

SUBSURFACE STRUCTURE AND ISOPACH MAPPING OF THE BLACK HAND MEMBER OF THE CUYAHOGA FORMATION

by
Erika M. Danielsen & Samuel R. W. Hulett

Open-File Report 2020-2
Columbus 2020



DISCLAIMER

The information contained herein has not been reviewed for technical accuracy and conformity with current ODNR Division of Geological Survey standards for published or open-file materials. The ODNR Division of Geological Survey does not guarantee this information to be free from errors, omissions, or inaccuracies and disclaims any responsibility or liability for interpretations or decisions based thereon.

CARTOGRAPHY: Dean R. Martin

GRAPHIC DESIGN & LAYOUT: Jeremy E. Gladden

EDITING: Anthony J. Bresnen

RECOMMENDED CITATION:

Danielsen, E.M., and Hulett, S.R.W., 2020, Subsurface structure and isopach mapping of the Black Hand Member of the Cuyahoga Formation: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Open-File Report 2020-2, 11 p., 2 plates.

CONTENTS

Abstract	1
Introduction	1
Stratigraphic background	1
Previous maps of the Black Hand Member	2
Methods	2
Results	3
Discussion	3
Conclusions	5
Acknowledgements	5
References cited	11

FIGURES

1. Generalized nomenclature for Upper Devonian to Lower Pennsylvanian strata in eastern Ohio	1
2. Map of Black Hand Facies from Ver Steeg (1947)	3
3. Map of Black Hand Member subsurface extent with lines for stratigraphic cross sections and well locations	4
4. Geophysical well log in the Black Hand type area	5
5. Stratigraphic cross section A-A'	6
6. Stratigraphic cross section B-B'	7
7. Stratigraphic cross section C-C'	8
8. Stratigraphic cross section D-D'	9
9. Stratigraphic cross section E-E'	10

PLATES

1. Subsurface structure-contour map on top of the Black Hand Member of the Cuyahoga Formation in Ohio	13
2. Subsurface isopach map of the Black Hand Member of the Cuyahoga Formation in Ohio	14

ABBREVIATIONS USED IN THIS REPORT

Units of Measure

Foot/feet ft
Kilometer(s) km
Meter(s) m
Mile(s) mi

Other

Underground source(s) of drinking waterUSDW

Subsurface Structure and Isopach Mapping of the Black Hand Member of the Cuyahoga Formation

By
Erika M. Danielsen and Samuel R.W. Hulett

ABSTRACT

New maps of the Black Hand Member of the Cuyahoga Formation in Ohio were added to the growing database of subsurface units mapped by the Ohio Department of Natural Resources (ODNR), Division of Geological Survey. The Black Hand is a Mississippian sandstone unit that crops out in central Ohio and is one of the deepest underground sources of drinking water (USDW) in east-central Ohio. In drilling reports, the Black Hand and other Mississippian–Pennsylvanian sandstones were frequently referred to as the same rock unit, the “Big Injun.” Consequently, older subsurface studies of Mississippian and Pennsylvanian strata typically produced maps of the “Big Injun,” as opposed to the Black Hand Member as it is defined at the surface. The focus of this project was to map the full extent of the Black Hand in the subsurface and distinguish it from other “Big Injun” sandstone units.

Structure contours on the top of the Black Hand and an isopach map were generated using 993 geophysical well logs. The structure-contour map covers more area than previous studies and shows newly mapped areas possibly influenced by Precambrian basement faults. The isopach map of the Black Hand shows the unit thinning to the east and highlights some of the stratigraphic complexities of the Cuyahoga Formation in the southwestern map area. The new top structure and isopach maps complement the basal structure contours created for the Ohio USDW map and provide a new tool for regional aquifer analysis.

INTRODUCTION

The Black Hand Member of the Cuyahoga Formation, also known as the Black Hand Sandstone, is exposed in a 84-mi (135-km) outcrop belt across central Ohio from Hocking County to Knox County. The scenic cliffs of the Hocking Hills region and Black Hand Gorge are formed from the Black Hand Member. These prominent exposures were the subject of several early studies on Mississippian stratigraphy in Ohio (e.g., Hicks, 1878; Prosser, 1901; Hyde, 1915; Holden, 1942). East of the outcrop area, the Black Hand dips into the subsurface, where it has been identified as an aquifer and the deepest underground source of drinking water (Riley, 2012).

Ver Steeg (1947) was the first to publish a detailed map of the Black Hand in the subsurface, correlating the Black Hand to the “Big Injun” sandstone, an informal subsurface unit used in drillers’ logs. More localized studies of the Black Hand have since demonstrated that the “Big Injun” is not equivalent to the Black Hand everywhere (Wolfe and others, 1962; Norris and Mayer, 1982; Majchszak, 1984; Matchen and Kammer, 2006). Updated structure-contour and isopach maps of the Black Hand Member in the subsurface are presented in this report. Geophysical well logs were utilized for correlation to define the extent and thickness of the Black Hand and distinguish it from the “Big Injun” where necessary. This report details the methodologies and assumptions used to create the new maps and includes a brief discussion on geologic insights and potential map interpretations.

Stratigraphic Background

Lower Mississippian strata in eastern Ohio represent part of the final influx of sediment from the Acadian highlands into the Appalachian Basin (Pashin and Ettensohn, 1995; Ettensohn and

others, 2002). The Devonian–Mississippian boundary sits on or near the top of the Berea Sandstone (Ettensohn and others, 2002), which caps the underlying Devonian shale sequence. In eastern Ohio, the Mississippian is primarily represented, in ascending order, by the Sunbury Shale, Cuyahoga Formation, Logan Formation, and in parts of southeastern Ohio, the Maxville Limestone (Hyde, 1915; Holden, 1942; Wolfe and others, 1962; Scatterday, 1963). This is overlain by the Sharon sandstone/conglomerate of the Lower Pennsylvanian Pottsville Group, marking the major hiatus at the Mississippian–Pennsylvanian boundary (e.g., Evans, 2004; fig. 1).

System	Series	Lithostratigraphy
Penn.	Lower	Sharon ss/cong (Pottsville Group)
	Upper	Maxville Limestone Rushville Sh Vinton Member Allensville Member Byer Member Berne Member
Mississippian	Lower	Logan Formation Cuyahoga Formation Sunbury Shale Black Hand Mbr
	Upper	Berea Sandstone Bedford Shale

FIGURE 1. Generalized nomenclature for Upper Devonian to Lower Pennsylvanian strata in eastern Ohio. The Cuyahoga Formation contains numerous members depending on location, facies, and interpretation. Dev. = Devonian, Penn. = Pennsylvanian. Modified from Slucher (2004).

