Structure and Isopach Mapping of the Mississippian Black Hand Sandstone in Eastern Ohio, Northwestern Appalachian Basin

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Introduction

The Black Hand Sandstone Member of the Cuyahoga Formation is a massive to cross-bedded, medium-to coarse-grained conglomeratic, sandstone, bounded by finer-grained marine sandstones and shales of the Cuyahoga Formation and the overlying Logan Formation. The unit is a prominent cliff former in a 135-km outcrop belt running north–south through central Ohio. It dips eastward into the subsurface where it serves as a local aquifer and the deepest underground source of drinking water (USDW) in several counties. Previous subsurface maps of the Black Hand correlate this unit to the drillers' "Big Injun," a term frequently applied to several Mississippian and Pennsylvanian sandstone units, including sandstones in the Logan Formation and the Pennsylvanian Pottsville Group (Fig. 1). This project utilized more than 1,000 geophysical well logs to map the Black Hand in the subsurface and distinguish it from the "Big Injun." These maps will provide tools for managing ground-water resources and determining casing depths in areas where oil-and-gas drilling is common, and they will aid researchers interested in the hydrogeology, stratigraphy, and sedimentology of the Mississippian in Ohio.

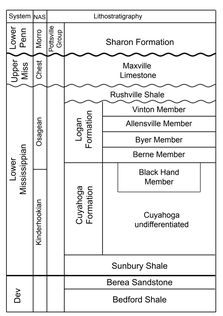


Figure 1. Generalized nomenclature for Upper Devonian to Lower Pennsylvanian strata in eastern Ohio. The Cuyahoga Formation contains numerous members depending on location, facies, and interpretation; here we informally call all units that underlie the Black Hand Member "Cuyahoga undifferentiated" to simplify the figure. NAS = North American Stage, Dev = Devonian, Miss = Mississippian, Penn = Pennsylvanian, Chest = Chesterian, Morro = Morrowan.

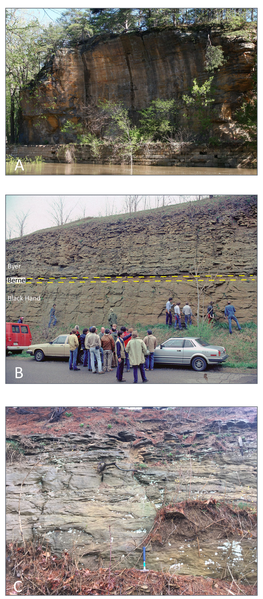


Figure 2. Photos of the Black Hand Member in the type area, Hanover Township, Licking County, Ohio. **A**. View facing north across the Licking River in Black Hand Gorge State Nature Preserve showing the cliff-forming nature of the Black Hand at the type locality. The structure beneath is part of the Erie Canal towpath. **B**. View facing north on Rock Haven Road showing the Black Hand Member of the Cuyahoga Formation and the overlying Berne and Byer members of the Logan Formation (c. 1980). **C**. View facing north on Marne Road showing cross bedding in the Black Hand.

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 et al., 2002). The Devonian-Mississippian boundary sits on top of the Berea Sandstone, which caps the underlying Devonian shale sequence. The Mississippian in eastern Ohio is mostly represented by marine siltstones and shales with occasional coarse, conglomeratic sandstones (i.e., Black Hand, Berne, and Allensville members) and in some areas of southeastern Ohio the succession is capped by the Maxville Limestone. The Mississippian in Ohio is overlain by the Sharon Formation of the Lower Pennsylvanian Pottsville Group (Fig. 1).

The Black Hand Member is well-known for creating the cliffs of the Hocking Hills region and Black Hand Gorge (Fig. 2). These prominent outcrops caught the attention of early Mississippian workers who formally designated the sandstone as the Black Hand Member of the Cuyahoga Formation with the type locality at Black Hand Gorge in Licking County (Hicks, 1878; Prossor, 1901; Hyde, 1915). Ver Steeg (1947) produced the first subsurface maps of the Black Hand Member correlating it to the drillers' "Big Injun." The subsurface correlations have since been revised (Majchszak, 1984), and the new subsurface maps focus on distinguishing the Black Hand Member of the Cuyahoga Formation from the "Big Injun."

