

Mapping Isopach and Porosity of the Silurian Lockport Dolomite in Eastern Ohio

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INTRODUCTION

The Silurian Lockport Dolomite is a fine to coarsely crystalline, fossiliferous dolostone that extends throughout the Appalachian Basin¹. The Lockport is a potential injection target for CO₂ storage in eastern Ohio and currently is used as a brine injection target in northeastern Ohio, demonstrating its storage capability².

The Lockport Dolomite is primarily dolostone, yet consists of a shaley interval at the base that grades into the underlying Clinton Group in eastern Ohio (fig. 1). The dolostone underlies an extensive anhydrite bed from the Silurian Salina Group throughout much of eastern Ohio¹. The Lockport can vary in thickness from 40 ft (12 m) to greater than 400 ft (122 m). It was deposited on a warm, broad carbonate platform, and outcrop indicates reef systems have been preserved and preferentially undergone dissolution, creating vugs concentrated throughout the reefs² (fig. 2). These reef systems present themselves in the subsurface as broad, linear thickening trends. They have the potential for CO₂ and other waste product storage in the subsurface if the porosity is present and connected. Structural influence on the formation could also present secondary porosity in the formation, creating another potential area for storage, or a leakage pathway to shallow aquifers or the surface. Detailed mapping of the thickness of the Lockport Dolomite may provide insights to movement along known structural features, as well as identification of potentially unknown structures, and porosity thickness mapping may indicate major controls on porosity.

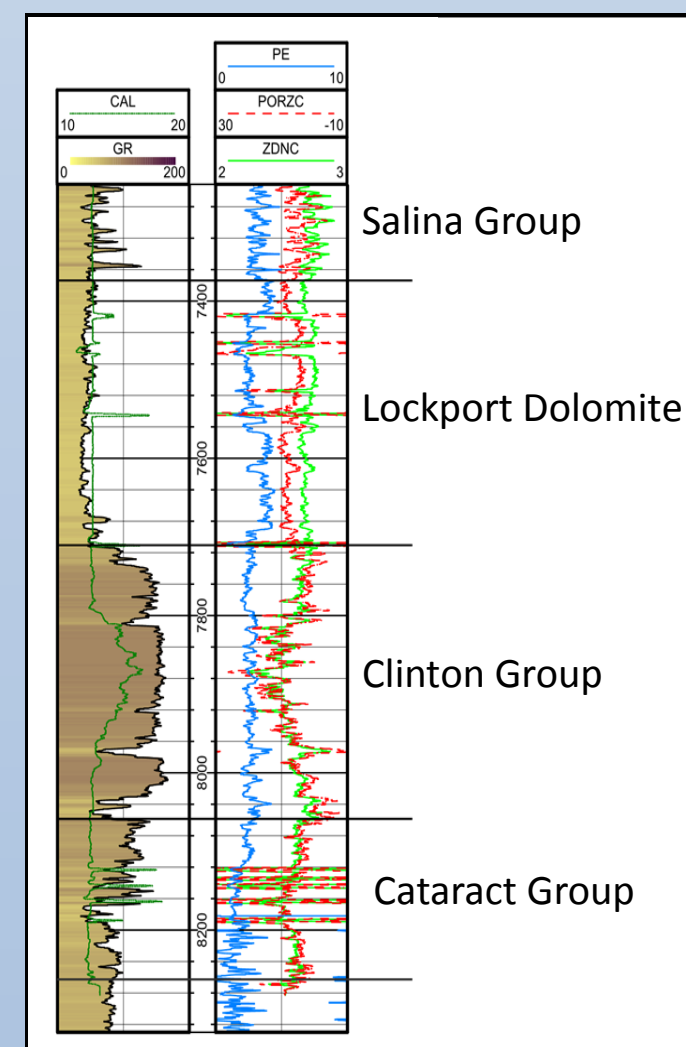


Figure 1. Type log for Cataract Group through Lockport Dolomite—GEORGETOWN MARINE (SWIW #1); Belmont County. CAL = Caliper, GR = Gamma ray, PE = Photoelectric, PORZC = Neutron porosity, ZDNC = Density.