The Cuyahoga and Logan Formations are composed primarily of fine-grained marine sandstones and shales with occasional coarser-grained sandstones and conglomerates. The Black Hand, where present, is the uppermost member of the Cuyahoga Formation. The name “Black Hand” was first used by Hicks in 1878 to describe the sandstones and conglomerates at Black Hand Gorge, near the village of Hanover in Licking County. Prosser (1901) formally designated the Black Hand as a formation, and Hyde (1915) reclassified the Black Hand as a member of the Cuyahoga Formation. In its type area, the Black Hand is a cross-bedded, medium- to coarse-grained, quartz-rich sandstone with conglomeratic lenses. Depending on geographic location, it is underlain by finer-grained sandstones and shales of various members of the Cuyahoga Formation. Overlying the Black Hand is the Berne Member of the Logan Formation. In the Black Hand type area, the Berne is a thin (1- to 2-ft-thick) pebble conglomerate, though it apparently reaches thicknesses up to 30 ft (10 m) with varying lithologies in other locations (Hyde, 1915; Wolfe and others, 1962). Most recent research interprets the Black Hand as representing either the upper Kinderhookian or lower Osagean Stages (Matchen and Kammer, 2006).

Previous maps of the Black Hand Member

The geologic maps of Hyde (1915) and Holden (1942) are some of the earliest maps of the Cuyahoga Formation and the Black Hand Member. These maps defined surface extents and outcrop areas for both units and focused on delineating facies relationships within the Cuyahoga Formation. Ver Steeg (1947) produced the first unit extent and isopach maps of the Black Hand that included data from both outcrop and the subsurface. Following Hyde (1915) and Holden (1942), Ver Steeg (1947) also mapped several facies of the Black Hand in and around its outcrop area. With the addition of subsurface data from driller’s logs, Ver Steeg (1947) identified a “Big Injun Facies” in the subsurface of easternmost Ohio, a sand body that was disconnected from, yet correlative to, the Black Hand Member (fig. 2).

Majchszak (1984) produced the first isopach and base-structure maps of the “Big Injun” and possible Black Hand equivalents using geophysical logs from oil-and-gas wells. His study area covered Guernsey, Muskingum, Coshocton, and southern Tuscarawas Counties. Majchszak determined the “Big Injun Facies” of Ver Steeg (1947) was not correlative to the Black Hand (Mississippian) but rather to the Sharon sandstone/conglomerate (Pennsylvanian), which limited the eastern extent of the Black Hand to the western edges of Coshocton and Muskingum Counties. Matchen and Kammer (2006) produced an isopach map through central Ohio for their study of the depositional system and sequence stratigraphic implications of the Black Hand. This map restrains the eastern extent of the Black Hand slightly farther west than that of Majchszak (1984).

Previous structure-contour maps on the top of the Black Hand are found in more local studies. Wolfe and others (1962) studied the Black Hand in detail for their work on the geology of Fairfield County and produced a structure-contour map on the Black Hand

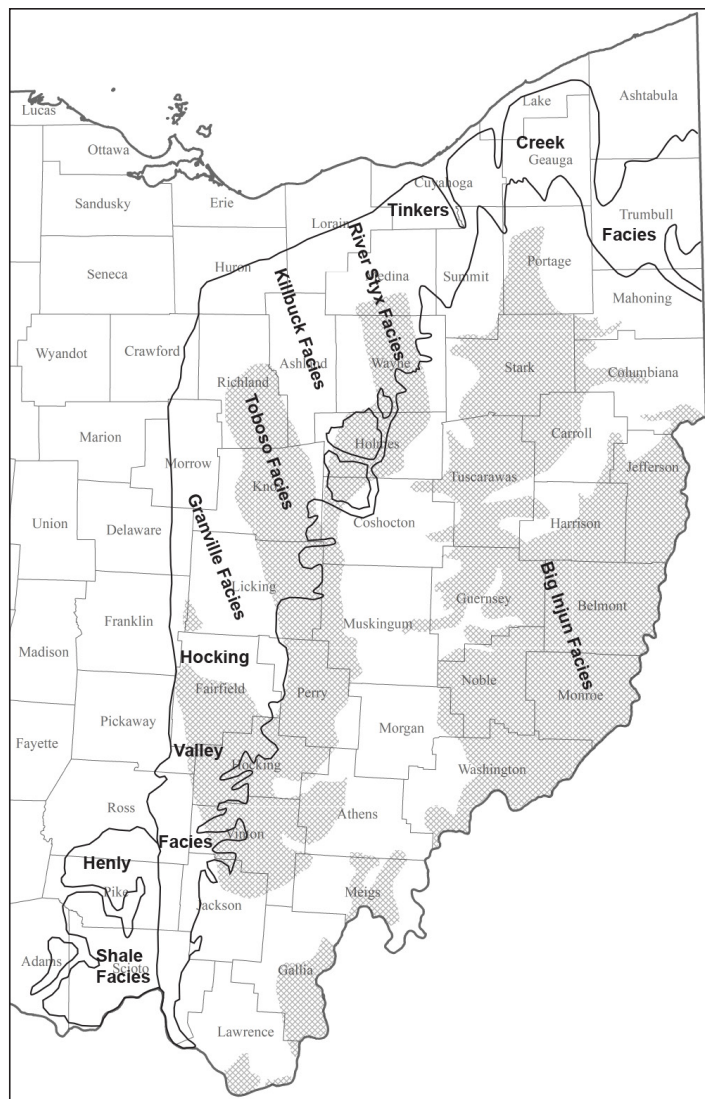


FIGURE 2. Map showing Black Hand facies of Ver Steeg (1947). Shaded areas represent the conglomerate facies; thicker black line represents the outcrop facies largely based off of Holden (1942). Figure modified from Ver Steeg (1947, fig. 3).

using outcrop data. Norris and Mayer (1982) combined the map of Wolfe and others with water well log data to map the top of the Black Hand in Vinton, Hocking, southern Fairfield, and southern Perry Counties for a study on the water resources of the Black Hand. In addition, the ODNr Division of Geological Survey published an elevation map of the deepest underground sources of drinking water (USDW) across most of the state (Riley, 2012). Part of this map included structure contours on a large portion of the base of the Black Hand. Hydrogeologic properties were considered when mapping the extent of the Black Hand for the USDW map, therefore it may not represent the true lithostratigraphic boundaries, and their interpretations of the upper and lower contacts differ from this report.

METHODS

Geophysical logs from oil-and-gas wells across central and eastern Ohio (tan-shaded area, plates 1, 2) were analyzed to identify the Black Hand Member in the subsurface. The Black Hand is not

a target for oil or gas production in Ohio; therefore, it is frequently scanned with geophysical tools through surface casing, and typically, only gamma-ray logs are available for use. The base of the Black Hand is not well exposed in the type area, and ODNR Division of Geological Survey records document no core and only a few wells with cuttings through the Black Hand. Therefore, logs from wells within 1–1.5 mi (1.6–2.4 km) of known outcrop in the type area were relied on for surface-to-subsurface correlation (figs. 3, 4). The lithology of the Black Hand and the overlying Logan Formation were field verified in the type area, and formation tops were picked in nearby gamma-ray logs. The consistency between the gamma-ray signatures allowed for a very confident assumption that the entirety of the Black Hand Member can be identified in the subsurface. Correlations were extended outward from the type area using the top of the widespread and lithologically distinct Berea Sandstone as a stratigraphic datum. A lithostratigraphic definition of the Black Hand was followed, so only cleaner sandstone (low gamma-ray value) signatures were identified as Black Hand.

