



Geological Note 12

Correlating Mississippian Stratigraphic Relationships between Southern Ohio and North-Central Kentucky

by
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STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
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Front cover: Exposure of the Cowbell Member of the Borden Formation along a railroad cut north of U.S. Route 52, east of the Sciotoville neighborhood of Portsmouth, Ohio.

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ABBREVIATIONS USED IN THIS GEOLOGICAL NOTE

Units of Measure

centimeter(s)	cm
foot (feet)	ft
inch(es)	in
kilometer(s)	km
meter(s)	m
mile(s)	mi

Lithologic and/or Stratigraphic Units*

Formation	Fm
Group	Gp
Member	Mbr/mbr
Sandstone	Ss
Shale	Sh

Other

Digital Elevation Model	DEM
U.S. Geological Survey	USGS

*Lowercase lithologic and stratigraphic names and abbreviations indicate informal status of a unit.

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ABSTRACT

Dating back to 1838, numerous geologic studies have evaluated Lower Mississippian strata in Ohio, resulting in a varied and diverse nomenclature for these units throughout the state. In the Portsmouth region of southern Ohio, Lower Mississippian strata are identified on the statewide *Bedrock Geologic Map of Ohio* as Logan and Cuyahoga Formations undivided, whose type localities are located in the central and northeastern regions of the state (Slucher and others, 2006). In 2015, the Ohio Department of Natural Resources, Division of Geological Survey (Ohio Geological Survey) began constructing a detailed lithologic bedrock map spanning the Ohio portions of four 7.5-minute quadrangles in the Portsmouth region. This study found that the Lower Mississippian units are sedimentologically dissimilar from both the shales of the Cuyahoga Formation and sandstones of the Logan Formation at their type localities. Instead, these strata correlate to members of the Borden Formation in adjacent north-central Kentucky. Reconciling the Portsmouth-area strata with the Borden Formation provides a logical stratigraphic framework for Lower Mississippian units in southern Ohio. Consequently, for the detailed lithologic bedrock map of the Portsmouth region, the Ohio Geological Survey replaced the Cuyahoga and Logan Formation nomenclature with Borden Formation members: Henley, Farmers, Portsmouth, Nancy, and Cowbell. As bedrock mapping continues to the north and east along the strike of the Mississippian section, the updated nomenclature of this study will be applied to strata in adjacent areas. The Ohio Geological Survey anticipates encountering the “traditional” Cuyahoga and Logan Formations in central Ohio as the Borden Formation members pinch out or as facies change.

INTRODUCTION

In 2015, the Ohio Department of Natural Resources, Division of Geological Survey (Ohio Geological Survey), began mapping the bedrock geology of the Portsmouth region (Fugitt and Blakeman, 2016). The region consists of Upper Devonian, Lower Mississippian, and Lower Pennsylvanian sedimentary rocks. Mapping was completed through a combination of field study and the utilization of existing geologic records, such as measured sections, core records, and water well data.

Initial reconnaissance revealed that the stratigraphy of the study area was inconsistent with the commonly accepted Lower Mississippian nomenclature and lithologic

descriptions of the units for the region. In addition, the Lower Mississippian units on the statewide *Bedrock Geologic Map of Ohio* (Slucher and others, 2006), which was compiled through reconnaissance mapping, did not appear to correspond with lithologic descriptions gathered during field observations.

Historical investigations of the Mississippian strata in Ohio have revealed numerous and often conflicting stratigraphic designations of these geologic units. Often, these names were applicable only to specific regions of the Mississippian rocks in Ohio and did not accurately represent sections in southern Ohio. However, recent reports and investigations in north-central Kentucky have named and described Mississippian geologic units that more accurately reflect the stratigraphy in southern Ohio (Sheppard, 1964; Erickson, 1966; Chaplin and Mason, 1978; Potter and others, 1991).

PROJECT AREA AND PURPOSE

In 2015, the Ohio Geological Survey was awarded a grant through the U.S. Geological Survey (USGS) STATEMAP program to produce 1:24,000-scale bedrock-geology maps of the Ohio portions of four 7.5-minute quadrangles in the Portsmouth region of southern Ohio: Friendship, New Boston, Portsmouth, and West Portsmouth (fig. 1). The city of Portsmouth, in Scioto County, is an important economic center in southern Ohio located at the confluence of the Scioto and Ohio Rivers in the Appalachian Plateaus physiographic province (Ohio Division of Geological Survey, 1998).

The objectives of this report are twofold. First, this report summarizes (1) the previous studies of the Lower Mississippian nomenclature in southern Ohio and (2) how the Lower Mississippian units in the Portsmouth region are lithologically similar to Lower Mississippian units in north-central Kentucky. Second, this report introduces the bedrock geology map of the Portsmouth project area, which utilizes the Lower Mississippian stratigraphic nomenclature from north-central Kentucky.

PREVIOUS WORK

Numerous studies have evaluated Upper Devonian and Lower Mississippian strata in Ohio. These studies date back to 1838, and several researchers have proposed varied and diverse interpretations of these units, each with its own specific stratigraphic nomenclature. In addition, the studies used numerous names and divisions for the

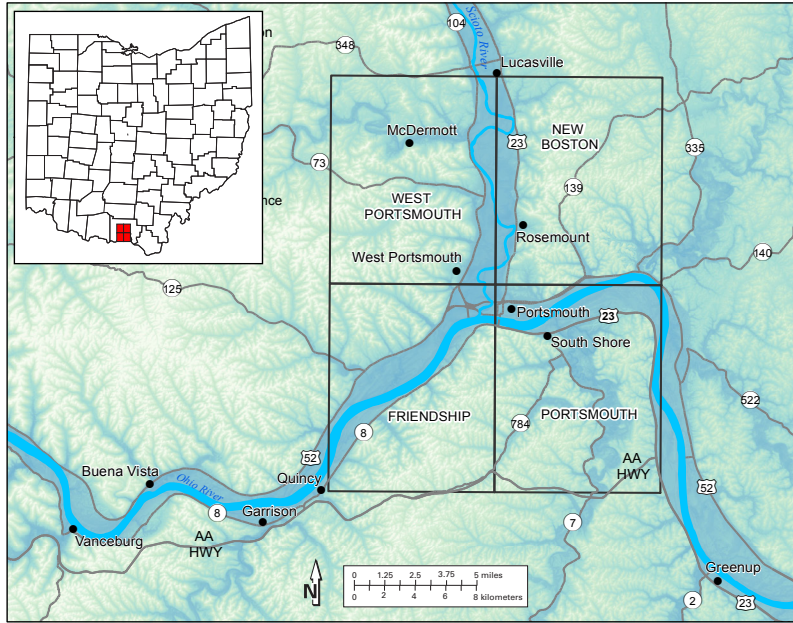


FIGURE 1. Map of south-central Ohio showing the 2015–2016 STATEMAP study area. Includes the Friendship, New Boston, Portsmouth, and West Portsmouth 7.5-minute quadrangles.

Mississippian formations. Some of the historical studies that addressed the Upper Devonian and Lower Mississippian nomenclature in southern Ohio and north-central Kentucky (plate 1) are discussed briefly in the following paragraphs.

In 1838, Briggs described alternations of sandstone and shale between the black shale (Ohio Shale) and the conglomerate (Sharon Sandstone) along the Scioto River valley between Portsmouth and Chillicothe. The entire section was named the Waverly Sandstone Series (plate 1) after quarries near the village of Waverly in Pike County. Briggs (1838) described the sandstones of this succession as very fine grained, occurring in beds of up to 6 ft (2 m) thick and ranging in color from blue to white or yellow. These sandstones provided a valuable building stone resource for Ohio (Briggs, 1838).