Figure 2. Example of vuggy porosity in the Lockport Dolomite from Genoa, Ohio quarry. Hand lens for scale (approx. 5 cm in length).

METHODS

Formation tops in more than 2,200 well logs were selected using IHS Petra (fig. 1). Correlations followed Cater and others¹. Data were exported for contouring in ESRI ArcGIS. Isopach contours initially were generated using Inverse Distance Weighting and then hand edited to better reflect formation thickness distribution patterns. Sudden thickness changes were verified using well logs.

Both neutron porosity and density porosity logs were used separately to calculate the thickness of porous strata within the Lockport Dolomite in eastern Ohio. A total of 1,339 wells containing either neutron or density porosity were examined either visually, if a raster log, or automatically, if a digital LAS file, in Petra software. Porous intervals were identified, summed, and contoured initially by Kernel Smoothing in ERSI ArcGIS and then hand edited. Only wells with porosity feet values were used in contouring (111 data points for neutron porosity; 196 data points for density porosity). Neutron porosity logs typically overestimate porosity. A porosity cutoff value of 8.0% was used when the gamma ray value was 0–40 API, 10.0% when the gamma ray value was 40–60 API, and 12.0% when gamma ray value was 60–80 API. When gamma ray value was above 80 API, the neutron porosity value was considered suspect and not included in calculations. Minimum bed thickness was 2 feet. Density porosity typically reflects porosity more accurately in the absence of hydrocarbon gas compared to neutron porosity. A porosity cutoff value of 6.0% and a gamma ray value cutoff of 80 API was used for density porosity calculations. Minimum bed thickness was 2 feet.