All picks and correlations were made using Petra[®] software by IHS. Well data and formation tops were then exported from Petra[®], and the maps were made using ArcGIS[®] software by ESRI. The isopach was mapped using inverse distance weighting geostatistical analysis, and the structure contours were mapped using Kriging geostatistical analysis. The output raster datasets for both maps were contoured with the contour tool and then hand edited to remove irregularities. The raster datasets and contours were then clipped to a digital elevation model of the bedrock surface. The locations where the top of the Black Hand intersects the surface is an estimation and was not verified with field mapping.

RESULTS

The base and top of the Black Hand were identified in 839 wells. The subsurface extent of the Black Hand was constrained using logs from 993 wells. The top of the Black Hand ranges in elevation from –643 to 1,281 ft (–195 to 390 m) relative to sea level, with higher elevations in the west and lower elevations to the east (plate 1). On average, the Black Hand strikes northeast–southwest and dips less than one degree to the southeast. The thickness of the Black Hand ranges from 0 to 497 ft (plate 2). In the type area, the Black Hand is approximately 250 ft thick. This trend persists to the north until the Black Hand pinches out or crops out in Ashland and Wayne Counties and to the south, where the Black Hand thickens considerably in Hocking, Vinton, and southern Fairfield Counties. The Black Hand thins abruptly to the east in a north–south trend from Vinton County to Coshocton County (figs. 5–9). This thinning occurs where the lower portion of the Black Hand Member transitions to a more shaly or silty facies (fig. 8) and eventually pinches out to the east (fig. 6). The western boundary is located where the top of the Black Hand intersects the surface. The northern boundary is a combination of facies changes and outcropping, and the southern boundary is the extent of reliable subsurface data.

DISCUSSION

The new structure contours generally agree with previously published maps that depict the top of the Black Hand (Wolfe and others, 1962; Norris and Mayer, 1982). While general elevation trends are similar, there is variation between the new structure contours and previously published contour maps due to differences in data type and data density. Previous structure-contour maps were created using primarily outcrop and water well log data, and at most covered smaller areas of a few counties.

The new structure-contour map covers a much larger area, and regional trends that possibly result from movement along basement faults are revealed. In southern Hocking and northern Vinton Counties, a structural low between the 500- and 700-ft contours could be a result of deformation from the Starr Fault System (Brannock, 1993; Baranoski, 2013). The structural low found from western Coshocton County through northern Holmes County is likely part of the Parkersburg-Lorain Syncline (Baranoski, 1993; Baranoski, 2013), which also is expressed at the surface in the Paleozoic sedimentary strata west of the Cambridge Arch in southeastern Ohio, as shown on the state bedrock map (Slucher and others, 2006). The new Black Hand structure contours do not extend far enough west to show influence from the Cambridge Arch.

The overall pattern and general thickness trends of the Black Hand Member isopach contours agree with previously published maps (Ver Steeg, 1947; Majschzak, 1984; Matchen and Kammer, 2006). East of the 100-ft contour, the thickness trends differ from the maps of Ver Steeg (1947) and Majschzak (1984) because they mapped the “Big Injun” rather than the Black Hand. We interpret the Black Hand in western Coshocton and Muskingum Counties as being much thinner than the “Big Injun.” Matchen and Kammer (2006) interpreted the Black Hand as pinching out entirely in eastern Coshocton, Muskingum, and Morgan Counties. The new isopach map shows abrupt thinning in that location, but the Black Hand continues farther east (figs. 6, 7).

The most anomalous area on the new isopach map is in southern Fairfield, Vinton, and Hocking Counties, where the Black Hand reaches a thickness of nearly 500 ft (150 m) (fig. 9). In this area, Hyde (1915) named the interbedded sandstones and shales below the Black Hand the Fairfield Member of the Cuyahoga Formation; however, it is debated if this is a distinguishable unit. Outcrop data has been used to argue both for and against a Fairfield Member (Hyde, 1915; Wolfe and others, 1962; Matchen, 2004; Matchen and Kammer, 2006), and there is no reliable surface-to-subsurface correlation in the southern part of our mapping area to determine if these units are identifiable or distinguishable in the subsurface. We followed Wolfe and others (1962) and consider the Fairfield Member of Hyde (1915) to be part of the Black Hand Member. Matchen and Kammer (2006) separated the units, and this distinction caused the thicknesses in the southwestern portion of their contour map to differ considerably from our contour map. In addition, Wolfe and others (1962) discussed in detail how the lower boundary of the Black Hand in Fairfield County is not easily traceable, owing to the intertonguing of the Black Hand with the