Andrews (1870) proposed names for the two economically important units within the Waverly Sandstone Series found along the Ohio River in Adams and Scioto Counties. At the base of the Waverly Series, just above the Ohio Shale, is an approximately 4-ft (1-m) thick sandstone unit that was heavily quarried for use as a Cincinnati building stone. Andrews referred to this unit as the City Ledge (plate 1). Above the City Ledge was a 47-ft (14-m) thick shale interval overlain by another series of sandstones which Andrews (1870) referred to as the Upper Waverly Sandstones. The Upper Waverly Sandstones also were quarried for building stone.

In 1874, Orton described the geology of Pike County and elaborated on Andrews' (1870) study by further subdividing the Waverly Series. At the base of the series, Orton noted a blue shale unit that differed from the underlying Ohio Shale. This shale ranged from

approximately 80 to 100 ft (24 to 30 m) in thickness and contained abundant ripple marks. He named this unit the Waverly Shales (plate 1; Orton, 1874).

Orton also renamed the top of the City Ledge of Andrews (1870) and called it the Waverly Quarry System. He described a black shale interval above the Waverly Quarry System and called that the Waverly Black Slate. Above the Waverly Black Slate lay what Andrews (1870) called the Upper Waverly Sandstones. Orton (1874) named this the Buena Vista Sandstone, based on the type locality along the Ohio River in Scioto County (plate 1).

Above the Buena Vista Sandstone, Orton recognized a heavily vegetated interval that extended in some cases up to 300 ft (91 m) in thickness. There were no exposures available to collect a complete description, so it remained undescribed and unnamed. Above this covered interval, Orton noted that the surrounding hills were capped with a dark-colored sandstone. He called this the Logan Sandstone after a previously described unit at approximately

the same stratigraphic interval near the town of Logan in Hocking County (Orton, 1874).

In 1888, Orton recognized the stratigraphic equivalency between the Waverly Shales of his 1874 report and the Bedford Shale that was previously described in Bedford, Ohio, by Andrews (1870). Orton acknowledged that these shales shared the same bounding units and lithologic characteristics and that the name Bedford Shale should be adopted (Orton, 1888). Orton also professed that the sandstone above the Bedford, which he referred to as the Waverly Quarry System in Pike County (Orton, 1874), was correlative with the Berea Grit of northern Ohio and thus adopted this name (Orton, 1888).

Orton (1888) also revised the name for the black shale he previously referred to as the Waverly Black Slate in 1874. Studies in northern Ohio (Meek, 1875) referred to this unit as the Berea Shale and demonstrated that this bituminous black shale was present above the Berea Grit. The Berea Shale clearly was present statewide, and because of this stratigraphic relationship, Orton (1888) decided to retain the association by adopting the name Berea Shale.

Above the Berea Shale, Orton (1888) noted the presence of the Buena Vista Sandstone in southern Ohio and kept this designation from his 1874 study. The remaining interval between the Buena Vista Sandstone and the Logan Formation is an argillaceous shale with occasional flaggy sandstone interbeds. Instead of differentiating the various lithologies, Orton referred to the entire interval as the Cuyahoga Shale; Andrews (1870) previously applied this name to the shale interval below the Logan Formation in northern Ohio. The Logan

Sandstone, referred to by Orton (1888) as the Logan Group, once again was noted as the uppermost unit of the Lower Mississippian section.

By 1905, the stratigraphic nomenclature in Ohio was divided into many local or regional names. The Ohio Geological Survey released *Revised Nomenclature of the Ohio Geological Formations* in an effort to standardize and formalize the stratigraphic nomenclature for the state (Prosser, 1905). The Lower Mississippian strata were divided, in ascending order, into the Bedford Shale, Berea Grit, Sunbury Shale, Cuyahoga Formation, and Logan Formation (Prosser, 1905). In southern Ohio, the Buena Vista Sandstone was retained as an official member the Cuyahoga Formation (plate 1).

The primary difference between the revised standard of Prosser (1905) and the previous work by Orton (1888) was that Prosser adopted the name Sunbury Shale in place of the name Berea Shale for the bituminous black shale above the Berea Sandstone. This shale originally was described near the town of Sunbury in Delaware County (Hicks, 1878). Prosser (1905) argued that Sunbury was a more suitable name for the unit since Berea already had been used to identify the Berea Sandstone.

Since the release of *Revised Nomenclature of the Ohio Geological Formations* (Prosser, 1905), geologic units have been either composited for mapping purposes or divided into various members in more detailed local studies.

Hyde (1915) proposed several divisions for the Upper Devonian and Lower Mississippian section in southern Ohio. First, he recognized that the Bedford Shale was classified as Devonian and argued that, because of the interbedded nature of the Bedford Shale and Berea Sandstone in southern Ohio, the Berea Sandstone must also be Devonian in age. The remainder of the Waverly Series is Mississippian in age. The Bedford Shale, Berea Sandstone, and Sunbury Shale are present and easily identifiable wherever this lower section is exposed in Ohio.

However, in southern Ohio the Cuyahoga Formation is distinctly lithologically different from northern Ohio. In northern Ohio, the Cuyahoga Formation is composed of a series of shales, whereas in southern Ohio it is composed of alternating shales and sandstones (Hyde, 1915).

Hyde (1915) recognized this distinction and subsequently divided the Cuyahoga Formation in southern

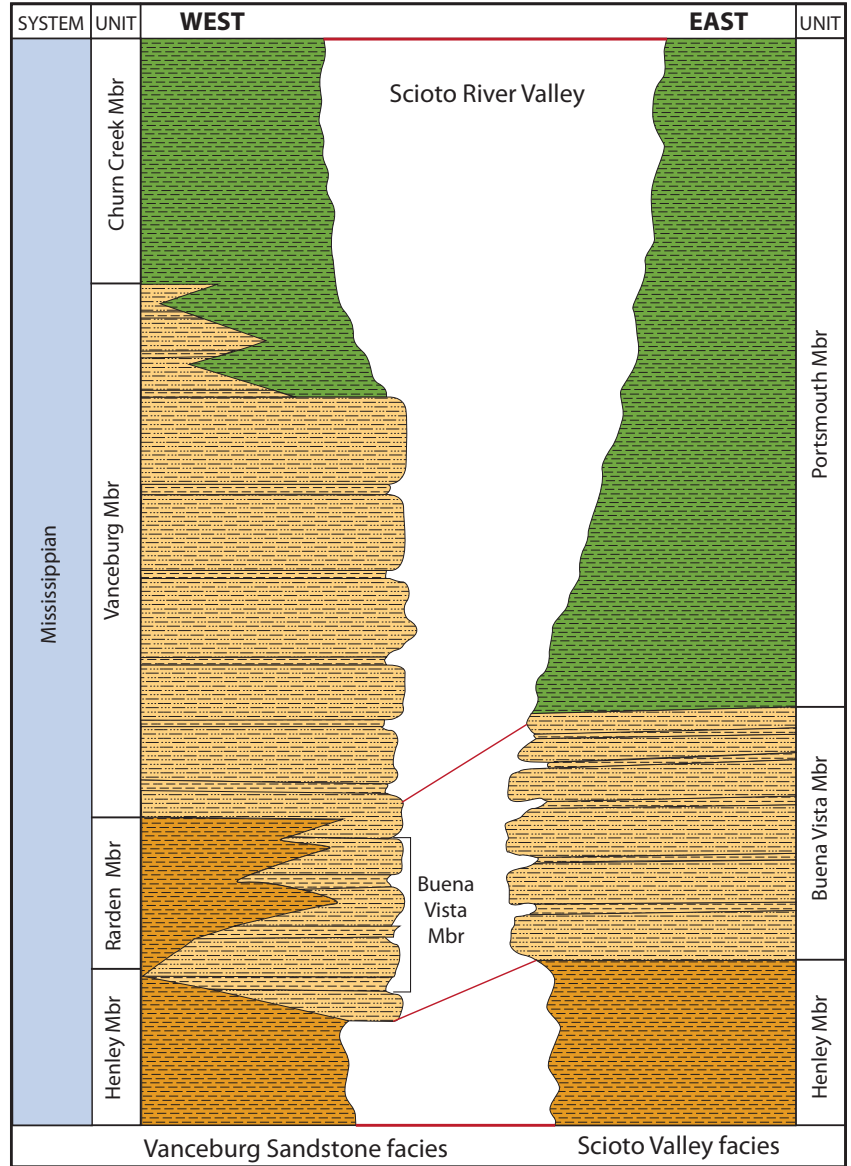


FIGURE 2. Stratigraphic columns based on the descriptions of the Scioto Valley and Vanceburg facies of the Cuyahoga Formation (Hyde, 1915), depicting the lateral changes Hyde recorded between the two facies. The red lines indicate the correlations he made between the Portsmouth Shale Member of the Scioto Valley facies and the upper three members of the Vanceburg facies.

