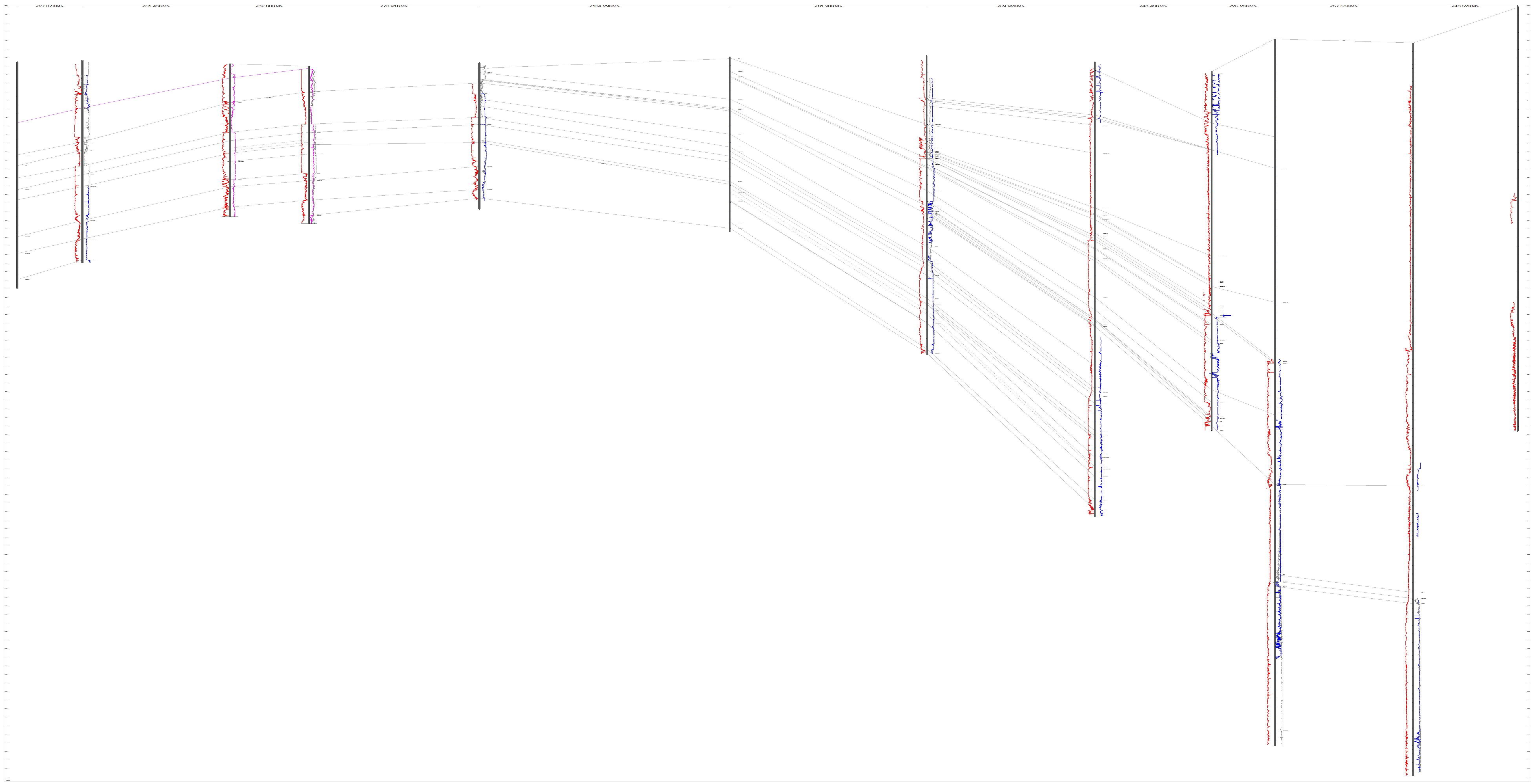

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