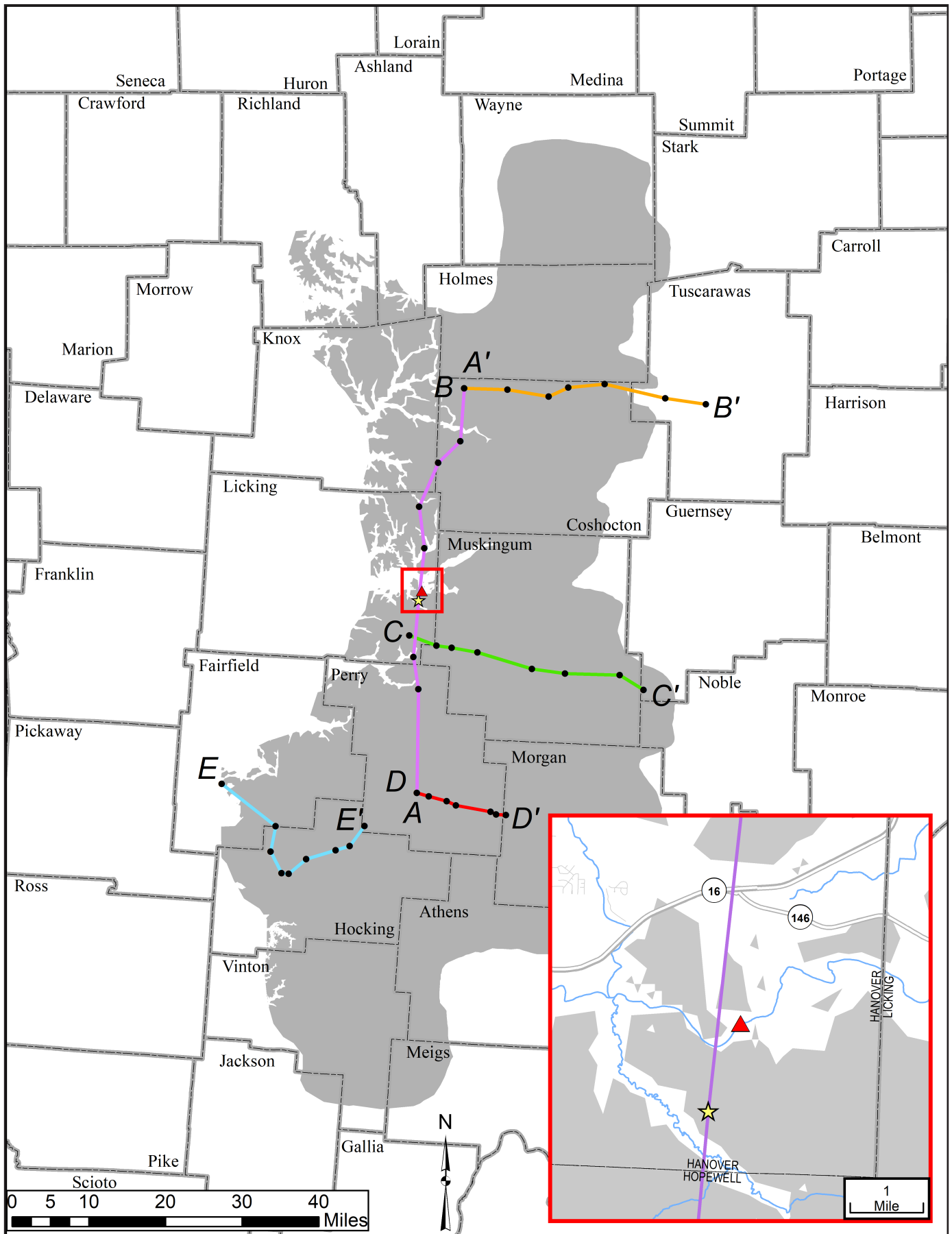


FIGURE 3. Map showing extent of the Black Hand Member in the subsurface, with lines for stratigraphic cross sections and well locations (figs. 5–9). Inset: map of the Black Hand Member type area in Hanover Township, Licking County. The red triangle marks the location of “Black Hand Rock,” an outcropping of the Black Hand along the banks of the Licking River at Black Hand Gorge. The yellow star marks the location of well API 34089227960000 (fig. 4).

Licking Co.
Spittler #1
34089227960000

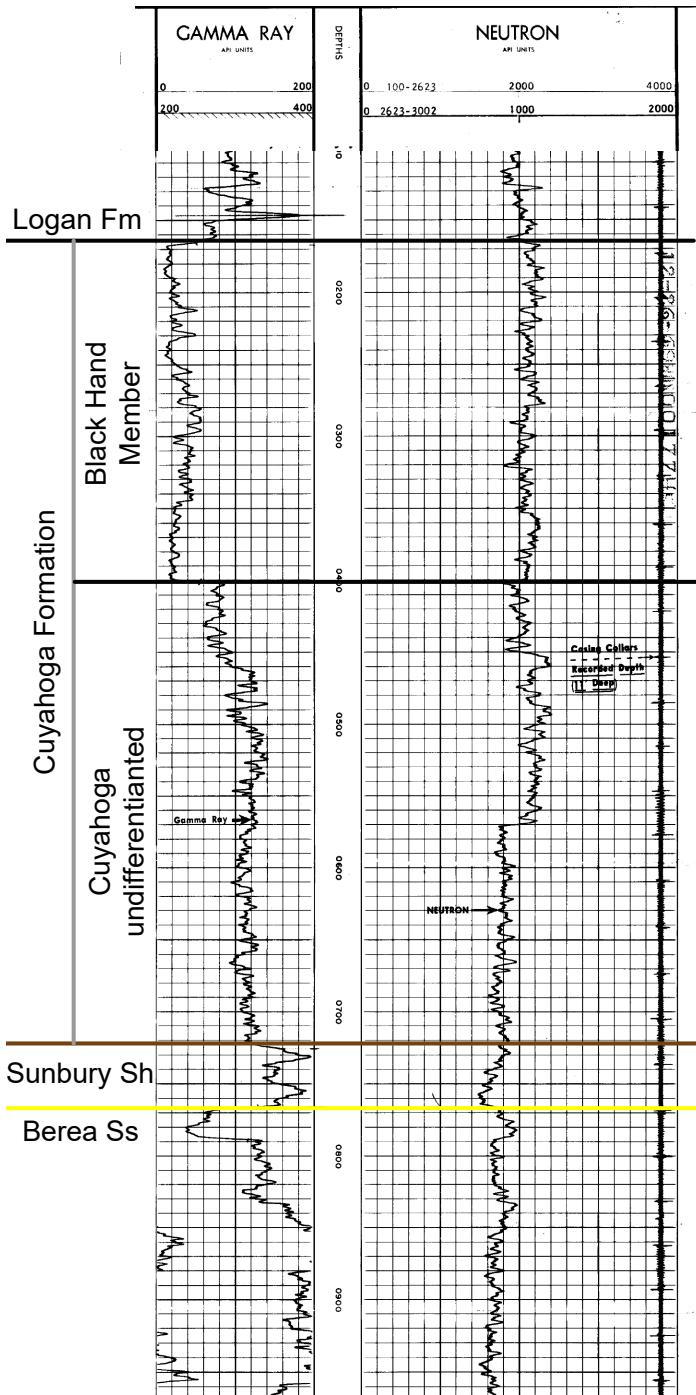


FIGURE 4. Typical geophysical well log from the type area of the Black Hand Member in Hanover Township, Licking County. Location shown in figure 3.

underlying shale, the Raccoon Member of the Cuyahoga Formation. Interbedded shale and sand signatures are evident in the gamma-ray logs in Fairfield County, so it is possible our interpretations for the base of the Black Hand are not correlative to the contact identified at the surface. Data points in Fairfield County should be considered tentative. Significantly more data is needed through the entirety of the Cuyahoga Formation to resolve these issues.

CONCLUSIONS

This report presents a new set of cross sections and maps of the Black Hand Member of the Cuyahoga Formation in central and eastern Ohio. The elevations, thicknesses, and extents shown on the maps were determined by the correlation of geophysical well logs. This updated interpretation of the Black Hand in the subsurface extends farther eastward than most recent examples and differs from previous interpretations because the Black Hand is not considered equivalent to the entirety of the “Big Injun.” The updated structure-contour map on the top of the Black Hand covers more area than previous studies and shows possible influences from basement faulting. The isopach map highlights some stratigraphic complexities, mainly in the southwestern map area in Fairfield, Hocking, and Vinton Counties. The identification of the Black Hand Member in the subsurface in these counties is questionable because of the interbedded nature of sand and shale lithologies at the boundary between the Black Hand Member and the underlying Raccoon Member. Also debatable is whether the interbedded sandstones and shales at the base of the Black Hand should be considered a separate member altogether, the Fairfield Member. These stratigraphic issues cannot be resolved with the limited subsurface data currently available.