Ohio into two facies, the Vanceburg Sandstone and Scioto Valley facies, and further subdivided these into members (fig. 2). The Scioto Valley facies of the Cuyahoga Formation included, in ascending order, the Henley Member, the Buena Vista Member, and the Portsmouth Member. The Vanceburg Sandstone facies was divided into the Henley Member, the Rarden Member, the Vanceburg Member, and the Churn Creek Member.

The Scioto Valley facies and the Vanceburg Sandstone facies both contain a red or gray shale above the Sunbury Shale, known as the Henley Member. In the Scioto Valley facies, the Buena Vista Member overlies the Henley

Member. The prominent Portsmouth Member occupies the remainder of the Cuyahoga Formation interval. The Portsmouth Member is a 250-ft (62-m) thick section of gray shale that contains some thin sandstone interbeds.

The Rarden Member occurs above the Henley Member in the Vanceburg Sandstone facies. The Rarden Member is a red-gray shale that is similar to the underlying Henley Member, which is separated from it by a thin sandstone bed. Above the Rarden Member lies the Vanceburg Member, which is composed of a thicker section of shale-interbedded sandstones, similar to the Buena Vista Member of the Scioto Valley facies. The Churn Creek Member is the uppermost member in the Vanceburg Sandstone facies and is composed of gray clay shale similar to that of the Portsmouth Member of the Scioto Valley facies.

Hyde (1915) divided the Logan Formation into three members in southern Ohio, in ascending order: the Byer Member, Allensville Member, and the Vinton Member. The Byer Member is a fine-grained sandstone that comprises the lowermost member of the Logan Formation in central Ohio. The Byer Member thickens and becomes finer-grained to the south at the Scioto River Valley in southern Ohio, and it is indistinguishable from the Portsmouth Member of the Cuyahoga Formation. The Allensville Member is the most recognizable member of the Logan Formation, being composed of coarse sandstone or conglomerate above the Byer Member. Finally, the Vinton Member is composed of hard sandstones (Hyde, 1915).

The statewide *Geologic Map of Ohio* was published in 1920 (Bownocker, 1920). This map condensed the Waverly Series for all of Ohio. The Upper Devonian and Lower Mississippian sections were jointly labeled "Waverly and Maxville."

In 1953, the Ohio Geological Survey released a posthumous collection of Hyde's work, titled *Mississippian Formations of Central and Southern Ohio*. In this volume, his earlier divisions of the Upper Devonian and Lower Mississippian section in southern Ohio, the Scioto Valley and Vanceburg facies, were retained. However, he recognized that the Allensville Member of the Logan Formation was absent in the Portsmouth area and concluded that the Logan Formation could not be divided into individual members in southern Ohio.

A partnership between the USGS and the Kentucky Geological Survey produced a geologic map for the Portsmouth and parts of the New Boston and Wheelersburg 7.5-minute quadrangles in the vicinity of Portsmouth, Ohio (Sheppard, 1964). This map includes strata on both sides of the Ohio River, and instead of using Cuyahoga and Logan Formation nomenclature, the units are separated into members of the Borden Formation of Kentucky. The Upper Member of the Borden Formation on Sheppard's map is composed of siltstones and shales that are correlative to the Logan Formation of southern Ohio, and the Lower Member is composed of shales and siltstones that correlate to Ohio's Cuyahoga Formation (Sheppard, 1964).

The Geological Society of Kentucky and the Ohio Geological Society conducted a joint field conference in southern Ohio and north-central Kentucky in 1968. The conference field trip visited Devonian- and Mississippian-aged units in both states. In contrast to Hyde (1915), which identified the Bedford Shale and Berea Sandstone as Devonian age, the field guide for the conference referred to these units as Mississippian or Devonian in age. The conference provided correlations between the Cuyahoga and Logan Formations in southern Ohio and the Borden Formation of Kentucky (Ohio Geological Society and Geological Society of Kentucky, 1968). The lower Cuyahoga of Ohio correlated to the Sandstone Member of the lower Borden Formation. The upper Cuyahoga correlated to the Shale Member of the Borden Formation, and the Logan Formation of Ohio correlated to the Siltstone Member of the Borden Formation (Ohio Geological Society and Geological Society of Kentucky, 1968).

In 1990, the *Generalized Column of Bedrock Units in Ohio* divided the Waverly Series units, in ascending order, into the Bedford Shale, Berea Sandstone, Sunbury Shale, Cuyahoga Formation (including the Buena Vista Member), and the Logan Formation (Ohio Division of Geological Survey, 1990). This work designated the Bedford Shale and Berea Sandstone as Upper Devonian in age.

Potter and others (1991) later correlated the Upper Devonian and Lower Mississippian units of southern Ohio to the modern members of the Borden Formation in Kentucky (plate 1). Ohio and Kentucky both recognize the Bedford Shale, Berea Sandstone, and Sunbury Shale as the basal units of what once was known as the Waverly Sandstone Series (Potter and others, 1991). Other correlations were made which adopted previous Kentucky nomenclature.

The *Bedrock Geologic Map of Ohio* (Slucher and others, 2006) was mapped at a reconnaissance level by using data such as measured sections, core, and water well records. The low resolution of this map did not allow for the differentiation of units at a member level. Consequently, the map presents the units in southern Ohio as the Sunbury Shale, Berea Sandstone, Bedford Shale undivided and the Logan and Cuyahoga Formations undivided (plate 1).

METHODOLOGY

During the 2015–2016 field season, Ohio Geological Survey geologists located outcrop exposures in the Portsmouth project area using topographic maps, digital elevation models (DEMs), slope coverages, and field reconnaissance. A total of 74 new outcrops were measured, described, sampled, and photographed. Outcrops were located in the field using GPS technology and were digitally linked to written descriptions and photographs in ESRI ArcGIS®.

In order to develop an understanding of stratigraphic divisions in the Portsmouth region, Ohio Geological Survey

geologists visited roadcuts along the AA Highway between Vanceburg and Greenup, Kentucky, and observed the lithologies of known Borden Formation units. These observations were subsequently compared with lithologic descriptions gathered from the Portsmouth region mapping area.

In addition to intensive field study, 1,028 water well records, 39 archival measured sections, 16 oil-and-gas well logs, and 19 cores from the study area were examined. Slope coverages were integral in identifying land features, erosional patterns, and abandoned mine pits of particular stratigraphic units that were covered or inaccessible.

DISCUSSION

For this study, field investigations and a literature review revealed that Mississippian-age strata in the Portsmouth region differ lithologically and stratigraphically from the units in the central and northern portions of Ohio, though they are classified under the same nomenclature. The current Upper Devonian and Lower Mississippian nomenclature in southern Ohio is based on the *Generalized Column of Bedrock Units in Ohio* and includes the Bedford Shale, Berea Sandstone, Sunbury Shale, Cuyahoga Formation, and the Logan Formation (Ohio Division of Geological Survey, 1990). However, geologists have long recognized the correlation between Upper Devonian and Lower Mississippian rocks of the Portsmouth region and similarly aged rocks in north-central Kentucky (Morse and Foerste, 1909; Morse and Foerste,

1912; Stockdale, 1939; Fagadau, 1952; Sheppard, 1964; Erickson, 1966; Ohio Geological Society and Geological Society of Kentucky, 1968; Potter and others, 1991; Martino and others, 1992).

