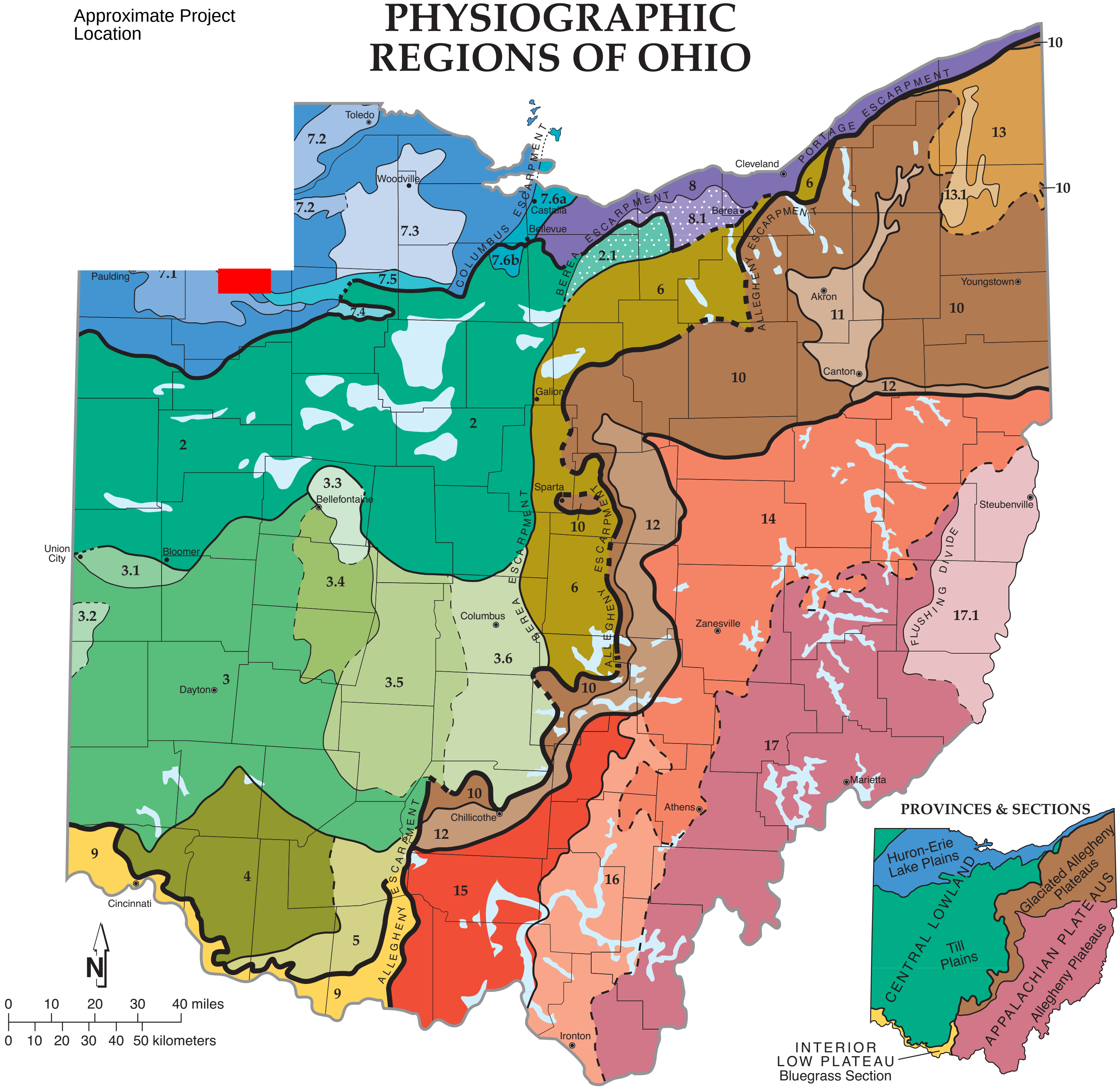
Appendix A

Atlas Maps

PHYSIOGRAPHIC REGIONS OF OHIO



Transitional boundary

Lake basin/deposits outside Huron-Erie Lake Plains

Till Plains

1. Steuben Till Plain
2. Central Ohio Clayey Till Plain
   - 2.1. Berea Headlands of the Till Plain
3. Southern Ohio Loamy Till Plain
   - 3.1. Union City-Bloomer Transitional Terrain
   - 3.2. Whitewater Interlobate Plain
   - 3.3. Bellefontaine Upland
   - 3.4. Mad River Interlobate Plain
   - 3.5. Darby Plain
   - 3.6. Columbus Lowland
4. Illinoian Till Plain
5. Dissected Illinoian Till Plain
6. Galion Glaciated Low Plateau