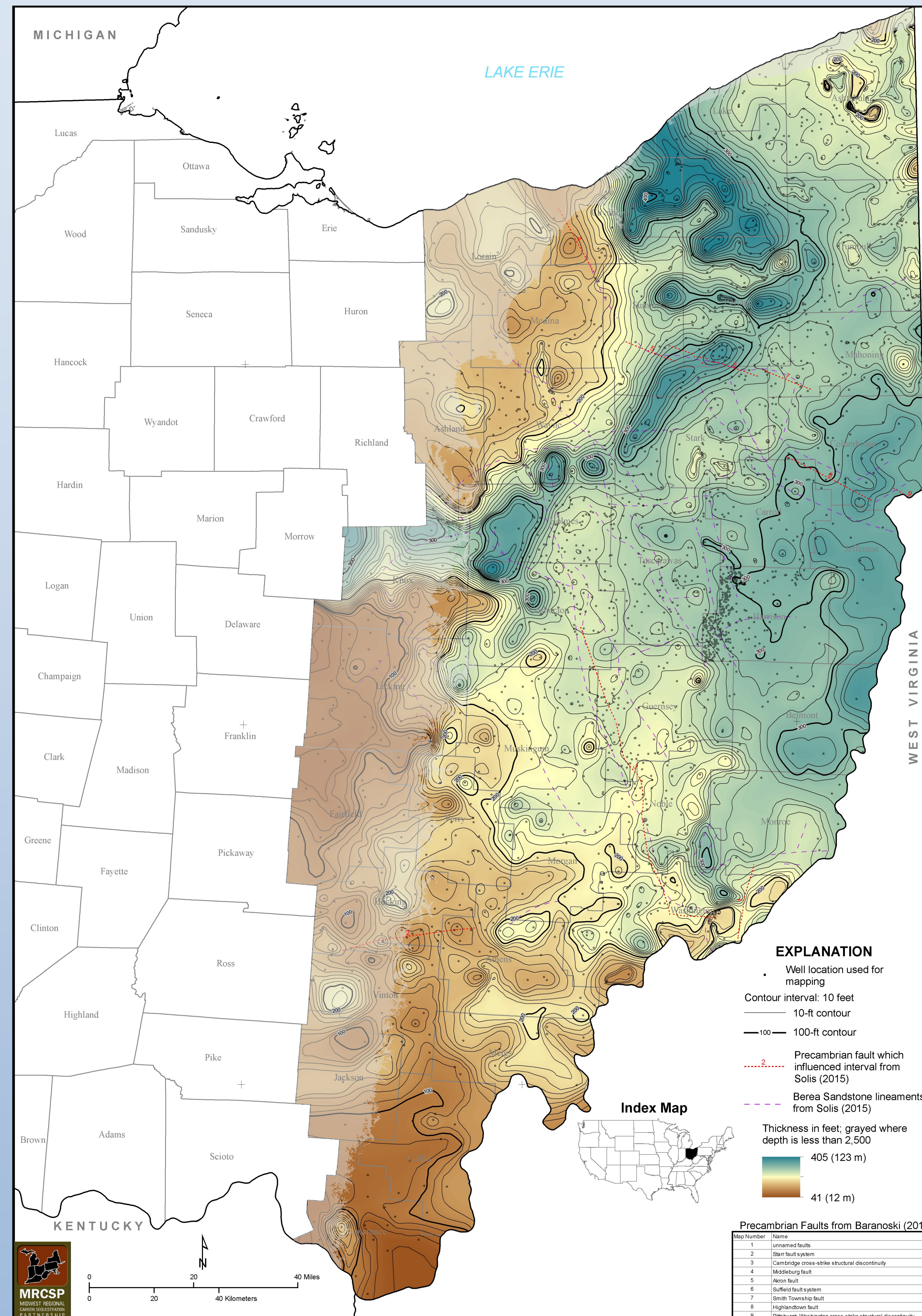


Figure 3. Isopach map of the Silurian Lockport Dolomite in eastern Ohio. Many abrupt changes in thickness correspond to known faults or lineaments (red dashed lines³), or to suggested lineaments from detailed structure mapping of the Berea Sandstone (purple dashed lines⁴)

ISOPACH MAP

An abrupt thickening is apparent from Knox to Trumbull Counties, which can be interpreted as a northeast–southwest striking reef body (fig. 3). The main body of the reef abruptly changes strike by nearly 90° to northwest–southeast within Coshocton and Knox Counties, continuing under Lake Erie. This abrupt change in strike may indicate structural influence on reef buildup during the Silurian Period. Further structural influence on the reef trend include where it is truncated in Holmes and Wayne Counties. In Trumbull County, along the Suffield fault system, the reef appears to be right laterally offset, suggesting potential small structural flexure and offset during and after deposition.

POROSITY MAPS

A zone of high porosity within the Lockport Dolomite is known in Ohio as the drillers’ “Newburg Zone” or “second water”^{5,6}. High-porosity zones within the Lockport should parallel the reef trend.

Neutron porosity (NPHI) shows large areas more than 150 ft (52 m) thick with porosity greater than 8% (fig. 4); however, many of these areas feature only a few data points so connectivity is not known. The NPHI map shows little spatial correlation between high porosity and the reef trend (figs. 1, 2), with only several small spots corresponding to the thickening of the Lockport. Structure appears to have influenced high porosity zones in the Lockport in eastern Ohio. In Holmes county, there is an area with 135 ft of porosity >8%, corresponding to the Killbuck Dome, a structural uplift originating in the Precambrian with several known episodic reactivations⁷. To the north in Cuyahoga County, the high-porosity thickness zone corresponds with the Middleburg fault, along with zones towards the south in Guernsey County corresponding to the Cambridge cross-strike structural discontinuity and the Starr fault system in Hocking County.

The DPHI map shows several areas with greater than 50 ft (15 m), and up to 89 ft (27 m) of porosity thickness greater than 6% (fig. 5). High-porosity areas within the DPHI map are also independent of the reef trend and consistent with areas of suspected structural influence.

CONCLUSIONS

Pre-existing crustal weaknesses appear to have reactivated during various tectonic events during the Appalachian orogeny⁸. Although Ohio was far from the loci of crustal loading, evidence points to fault reactivation coincident with Appalachian loading within the state, suggesting far-field tectonics throughout the basin^{7,9,10}. These reactivations resulted from movement of pre-existing crustal weaknesses during peripheral foreland basin bulge migration and changing stress directions during the Appalachian orogeny.