The Borden Formation of Kentucky includes five members, in ascending order: Henley Bed, Farmers Member, Nancy Member, Cowbell Member, and Nada Member. In the project area, incision at the unconformity between Mississippian and Pennsylvanian strata resulted in an absence of the Nada Member. These members have been interpreted as the depositional products of a delta prograding from the east-northeast into Ohio, Kentucky, and West Virginia during Late Devonian through Middle Mississippian time (fig. 3; Moore and Clarke, 1970; Ettensohn and others, 2004; Ettensohn and others, 2009; Ettensohn and others, 2012).

During Late Devonian through Middle Mississippian time, the Neocadian orogeny occurred to the east of the study area, and its sediments were transported into the Appalachian Basin to form a large delta complex known as the Price, Pocono, Grainger, or Borden (Ettensohn and others, 2004; Ettensohn and others, 2009). The Borden delta complex prograded into the Appalachian Basin and deposited the Borden Formation (fig. 3), which represents the subaqueous distal regions along the toe and delta front (Ettensohn and others, 2009). Ascending through the Borden Formation, each member represents shallower facies on the delta complex (fig. 3).

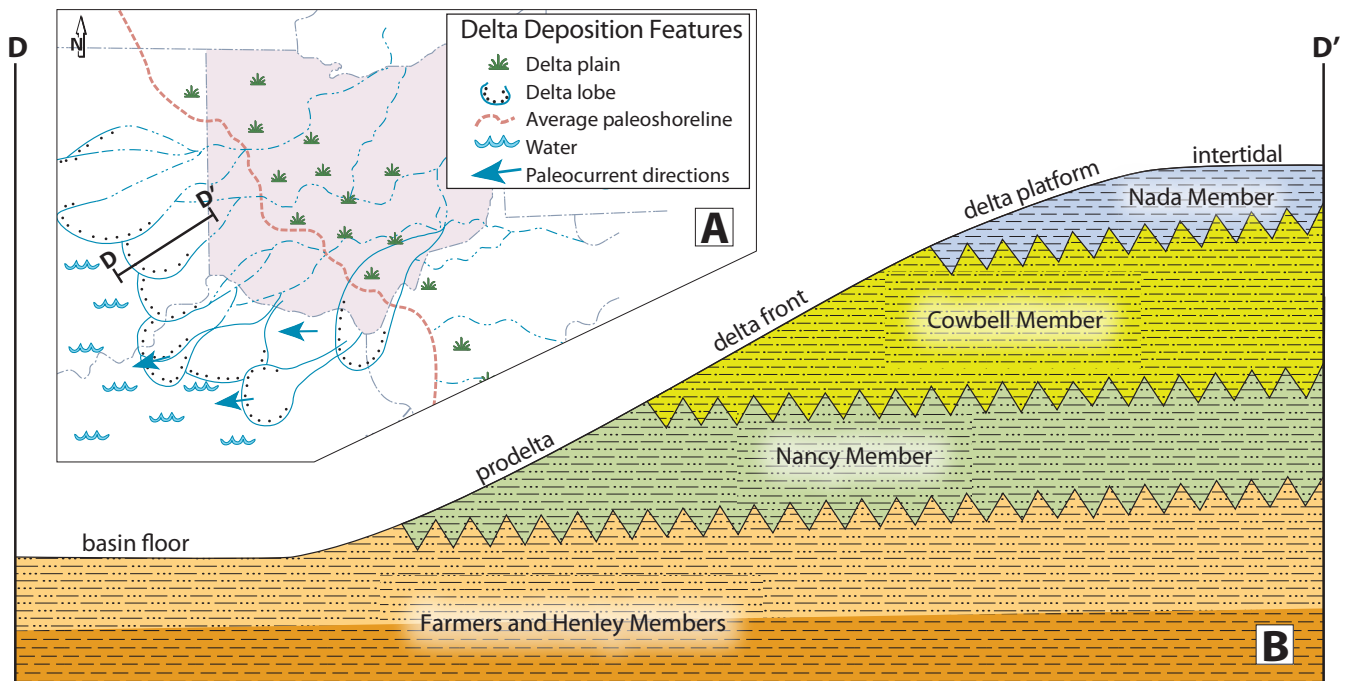


FIGURE 3. Delta model for deposition of the Borden Formation in Kentucky, Indiana, and Ohio during Early Mississippian time. (A) As Borden delta lobes prograded across the tristate area, away from the average paleoshoreline, the progressively younger and shallower members of the Borden Formation were deposited. (B) Each member of the Borden Formation represents a different position on the delta front. Modified from Kepferle (1977) and Ettensohn and others (2009).

Field observations of the Borden Formation along the AA Highway between Vanceburg and Greenup, Kentucky, confirmed the similarities to the strata mapped by Slucher and others (2006) as Logan and Cuyahoga Formations undivided in the Portsmouth project area. As a result of these similarities, and others noted during examination of outcrops, cores, and DEM data, the Ohio Geological Survey has adopted the stratigraphic nomenclature and applied member names of the Borden Formation to the Lower Mississippian strata in the Portsmouth project area (fig. 4, plate 2) after Potter and others (1991). The units on *Bedrock Geology of the Portsmouth, Ohio Region (Portsmouth, Friendship, West Portsmouth, & New Boston 7.5-Minute Quadrangles)* include, in ascending order: the Berea-Bedford undivided; Sunbury Shale and Henley Member of the Borden Formation undivided; and Borden Formation members, including the Farmers, Portsmouth, Nancy, and Cowbell. The Lower Pennsylvanian strata depicted on the bedrock map are rocks of the Breathitt Group (plate 2; Fugitt and Blakeman, 2016).

Stratigraphic Correlations

The bedrock map for the Portsmouth region (plate 2) includes the Bedford Shale and Berea Sandstone as basal units. These rocks are Devonian in age and are not divided for mapping purposes because of the heavily interbedded and highly gradational nature of the units.

Overlying the Berea Sandstone is the Lower Mississippian Sunbury Shale. While easily distinguishable in outcrop, the Sunbury Shale is not divided from the overlying Henley Member of the Borden Formation for the purposes of mapping. The decision to combine these units on the geologic map (plate 2) resulted from the map scale; at 1:24,000 scale, the

resolution is not high enough to separate beds that average approximately 20 ft (6 m) in thickness.

Henley Member

The Henley Bed of the Borden Formation of Kentucky (Ettensohn and others, 2004) is a recognized unit in both Ohio and Kentucky. In Kentucky, the Henley Bed is the lowermost member of the Borden Formation and is composed of homogenous mudstone with a