In addition to sedimentologic and stratigraphic research, the new maps have several potential uses. As previously mentioned, the Black Hand is a major regional aquifer, and more detailed maps can serve as tools for research on groundwater resources and aquifer analysis. The base of the deepest USDW is the depth at which surface casing is set during the oil-and-gas well drilling process to protect groundwater resources. The Black Hand is the deepest USDW in east-central Ohio, where unconventional oil-and-gas drilling has increased over the last decade. The isopach and structure-contour maps can be used to further define the Black Hand portion of the USDW map (Riley, 2012). Finally, these maps were created using GIS technology. Over the last few years, the ODNr Division of Geological Survey has been mapping many different geologic units in the subsurface. These new maps of the Black Hand are now included in the digital subsurface geology database and are available to the public.

ACKNOWLEDGEMENTS

The authors thank Derek Foley, Michael Solis, and Paul Spahr for their assistance with correlations and mapping methods.

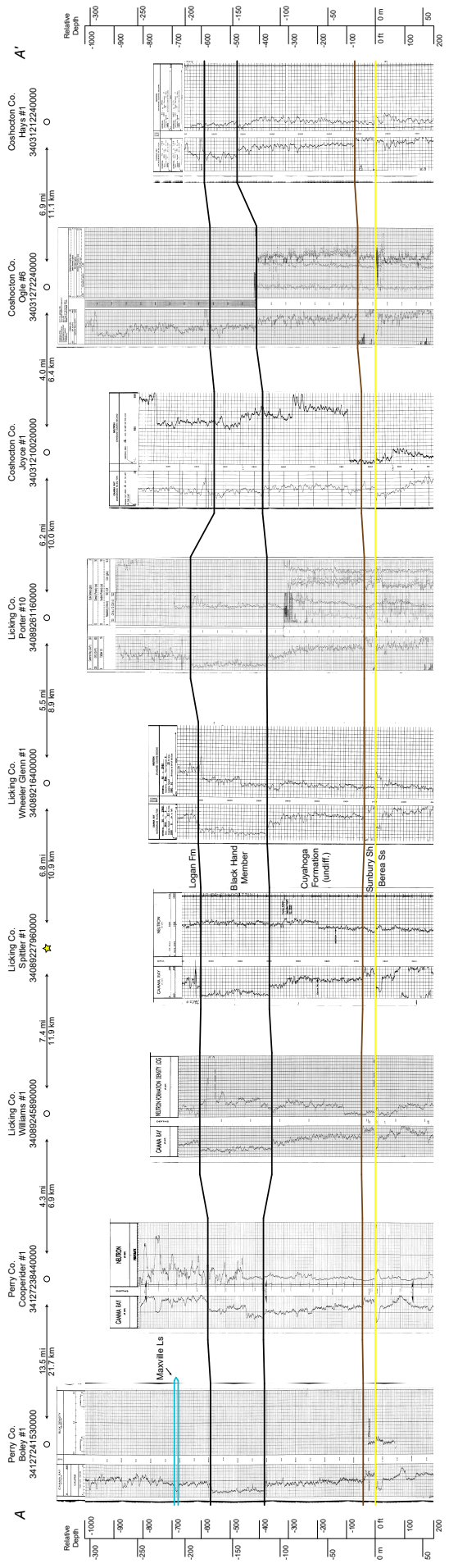


FIGURE 5. Stratigraphic cross section A-A': All cross sections (figs. 5-9) are stratigraphic cross sections with the top of the Berea Sandstone used as the datum; locations can be found in fig. 3. Undiff. = undifferentiated.

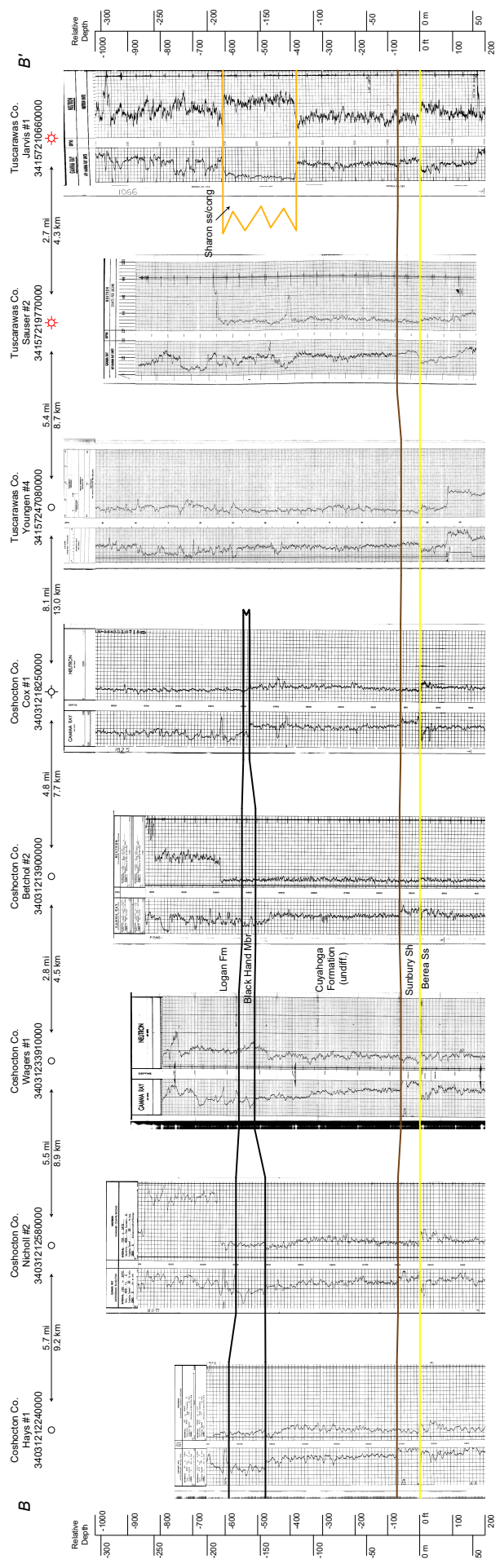


FIGURE 6. Stratigraphic cross section B-B' showing the Black Hand Member pinching out across northern Coshocton County and the Pennsylvanian Sharon sandstone/conglomerate truncating Mississippian strata.