Huron-Erie Lake Plains

7. Maumee Lake Plains
   - 7.1. Paulding Clay Basin
   - 7.2. Maumee Sand Plains
   - 7.3. Woodville Lake-Plain Reefs
   - 7.4. Findlay Embayment
   - 7.5. Fostoria Lake-Plain Shoals
   - 7.6a and 7.6b. Bellevue-Castalia Karst Plain
8. Erie Lake Plain
   - 8.1. Berea Headlands of the Erie Lake Plain

Bluegrass Section

9. Outer Bluegrass Region

Glaciated Allegheny Plateaus

10. Killbuck-Glaciated Pittsburgh Plateau
11. Akron-Canton Interlobate Plateau
12. Illinoian Glaciated Allegheny Plateau
13. Grand River Low Plateau
   - 13.1 Grand River Finger-Lake Plain

Allegheny Plateaus

14. Muskingum-Pittsburgh Plateau
15. Shawnee-Mississippian Plateau
16. Ironton Plateau
17. Marietta Plateau
   - 17.1. Little Switzerland Plateau

4/98

Recommended citation: Ohio Division of Geological Survey, 1998, Physiographic regions of Ohio: Ohio Department of Natural Resources, Division of Geological Survey, page-size map with text, 2 p., scale 1:2,100,00.