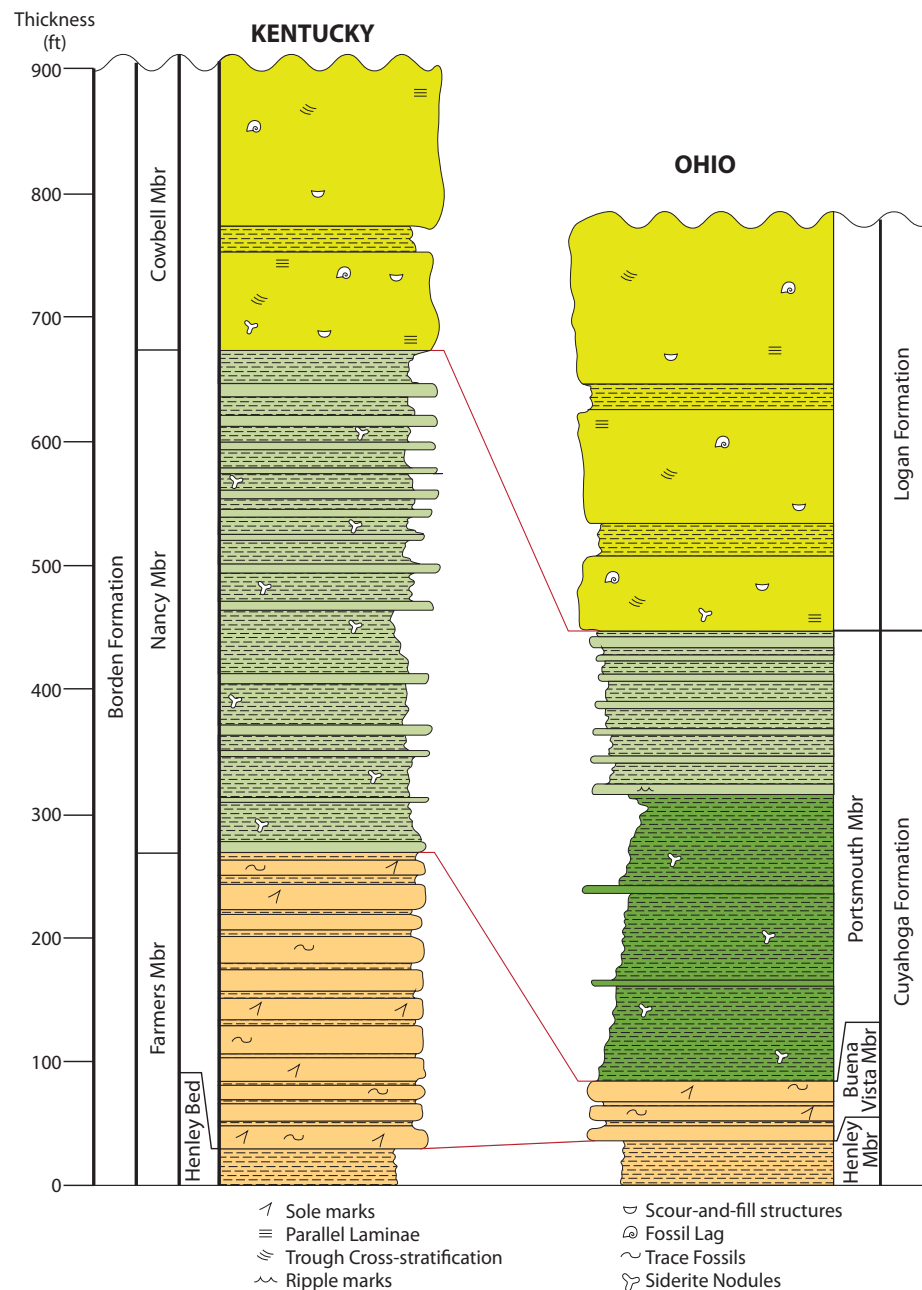


FIGURE 4. Stratigraphic columns correlating the units in the Portsmouth, Ohio, region with the Borden Formation in Kentucky (after Potter and others, 1991). Ohio unit names are based on Hyde (1953) in order to demonstrate the correlations between strata in southern Ohio and north-central Kentucky.

few interbedded, thin siltstones ranging in color from gray green at its southernmost extent to red in southern Ohio (Chaplin, 1980; Matchen and Kammer, 1994; Robinson and Mason, 2004). The Henley Bed ranges in thickness from 10 to 90 ft (3 to 27 m; Potter and others, 1991; Matchen and Kammer, 1994). Very few fossils are preserved in the Henley Bed, but it contains an abundant and diverse microfossil fauna (Chaplin, 1980).

In Ohio, the Henley Bed is recognized as the Henley Member of the Borden Formation. The Henley Member is composed of red or green silty shales that average 20 ft (6 m) in thickness. Siltstone beds are uncommon but occur in the Henley Member at some localities. No macrofossils have been observed in the Henley Member.

Farmers Member

In Kentucky, the Farmers Member of the Borden Formation overlies the Henley Bed and is composed of alternating, tabular-bedded siltstones and shales (fig. 5A). The siltstones in the Farmers Member typically are parallel laminated, and the individual beds are uniform in thickness across their areal distributions. Individual siltstone beds reach a maximum thickness of 3 ft (1 m) in Scioto County, Ohio, and contain an abundance of trace fossils on their upper surfaces, especially *Zoophycos*, and sole marks on their bases (Chaplin and Mason, 1978; Chaplin, 1980; Robinson and Mason, 2004). The siltstones contain internal sedimentary structures, such as parallel, current ripple, and convolute laminae.

The Farmers Member in Ohio is the lateral equivalent of the Farmers Member in Kentucky. The Farmers Member in the Portsmouth region is a white to yellowish-brown shale-interbedded siltstone (fig. 5B). The siltstone beds vary in thickness up to 18 in (45 cm) and exhibit abundant sole marks. These beds contain parallel laminations, ripple marks, and abundant trace fossils on their upper surfaces. *Zoophycos* trace fossils are abundant.

Portsmouth Shale Member

The Portsmouth Shale Member of the Borden Formation in Ohio is correlative with the lower portion of the Nancy Member of Kentucky. The Portsmouth Shale Member is primarily a gray clay shale with very few siltstone interbeds and a much higher clay composition than is found in the Nancy Member of Kentucky. At Portsmouth, the Portsmouth Shale Member reaches approximately 250 ft (76 m) in thickness and has a significant impact on the topography of the region, appearing as steep slopes and rutted terrain on DEMs and slope maps.

Nancy Member

In Kentucky, the Nancy Member of the Borden Formation gradationally overlies the Farmers Member and is composed of heavily bioturbated, blue-green shales that weather to buff-colored clays (fig. 5C). The Nancy Member also contains thin siltstone interbeds (Chaplin and Mason, 1978). The shale in the lower portion of the Nancy Member contains abundant fossiliferous siderite nodules and lenses (Chaplin, 1980; Etensohn and others, 2009).

The Nancy Member of Ohio correlates with the upper portion of the Nancy Member of Kentucky. Field observations indicate that the upper portion fits the description of the Nancy Member in Kentucky and is composed of siltstone-interbedded shales (fig. 5D). Siderite and phosphatic nodules are abundant in the silty shales of the Nancy Member.

Cowbell Member

The Cowbell Member of the Borden Formation in Kentucky conformably overlies the Nancy Member above a gradational contact and it ranges in thickness from approximately 300 to 380 ft (91 to 116 m). The Cowbell Member is composed of alternating massive siltstones and shales, with the highest abundance of shales in its middle interval and more massive siltstones at its base and top (fig. 5E). The Cowbell Member contains abundant siderite lenses, especially in its basal interval (Chaplin, 1980). The massive siltstone unit at its base is heavily pitted and bioturbated and contains scoured intervals and laminations (Chaplin, 1980).

The Logan Formation in the Portsmouth region shares sedimentological characteristics with the Cowbell Member of the Borden Formation in Kentucky. Therefore, the map of the study area adopted the Cowbell Member of the Borden Formation (plate 2; Fugitt and Blakeman, 2016). This unit is composed primarily of white to dark gray siltstones with uncommon shale intervals and includes parallel laminations, small- and large-scale scours, occasional fossil lag beds, and exhibits a characteristic spalling weathering pattern on outcrops (fig. 5F).

CONCLUSIONS

The bedrock units of southern Ohio that were originally defined as the Waverly Series by Briggs (1838) have undergone a continual evolution of nomenclature up to the present day. Early mappers were unmatched in their powers of observation and attention to detail. Their work formed the basis for later researchers who build on their work and benefit from having vast volumes of geologic and geographic data that can be managed by Geographic Information Systems. The availability of this data, and a better understanding of facies analyses, warrants clarification of their early work.