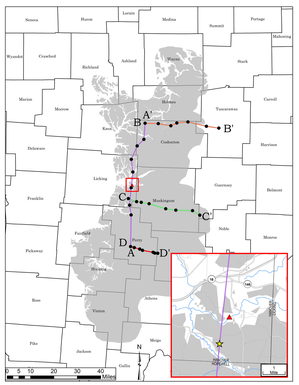
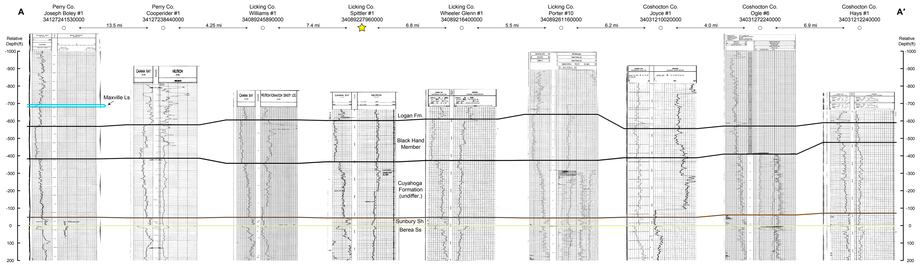
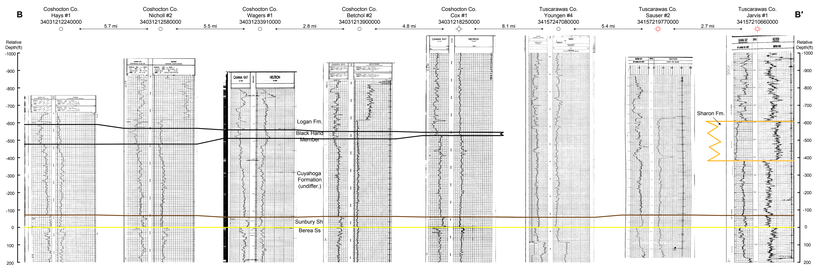
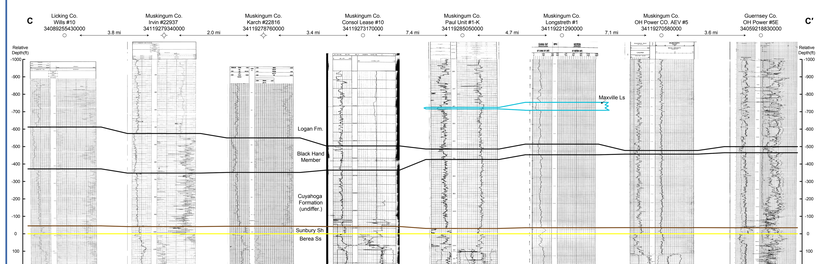
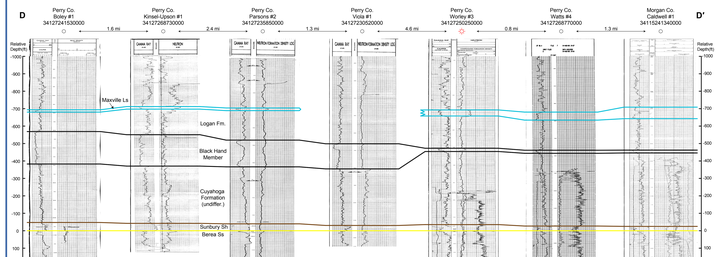


Figure 3. Stratigraphic cross sections and map showing extent of the Black Hand Member in the subsurface with well locations for cross sections A-D. The inset map is a close-up part of the type area of the Black Hand Member in Hanover Township, Licking County. The red triangle marks the location of the type locality of the Black Hand along the banks of the Licking River at Black Hand Gorge. The star marks the location of well API 34089227960000 in cross section A. The top of the Berea Sandstone was used as the stratigraphic datum for all cross sections, there is no horizontal scale. **A–A'** shows correlation of the Black Hand north and south from the type area. **B–B'** shows the Black Hand pinching out across northern Coshocton County and the Pennsylvanian Sharon Formation truncating Mississippian strata. **C–C'** shows the Black Hand thinning across Muskingum County. **D–D'** shows the Black Hand thinning across Perry County.









Methods

The Black Hand Member was identified in 842 geophysical well logs; more than 1,000 logs were used to determine its subsurface extent. The Black Hand is typically scanned through surface casing, so frequently only gamma ray logs were available. There is no core of the Black Hand on record with the Ohio Geological Survey, and there are only a few well samples. Therefore, wells within 1–1.5 miles of known outcrop in the type area were relied on for surface to subsurface correlation. A lithostratigraphic definition of the Black Hand Member was followed, so only cleaner sandstone (low gamma value) signatures were identified as Black Hand (Fig. 3). All picks were made using Petra (IHS), data were exported, and maps were made using ArcGIS (Esri). The isopach was mapped using IDW, and Kriging was used for the structure. The output contours for both maps were hand edited. The maps were then clipped to a DEM of the bedrock surface. The location where the top of the Black Hand intersects the surface is an estimation and was not verified with field mapping.