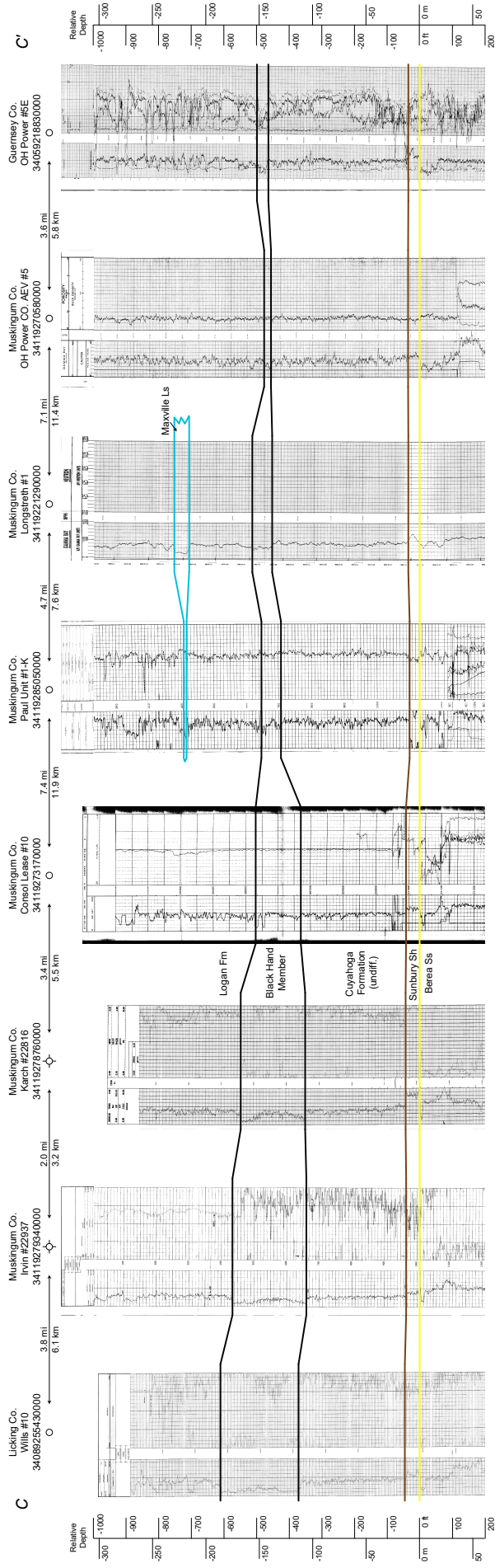


FIGURE 7. Stratigraphic cross section C-C' showing the Black Hand Member thinning across Muskingum County.

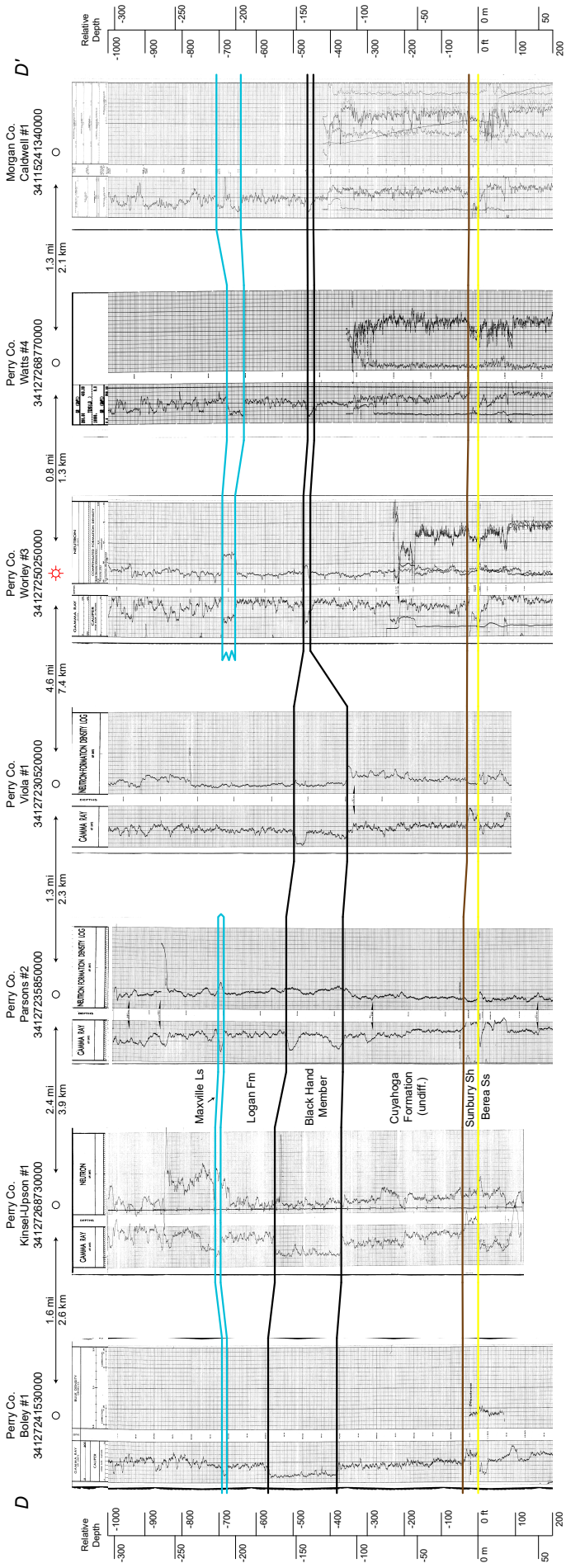


FIGURE 8. Stratigraphic cross section D-D' showing the Black Hand Member thinning across Perry County.

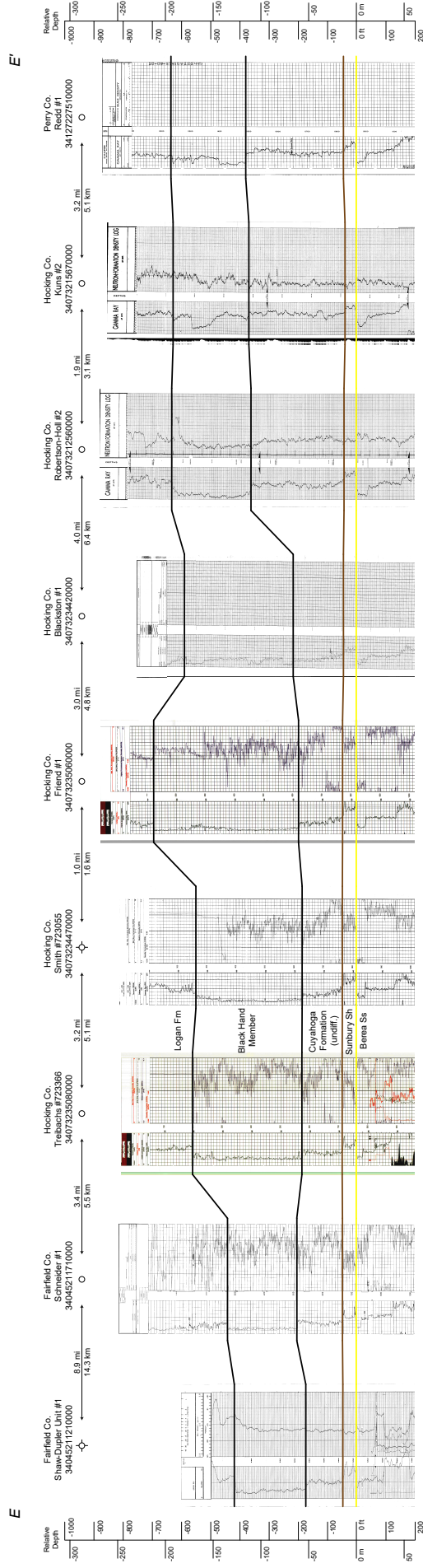


FIGURE 9. Stratigraphic cross section E-E' through Perry, Hocking, and Fairfield Counties. This study followed Wolfe and others (1962) and considered the Fairfield and Black Hand to be one member; however, the identification of the Black Hand in the subsurface in Fairfield County is tentative.