Early researchers tended to think of geologic units as flat lying, homogenous, and regionally continuous. Modern stratigraphers understand that this is only the case in certain circumstances, such as large sedimentary basins. Many depositional systems, such as deltas, are capable of depositing massive amounts of sediments in short periods of time and then shifting across wide distances. Under such circumstances, the nature of sediments can change markedly within a relatively short lateral distance while being a part of the same overall basin. Geologists now understand these processes better through studies of modern deltaic and fluvial analogs and their comparison to

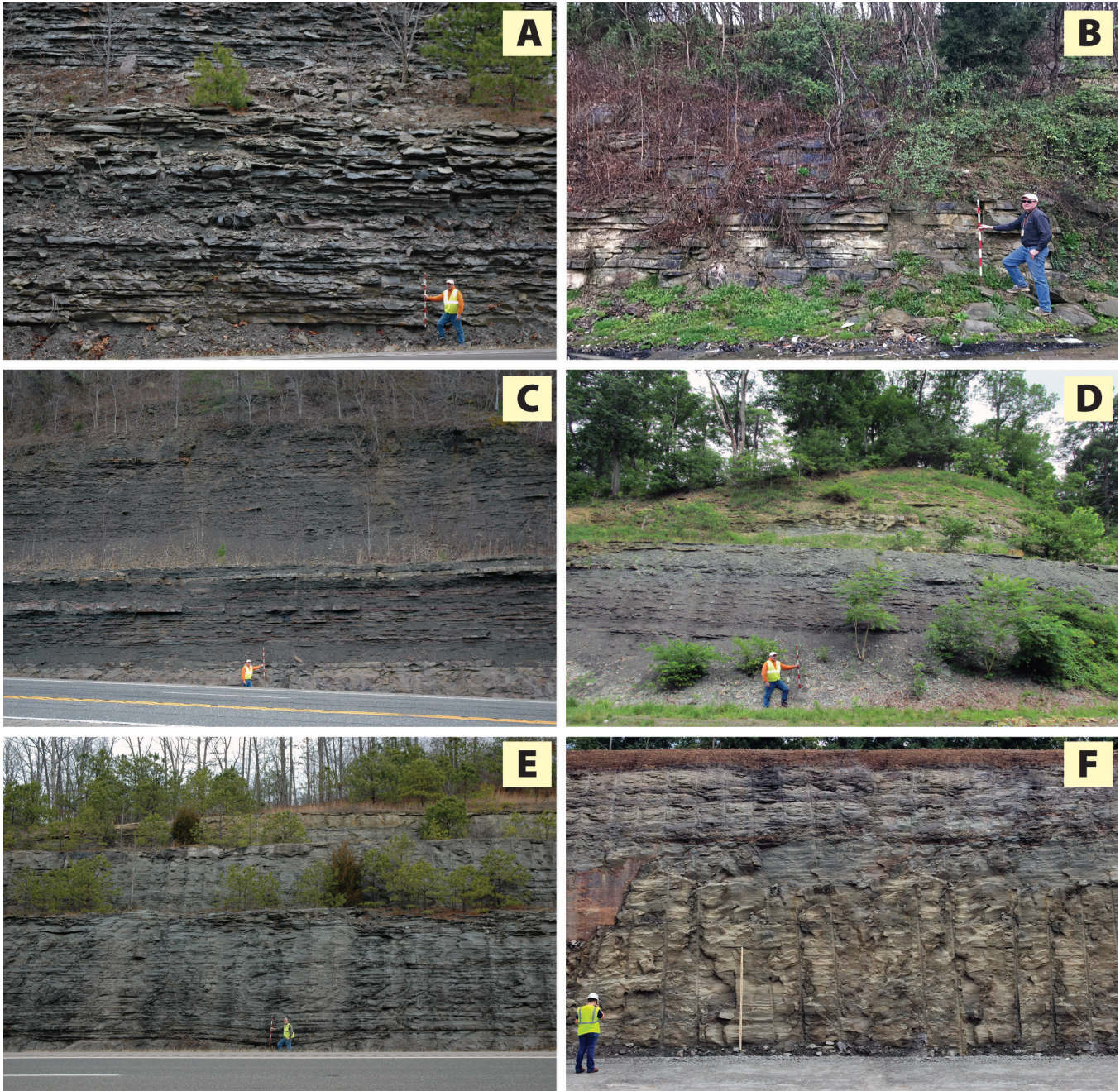


FIGURE 5. Photos demonstrating similarities observed between Lower Mississippian Borden Formation units in the Portsmouth region of Ohio and the Vanceburg region of Kentucky. (A) Farmers Member in Kentucky, while significantly thicker than in the Portsmouth region, is also composed of buff to white-colored shale-interbedded siltstone. (B) Farmers Member in Ohio, composed of buff to white shale-interbedded siltstone. (C) Nancy Member outcrop in Kentucky showing a silty shale with siltstone interbeds. (D) Outcrop of the Nancy Member in Ohio, composed primarily of silty shales interbedded with thin siltstones. (E) Roadcut exposure of the Cowbell Member in Kentucky depicting a laminated siltstone unit containing large-scale scour features. (F) Exposure of the Cowbell Member in southern Ohio; this exposure is composed primarily of laminated siltstone with large scour features.

rocks in the geologic record using outcrops, quarries, core, electric logs, and other sources of analysis.

Such is the case with rocks of the lower Mississippian-age units in southern Ohio, as discussed in this paper. Unlike the units of the Devonian, where general agreement of the stratigraphic nomenclature took place relatively early on (for example, Prosser, 1905), the Mississippian nomenclature have been in a constant state of flux. This is likely because the depositional systems during Mississippian time were vastly different from those during the Devonian Period. However, early workers did not consider this and tried to fit the Mississippian units into a single, flat-lying, continuous system and applied a nomenclature statewide. Today, we see that many of these units are, in fact, separate units deposited within approximately the same time but as part of separate depositional systems. The matter was further complicated by the fact that researchers working in different parts of the state tried to apply the nomenclature too far afield from their type localities. One of the problems specifically encountered in this research is the frequent usage of the names *Logan* and *Cuyahoga*, which were originally described in central and northern Ohio and then frequently (and incorrectly) applied to similar-aged units in southern Ohio.

Clarity finally began to appear as Ohio geologists began working with geologists from Kentucky and realized that geologic units can, not surprisingly, be continuous across rivers and state lines. The stratigraphic columns of Sheppard (1964), OGS/GSK (1968), and Potter and others (1991) illustrate the results of the exchange of information between geologists of the two states (plate 1).

The detailed bedrock mapping of the four quadrangles in Scioto County (plate 2; Fugitt and Blakeman, 2016) confirms what past researchers have proposed; the lower Mississippian strata is continuous between northern Kentucky and southern Ohio. Therefore, it is proposed that Ohio adopt some of the nomenclature from Kentucky and apply these names to similar mapped units in Ohio. Specifically, it is proposed that usage of the Cuyahoga and Logan Formations in the Portsmouth region be eliminated and replaced with the Borden Formation and its members: Henley, Farmers, Portsmouth, Nancy, and Cowbell (plate 1).

The bedrock mapping program proposed in 2017, and approved by the Bedrock Mapping Advisory Council in July 2017, intends to continue the bedrock mapping northward into areas more traditionally mapped as Cuyahoga and Logan Formations. Additional mapping likely will shed light on the relationship between the “southern” Mississippian stratigraphy and the more traditional “northern” stratigraphy of the Logan and Cuyahoga Formations. Whether the change will be gradational or abrupt remains to be confirmed.

ACKNOWLEDGMENTS

Mapping of the Friendship, New Boston, Portsmouth, and West Portsmouth 7.5-minute quadrangles was made possible through a STATEMAP grant provided by the U.S. Geological Survey. Thanks are extended to Dr. Ron Martino and Dr. Paul Potter for their invaluable assistance in observing the Borden Formation in northern Kentucky, as well as for their assistance during the review process. Special thanks also to Frank Fugitt of the Ohio Geological Survey for his guidance, mentorship, and enthusiasm in both the office and the field.