Because the structure of Ohio is subtle, sudden thickness changes (fig. 3) or unexplained areas of porosity (figs. 4, 5) provide further evidence of a more complicated structure and geologic history than previously thought. Further high-spatial resolution mapping may show that the abrupt changes in thickness or porous zones in the Lockport Dolomite correspond with abrupt changes in thickness or anomalous characteristics in other formations, indicating recurrent motion along faults during different time periods. At this time, the origins of suspected Paleozoic structural fabrics are not well understood. However, the occurrence of changing thicknesses incident to the Berea Sandstone lineaments⁴ (fig. 3) suggest unmapped faults may disrupt the Silurian Lockport Dolomite and potentially extend further throughout the section. With a lack of seismic coverage throughout Ohio, detailed correlation and isopaching of the Paleozoic section may be more useful recognizing unknown faults than mapping surfaces.

Furthermore, subsurface structure in Ohio should be carefully characterized during site selection for CO₂ injection, as unknown structures could help or hinder storage efforts.

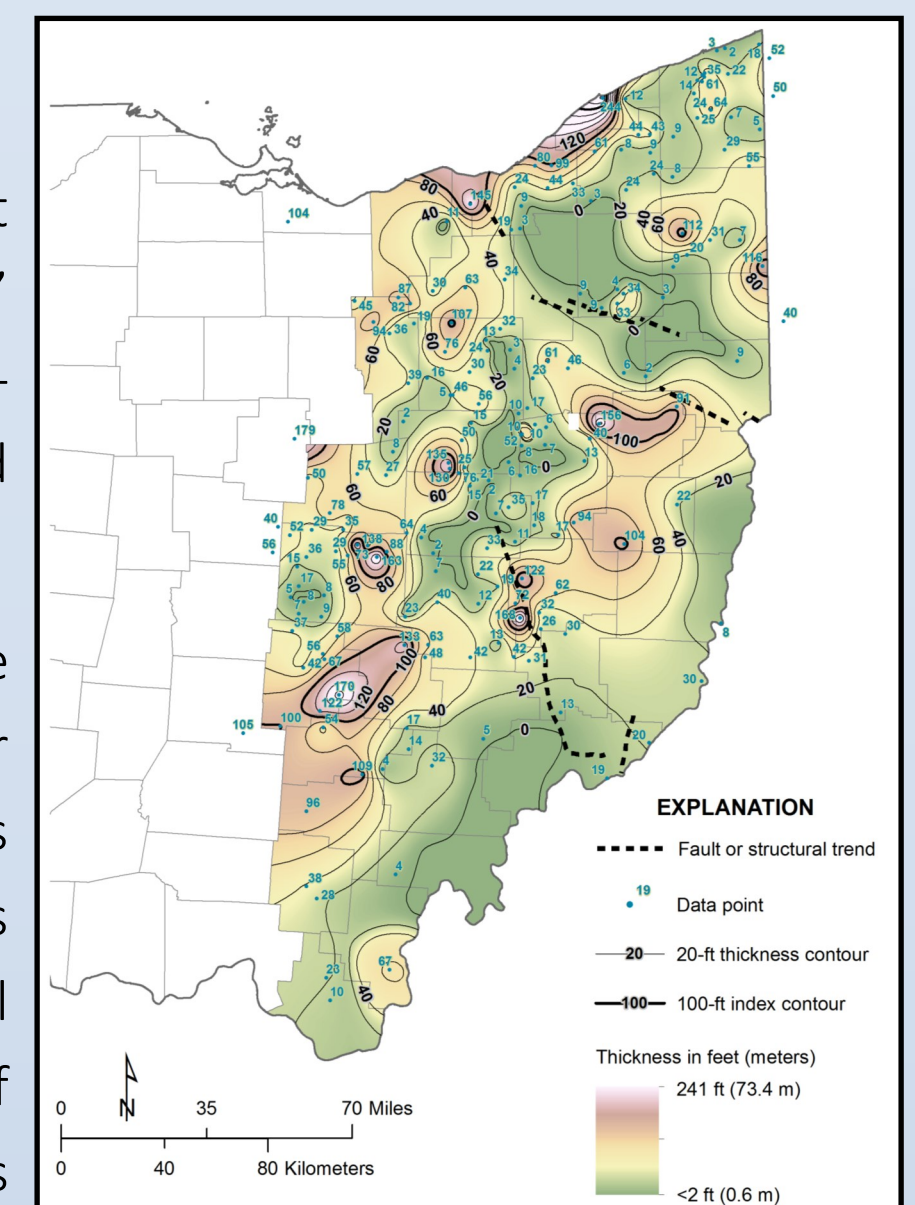


Figure 4. Porosity thickness map using neutron porosity (NPHI) geophysical log.