REFERENCES CITED

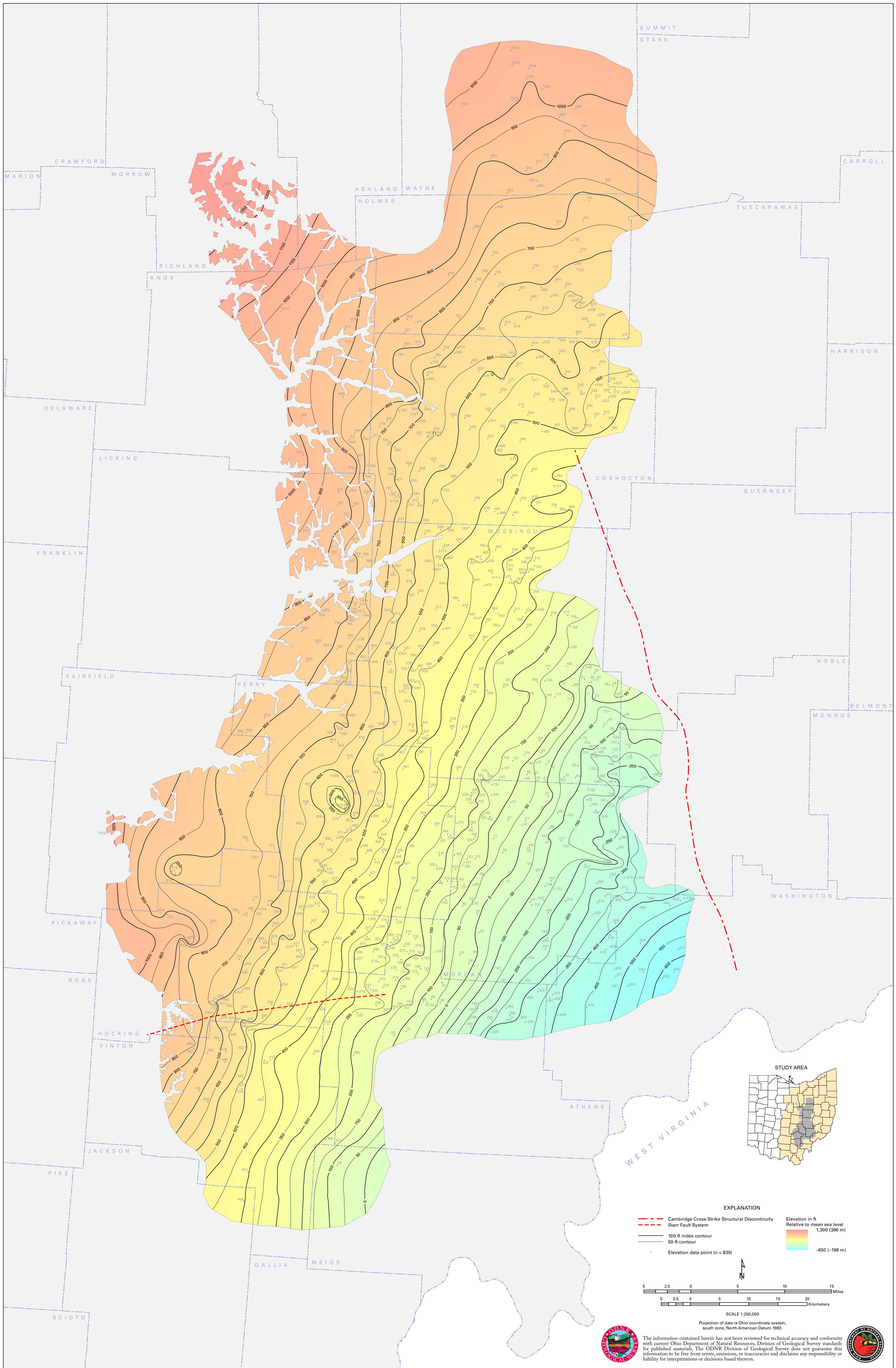
- Baranoski, M.T., 1993, The Cambridge Monocline: a revision of a major positive structural inversion in southeastern Ohio: Ohio Geological Society, Special Meeting, Canton, Ohio, Oct. 1993, [Proceedings], 10 p.
- Baranoski, M.T., 2013, Structure contour map on the Precambrian unconformity surface in Ohio and related features: Ohio Department of Natural Resources, Division of Geological Survey, Map PG-23, scale 1:500,000, 17 p. text.
- Brannock, M.C., 1993, The Starr Fault system of Southeastern Ohio, *in*, An update on Ohio's subsurface geology: Ohio Geological Society, Special Meeting, Canton, Ohio, Oct. 1993, [Proceedings], 37 p.
- Ettensohn, F.R., Greb, S.F., Chesnut Jr., D.R., Harris, D.C., Mason, C.E., Eble, C.F., Howell, P.D., Watson, A.E., and Johnson, W.K., 2002, Mississippian stratigraphy, depositional environments, and tectonic framework of the central Appalachian basin, eastern Kentucky, U.S.A, *in* Hills, L.V., Henderson, C.M., and Bamber, E.W., eds., Carboniferous and Permian of the World: Canadian Society of Petroleum Geologists, Memoir 19, p. 22–40.
- Evans, J.E., 2004, Chapter 2, The early Pennsylvanian Sharon Formation of northeastern Ohio, *in* Foos, A.M., ed., Pennsylvanian Sharon Formation, past and present: Sedimentology, hydrogeology, and historical and environmental significance: Ohio Department of Natural Resources, Division of Geological Survey Guidebook 18, 93 p.
- Hicks, L.E., 1878, The Waverly Group in Central Ohio: American Journal of Science, v. 16, p. 216–224.
- Holden, F.T., 1942, Lower and Middle Mississippian stratigraphy of Ohio: Journal of Geology v. 50, no. 1, p. 34–67
- Hyde, J.E., 1915, Stratigraphy of the Waverly Formations of Central and Southern Ohio: Journal of Geology, v. 23, p. 655–682, 757–779.
- Majchszak, F.L., 1984, Geology and formation-water quality of the “Big Injun” and “Maxton” sandstones in Coshocton, Muskingum, and southern Tuscarawas counties, Ohio: Ohio Department of Natural Resources, Division of Geological Survey Report of Investigations No. 124, 36 p.
- Matchen, D.L., 2004, Depositional environments, age, and regional correlation of the Black Hand Sandstone Member of the Cuyahoga Formation and the Lower Mississippian of the central Appalachians [PhD thesis]: West Virginia University, Morgantown, 170 p.
- Matchen, D.L., and Kammer, T.W., 2006, Incised valley fill interpretation for Mississippian Black Hand Sandstone, Appalachian Basin, USA: Implications for glacial eustasy at Kinderhookian–Osagean (Tn2–Tn3) boundary: Sedimentary Geology, v. 191, p. 89–113.
- Norris, S.E., and Mayer, G.C., 1982, Water resources of the Black Hand Sandstone Member of the Cuyahoga Formation and associated aquifers of Mississippian age in southeastern Ohio: USGS Open-File Report 82-170, 72 p.
- Pashin, J.C., and Ettensohn, F.R., 1995, Reevaluation of the Bedford–Berea Sequence in Ohio and Adjacent States: Forced Regression in a Foreland Basin: Geological Society of America Special Paper 298, 68 p.
- Prosser, C.S., 1901, The Classification of the Waverly Series of Central Ohio: Journal of Geology, v. 9, p. 205–231.
- Riley, R.A., 2012, Elevation on the base of the deepest underground source of drinking water in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, Map EG-6, scale 1:500,000.
- Scatterday, J.W., 1963, Stratigraphy and conodont faunas of the Maxville Group (Middle and Upper Mississippian) of Ohio [PhD Thesis]: The Ohio State University, Columbus, 162 p.
- Slucher, E.R., 2004 (rev.), Generalized column of bedrock units in Ohio: Ohio Department of Natural Resources, Division of Geological Survey, 1 p.
- Slucher, E.R., Swinford, E.M., Larsen, G.E., Schumacher, G.A., Shrake, D.L., Rice, C.L., Caudill, M.R., and Rea, R.G., 2006, Bedrock geologic map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map BG-1, Version 6.0, scale 1:500,000.
- Ver Steeg, K., 1947, Black Hand sandstone and conglomerate in Ohio: Geological Society of America Bulletin, v. 58, p. 703–728.
- Wolfe, E.W., Forsyth, J.L., and Dove, G.D., 1962, Geology of Fairfield County: Ohio Department of Natural Resources, Division of Geological Survey Bulletin 60, 230 p.