Results

The top of the Black Hand Member ranges in elevation from −643 to 1,281 ft relative to sea level, with higher elevations in the west and lower elevations to the east. 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 through east-central Ohio. In the type area, the Black Hand is approximately 250 ft thick (Fig. 3A). This trend persists to the north until it 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. To the east of the type area, the Black Hand thins abruptly in a north–south trend from Vinton to Coshocton Counties. This occurs where the lower portion of the Black Hand Member transitions to a more shaly or silty facies and eventually pinches out to the east (Fig. 3B,C,D). The western boundary is a result of more modern erosion that has removed the Black Hand. The northern boundary is a combination of modern-day erosion and facies changes. The southern boundary is the extent of reliable subsurface data.

Comparison with Previous Maps

First subsurface extent map, Ver Steeg (1947)

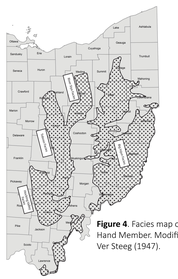


Figure 4. Facies map of the Black Hand Member. Modified from Ver Steeg (1947).

Ver Steeg (1947) produced the first unit extent and isopach maps of the Black Hand Member in the subsurface (Fig. 4). Using field observations and drillers' logs, he correlated the Black Hand to the drillers' "Big Injun" and defined two major sand bodies. The sand to the west was divided into several facies following Hyde (1915) and Holden (1942). The "Big Injun Facies" to the east was identified in drilling logs. Majchszak (1984) determined this sand body was not correlative to the Black Hand but rather to the Sharon Formation of the Pottsville Group (lower Pennsylvanian). Therefore, the new maps show a much narrower extent of the Black Hand.

Most recent isopach, Matchen and Kammer (2006)

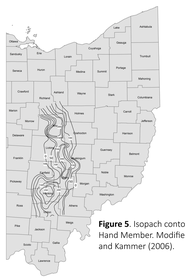


Figure 5. Isopach contours of the Black Hand Member. Modified from Matchen and Kammer (2006).

Matchen and Kammer (2006) interpret the Black Hand Member as pinching out entirely in eastern Coshocton, Muskingum, and Morgan Counties (Fig. 5). The new isopach shows an abrupt thinning in the same area but continues farther east. Another major difference is the thickness in Vinton, Hocking, and southern Fairfield Counties where the new maps show the Black Hand nearing 500 feet thick. There is a debate about whether Hyde's (1915) "Fairfield member" of the Cuyahoga is distinguishable from the overlying Black Hand. Matchen and Kammer separate them, while we follow Wolfe et al. (1962) and consider the Fairfield and Black Hand one unit.

Ohio basement structure, Baranoski (2013)

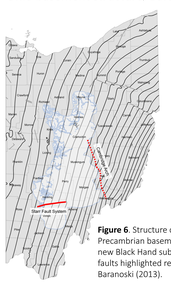


Figure 6. Structure contours on the Precambrian basement overlain on the new Black Hand subsurface extent, select faults highlighted red. Modified from Baranoski (2013).

The structure contours on the top of the Black Hand reveal two areas possibly influenced by basement faulting (Fig. 6) The first, in southern Hocking and Vinton Counties, shows deformation in the Black Hand that could be a result of the Starr Fault System (Brannock, 1993; Baranoski, 2013). The other can be seen in the structural low in western Coshocton through northern Holmes Counties, which is part of the Cambridge Arch and Parkersburg-Lorain Syncline (Baranoski 1993; Slucher, 2006; Baranoski, 2013). The Black Hand structure map reveals the Parkersburg-Lorain Syncline but does not extend far enough west to show the Cambridge Arch.

Deepest underground source of drinking water (USDW), Riley (2012)

Figure 7. Structure contours on the base of the Black Hand Member. Modified from Riley (2012).

The Ohio Geological Survey published a map of elevation contours on the USDW across most of Ohio (Riley, 2012). This included structure contours on a large portion of the base of the Black Hand Member (Fig. 7). Drillers' tops were used to make the USDW map, so the new data set for the updated maps could be used to update the base structure contours of the Black Hand. However, several factors, including water quality and other hydrogeologic properties, influenced the boundaries of the Black Hand on the USDW map, and these must be taken into consideration when determining the deepest USDW and surface casing depth.

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