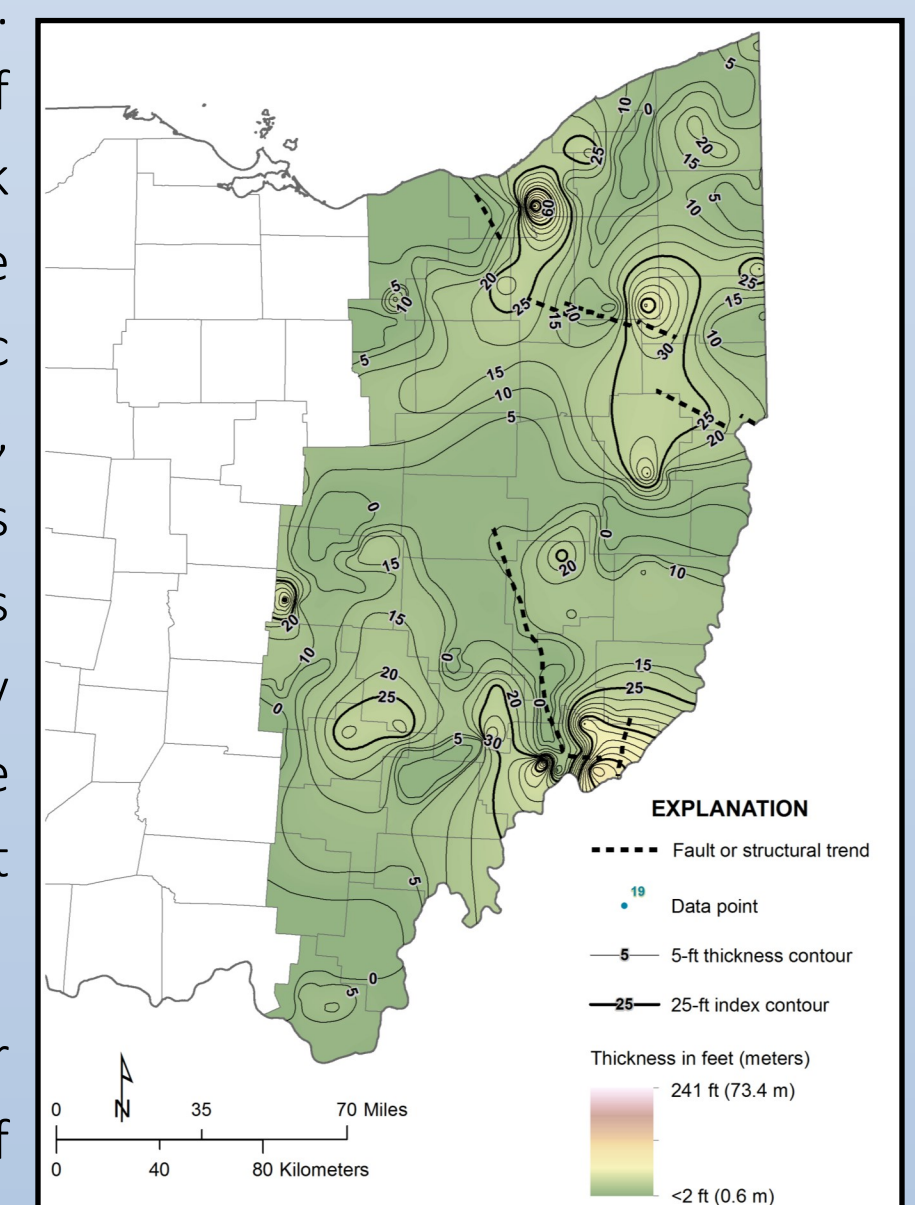


Figure 5. Porosity thickness map using density porosity (DPHI) geophysical log. Thickness ranges from 2 to 89 ft (0.6–27 m). Range of colors was selected for easy comparison to the neutron porosity map (fig. 3).

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