Ohio Department of Natural Resources
Division of Geological Survey
2045 Morse Road, Bldg. C-1
Columbus, OH 43229-6693
Telephone: (614) 265-6576
Fax: (614) 447-1918

SUBSURFACE STRUCTURE CONTOUR MAP ON TOP OF THE BLACK HAND MEMBER OF THE CUYAHOGA FORMATION IN OHIO

by
Erika M. Danielsen and Samuel R. W. Hulet

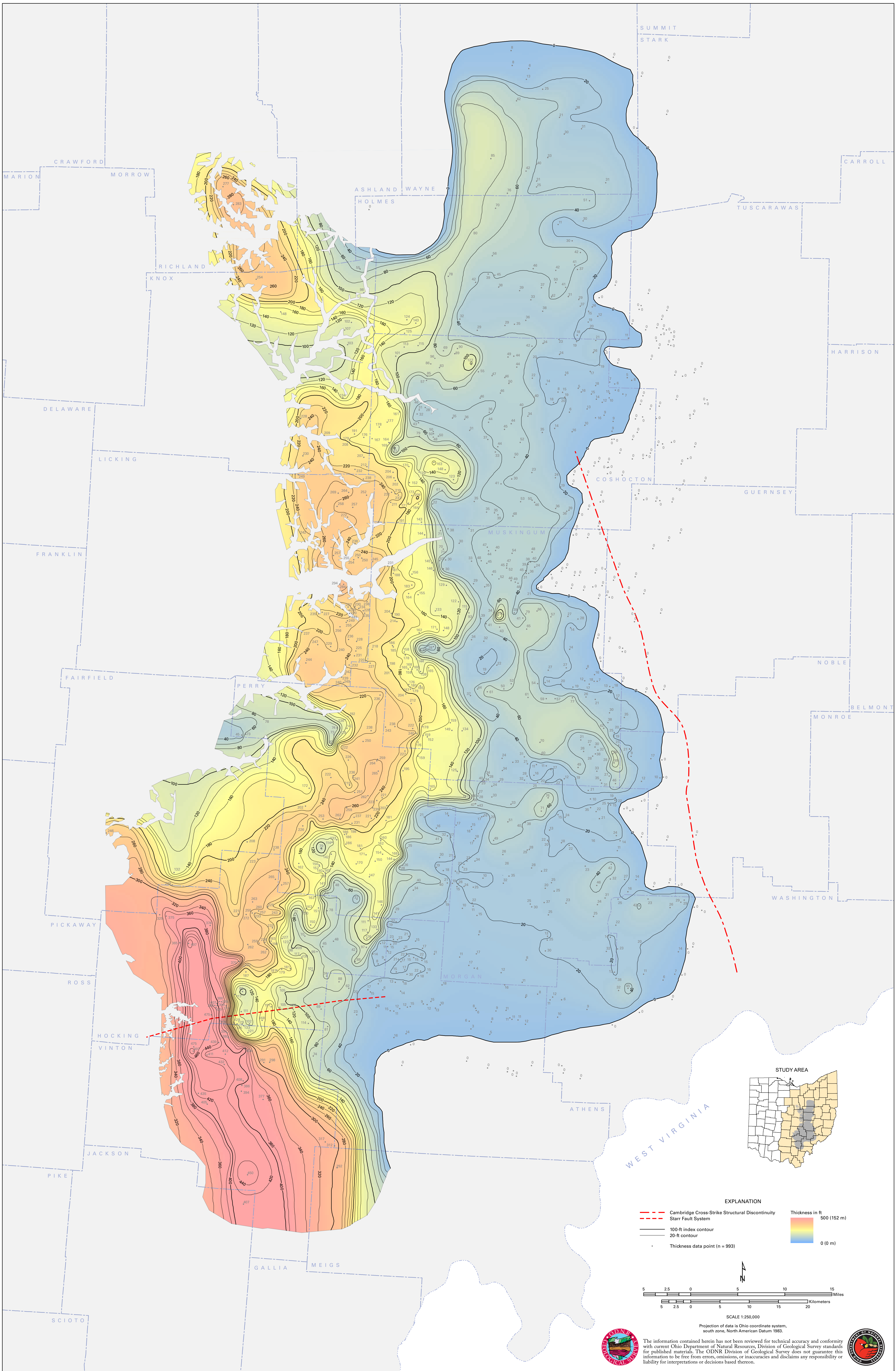


The information contained herein has not been reviewed for technical accuracy and conformity with current Ohio Department of Natural Resources, Division of Geological Survey standards for published materials. The ODNR Division of Geological Survey does not guarantee this information to be free from errors, omissions, or inaccuracies and disclaims any responsibility or liability for interpretations or decisions based thereon.



SUBSURFACE ISOPACH MAP OF THE BLACK HAND MEMBER OF THE CUYAHOGA FORMATION IN OHIO

by
Erika M. Danielsen and Samuel R. W. Hulet



The information contained herein has not been reviewed for technical accuracy and conformity with current Ohio Department of Natural Resources, Division of Geological Survey standards for published materials. The ODNR Division of Geological Survey does not guarantee this information to be free from errors, omissions, or inaccuracies and disclaims any responsibility or liability for interpretations or decisions based thereon.