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PLATE 1.

Historic nomenclature of Upper Devonian and Lower Mississippian strata in southern Ohio. Nomenclature that resulted from the exchange of geologic information between Ohio and Kentucky geologists are shown with gray column headings.

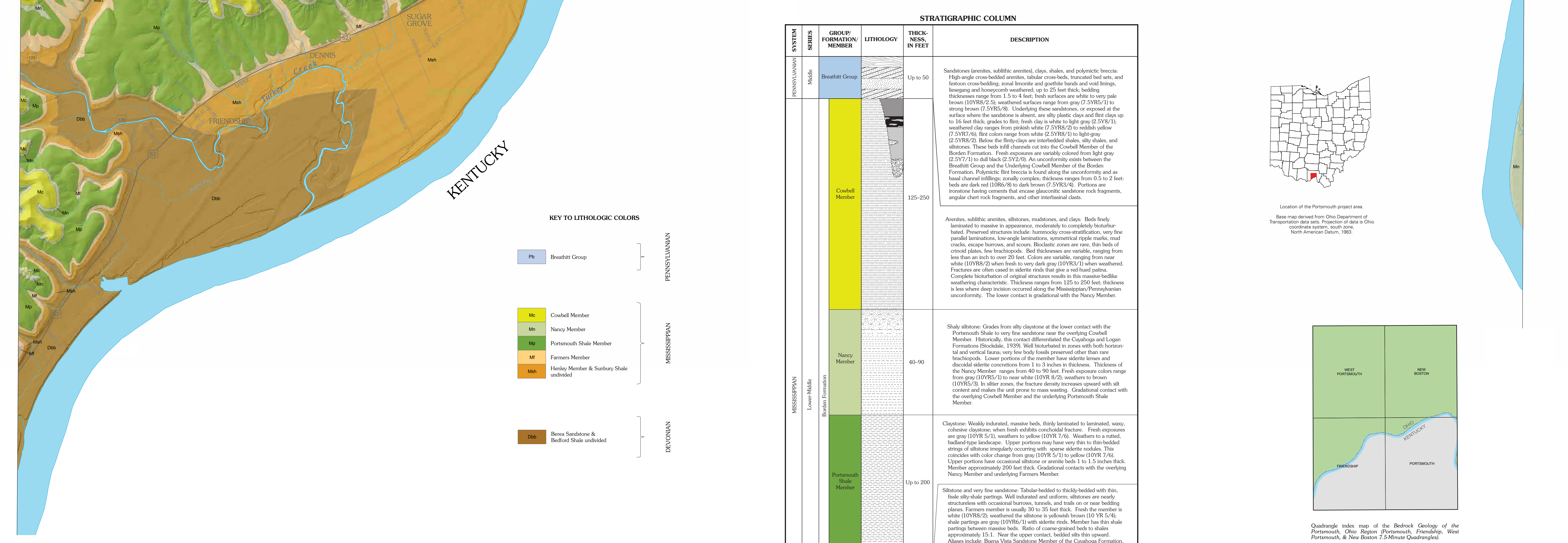
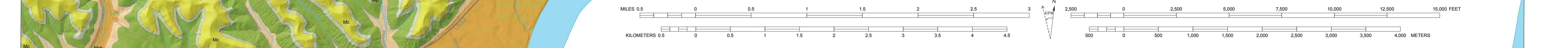
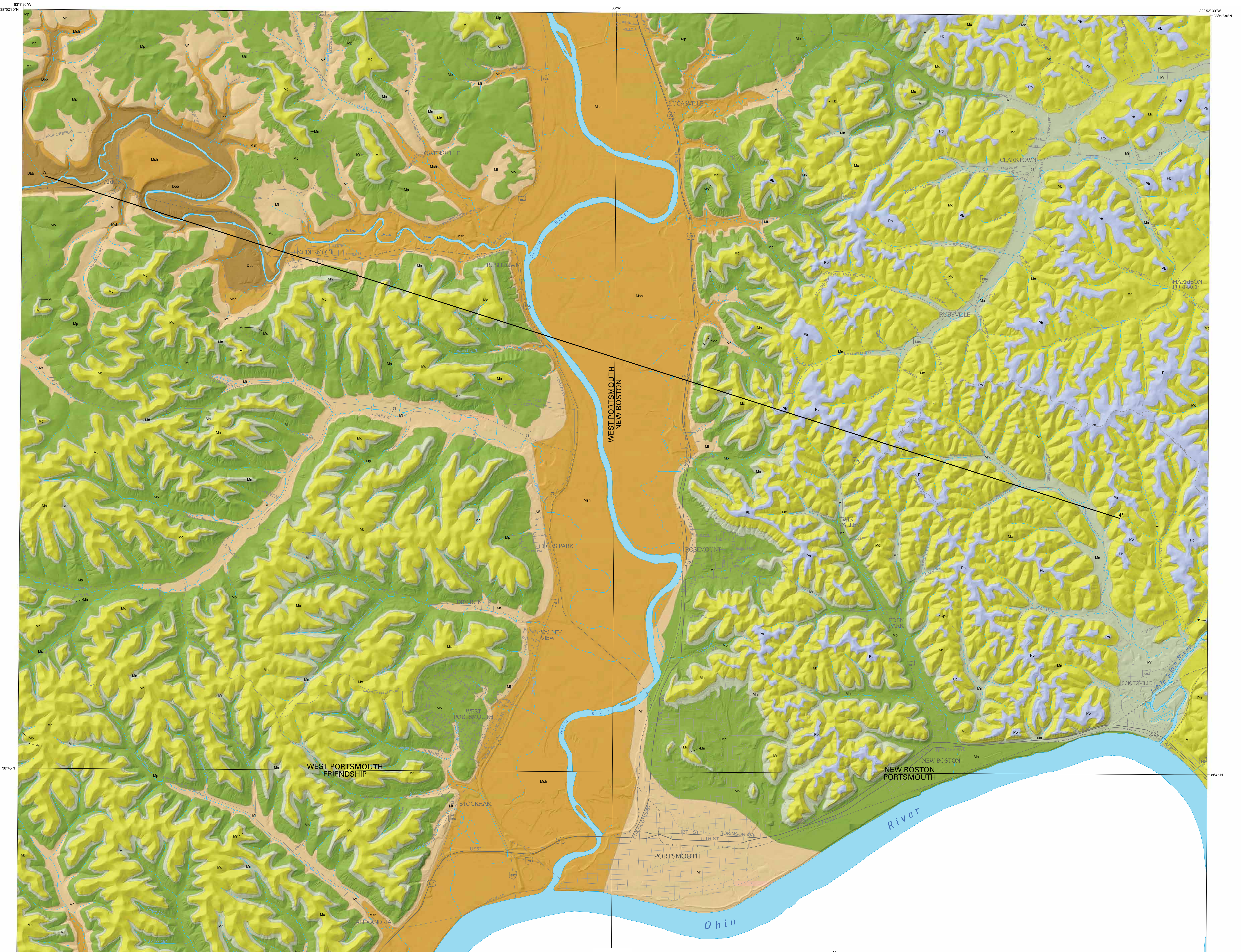
System ¹	Briggs, 1838	Andrews, 1870	Orton, 1874	Orton, 1888	Prosser, 1905	Hyde, 1915	Bownocker, 1920	Hyde, 1953 ²	Sheppard, 1964	Ohio Geological Society and Geological Society of Kentucky, 1968	Ohio Division of Geological Survey, 1990	Potter and others, 1991	Slucher and others, 2006	Fugitt and Blakeman, 2016																
Lower Mississippian	Waverly Sandstone Series	Waverly Sandstone Series	-	Logan Ss	Logan Gp	Logan Fm	Logan Fm	Vinton Mbr	Upper Borden Fm	-	siltstone mbr	Logan Fm	Cowbell Mbr	Logan and Cuyahoga Fms undivided	Cowbell Mbr															
				--	Cuyahoga Sh			Cuyahoga Fm								--	Cuyahoga Fm	SCIOTO VALLEY FACIES	Portsmouth Mbr	VANCEBURG SANDSTONE FACIES	Churn Creek Mbr	Lower Borden Fm	-	shale mbr	Cuyahoga Fm	--	Borden Fm	Nancy Mbr	Borden Fm	Nancy Mbr
																					Byer Mbr									
			Upper Waverly Ss	Buena Vista Ss	Buena Vista Ss	Buena Vista Mbr	Buena Vista Mbr	Buena Vista Mbr	Buena Vista Mbr	Buena Vista Mbr	Rarden Mbr	Rarden Mbr	Rarden Mbr		Lower Borden Fm	shale mbr	Buena Vista Mbr	Farmers Mbr	Farmers Mbr	Farmers Mbr										
			--	Waverly Black Slate	Berea Sh	Sunbury Sh	Sunbury Sh	Sunbury Sh	Sunbury Sh	Sunbury Sh	--	Sunbury Sh	Sunbury Sh		Sunbury Sh	Sunbury Sh	Sunbury Sh	Sunbury Sh												
			City Ledge Ss	Waverly Quarry System	Berea Grit	Berea Grit	Berea Grit	Berea Grit	Berea Grit	Berea Grit	Berea Ss	--	Berea Ss		Berea Ss	Berea Ss	Berea Ss	Sunbury Sh, Berea Ss, and Bedford Sh undivided	Berea Ss											
				Waverly Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	--	Bedford Sh		Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh											
			Upper Devonian	Waverly Sandstone Series	Waverly Sandstone Series	-	Berea Sh	Berea Grit	Berea Grit	Berea Grit	Berea Ss	--	Berea Ss		Berea Ss	Berea Ss	Berea Ss	Sunbury Sh, Berea Ss, and Bedford Sh undivided	Berea Ss											
																				Waverly Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh	Bedford Sh

Fm	Formation
Gp	Group
Mbr	Member
Ss	Sandstone
Sh	Shale

¹ Not to scale. Shows relative stratigraphic positions of units, not thicknesses.
² Published posthumously. Work completed prior to 1936.
³ -- Absent or not described.

BEDROCK GEOLOGY OF THE PORTSMOUTH, OHIO REGION (PORTSMOUTH, FRIENDSHIP, WEST PORTSMOUTH, & NEW BOSTON 7.5-MINUTE QUADRANGLES)

by Frank L. Fugitt and Audrey A. Blakeman GIS Database Administration by Joseph G. Wells GIS Cartography by Dawn R. Martin

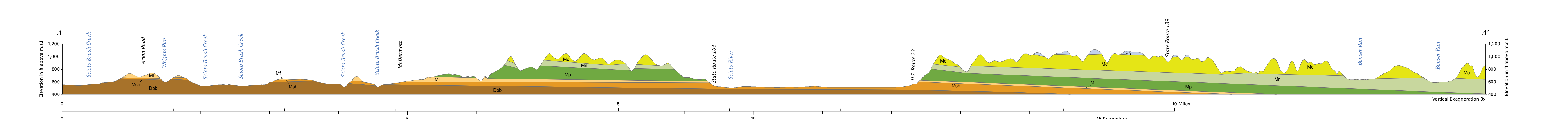


KEY TO LITHOLOGIC COLORS: PB Beechell Group, MC Cowbell Member, MN Nancy Member, MS Portsmouth Shale Member, FM Farmers Member, HB Haskin Member & Starbury Shale undivided, RS Rensselaerville & Beechell Shale undivided.

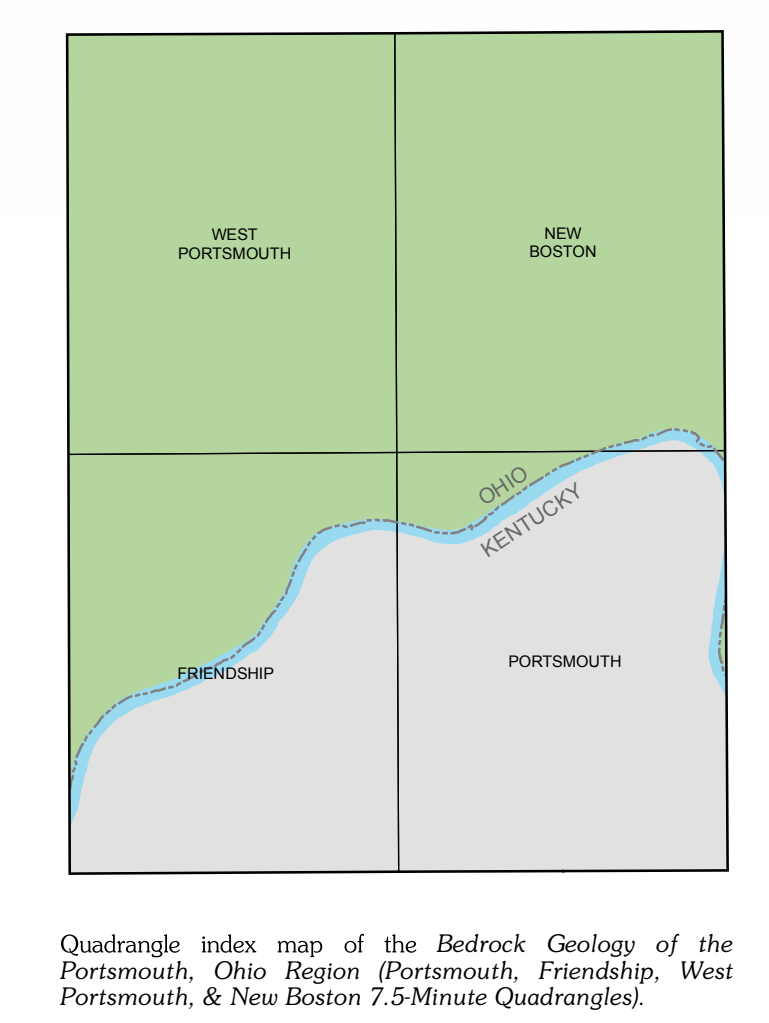
ACKNOWLEDGMENTS: This map project was partially funded by the United States Geological Survey, STATEMAP component of the National Cooperative Geologic Mapping Program (NCGMP).

REFERENCES: Chapin, J.R., and Mason, C.E., 1978. Geologic map of the Goshen quadrangle, Kentucky, Ohio, and part of the Paul Run quadrangle, Lane County, Kentucky. U.S. Geological Survey Geologic Quadrangle Map G-278, scale 1:250,000.

MAPPING CONVENTIONS: Between 1965 and 1997, the Ohio Department of Natural Resources, Division of Geological Survey (Ohio Geological Survey) produced reconnaissance bedrock geologic maps of Ohio's 708 individual 7.5-minute quadrangles.



Cross-section of the Bedrock Geology of the Portsmouth, Ohio Region (Portsmouth, Friendship, West Portsmouth, & New Boston 7.5-Minute Quadrangles). See Key to Lithologic Colors for explanation of symbols and Stratigraphic Column for explanation of lithology units.



DISCLAIMER: The product of the Ohio Department of Natural Resources (ODNR), Division of Geological Survey is intended to provide a broad bedrock geologic framework and general information only and should not be used for any other purpose.

Recommended Bibliographic Citation for this Map: Fugitt, F.L., and Blakeman, A.A., 2016. Bedrock geology of the Portsmouth, Ohio region (Portsmouth, Friendship, West Portsmouth, & New Boston 7.5-minute quadrangles). Columbus, Ohio: Department of Natural Resources, Division of Geological Survey Map BG-2-POR, scale 1:250,000.

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