PHYSIOGRAPHIC REGIONS OF OHIO

Major Divisions	Provinces	Sections *	DISTINGUISHING CHARACTERISTICS OF REGIONS & DISTRICTS	GEOLOGY	BOUNDARIES
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**1. Steuben Till Plain.** Hummocky terrain with rolling hills, interspersed flats and closed depressions; wetlands, few streams, deranged drainage; only a small part of the region is in Ohio; elevation 950'-1100', moderately low relief (60')	Wisconsinan-age (latest Ice-Age) loamy till from a northern source (Saginaw glacial lobe) over Mississippian-age Coldwater Shale	Southeast: edge of Wabash Moraine
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**2. Central Ohio Clayey Till Plain.** Surface of clayey till; well-defined moraines with intervening flat-lying ground moraine and intermorainal lake basins; no boulder belts; about a dozen silt-, clay- and till-filled lake basins range in area from a few to 200 square miles; few large streams; limited sand & gravel outwash; elevation 700'-1150', moderate relief (100')	Clayey, high-lime Wisconsinan-age till from a northeastern source (Erie glacial lobe) and lacustrine materials over Lower Paleozoic-age carbonate rocks and, in the east, shales; loess thin to absent	North: Lake Plain; northeast: limit of Berea Sandstone; east: Berea Escarpment; south: Powell and Union City/Bloomer Moraines; northern segment boundaries: Wabash Moraine and lake plain
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**2.1. Berea Headlands of the Till Plain.** Gently rolling to flat terrain of thin drift descending to Lake Erie; punctuated by more than 20 streamlined "whalebacks" of Berea Sandstone, 0.5 to 2.5 miles long, 30'-60' high; somewhat poorly drained; elevation 800'-1000', low relief (20')	Thin, clayey, medium-lime Wisconsinan-age till over resistant Mississippian-age Berea Sandstone	South: limit of Berea Sandstone; elsewhere: Berea Escarpment and/or margin of highest Pleistocene lake
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3. Southern Ohio Loamy Till Plain.** Surface of loamy till; end and recessional moraines, commonly associated with boulder belts, between relatively flat-lying ground moraine, cut by steep-valleyed large streams; stream valleys filled with outwash and alternate between broad floodplains and narrows; buried valleys common; elevation 530'-1150', moderate relief (200')	Loamy, high-lime Wisconsinan-age till, outwash, and loess over Lower Paleozoic-age carbonate rocks and, in the east, shales	East: Berea and Allegheny Escarpments; north: Powell and Union City/Bloomer Moraines; south: limit of Wisconsinan-age till
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3.1. Union City-Bloomer Transitional Terrain.** Well-defined moraines with low-relief, hummocky ground moraine like the Central Ohio Clayey Till Plain to the north; loamy till with loess cap like Southern Ohio Loamy Till Plain to the south; elevation 920'-1075', moderately low relief (30')	Loamy, high-lime Wisconsinan-age till with thin loess cap over Silurian-age dolomites	North: Bloomer Moraine and limit of loamy till; south: Union City Moraine
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3.2. Whitewater Interlobate Plain.** An upland between two converging glacial lobes with hummocky moraines, moraine complexes, kames, boulder belts, and broad outwash trains/plains; contains highest elevations in Indiana (1257') and in adjacent Ohio counties (1240'); elevation in Ohio 980'-1240', moderate relief (150')	Loamy, high-lime Wisconsinan-age till and sand and gravel outwash over resistant Silurian-age carbonate rocks (north) and less resistant Ordovician-age shales and limestones (south)	North: limit of Knightstown/Farmersville Moraines and kame fields; east: high, dissected hills draining to Whitewater River
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3.3. Bellefontaine Upland.** Moderately high relief (250') dissected topography with moraine complexes, boulder belts, high-gradient major streams, caves and sinkholes; few glacial depressions/kettles compared to surrounding areas; elevation 1100'-1549', includes highest elevation in Ohio (Campbell Hill, 1549')	Loamy, high-lime Wisconsinan-age till over generally deeply buried Silurian- to Devonian-age carbonate rocks and Ohio Shale	North: areas with hilltops above 1200'; elsewhere: hilltops above about 1300'
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3.4. Mad River Interlobate Plain.** Area between two major converging glacial lobes with extensive outwash, outwash terraces, and bordering moraines; springs and cool, ground-water-fed surface waters; elevation 800'-1350', moderate relief (200')	Loamy, high-lime Wisconsinan-age till and sand and gravel outwash over Silurian- to Devonian-age carbonate rocks and Ohio Shale	East and north: rear edge of Cable Moraine Complex; south: outwash to Clifton Gorge; west: western edge of Mad River Outwash
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3.5. Darby Plain.** Moderately low relief (25'), broadly hummocky ground moraine with several broad, indistinct recessional moraines; between hummocks are broad, poorly drained swales which held wet prairies/meadows in pioneer days; few large streams; elevation 750'-1100'	Loamy, high-lime Wisconsinan-age till and sparse outwash over Silurian- and Devonian-age carbonate rocks and Ohio Shale in the southeast	South and west: front of Reesville and rear of Cable Moraines; north: Powell Moraine; east: increasing eastward slope (see 3.6)
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**3.6. Columbus Lowland.** Lowland surrounded in all directions by relative uplands, having a broad regional slope toward the Scioto Valley; many larger streams; elevation 600'-850' (950' near Powell Moraine), moderately low relief (25')	Loamy, high-lime (west) to medium-lime (east) Wisconsinan-age till and extensive outwash in Scioto Valley over deep Devonian- to Mississippian-age carbonate rocks, shales, and siltstones	North: Powell Moraine; east and south: Berea and/or Allegheny Escarpments; west: flatter and higher Darby Plain
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**4. Illinoian Till Plain.** Rolling ground moraine of older till generally lacking ice-constructional features such as moraines, kames, and eskers; many buried valleys; modern valleys alternating between broad floodplains and bedrock gorges; elevation 600'-1100', moderately low relief (50')	Silt-loam, high-lime, Illinoian-age till with loess cap; soils leached several feet; underlain by Ordovician- and Silurian-age carbonate rocks and calcareous shales	North: Wisconsinan glacial margin (Cuba and Hartwell Moraines); elsewhere: limit of common till-covered hillslopes
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**5. Dissected Illinoian Till Plain.** Hilly former till plain in which glacial deposits have been eroded from many valley sides; relatively high stream density; elevation 600'-1340', moderate relief (200')	Hilltops of high-lime Illinoian-age till with loess cap; slopes of bedrock- and till-derived colluvium and Ordovician- and Silurian-age carbonate rocks and calcareous shales	East: maximum glacial margin; elsewhere: limit of general absence of till on hillslopes
INTERIOR PLAINS	CENTRAL LOWLAND	Till Plains	**6. Galion Glaciated Low Plateau.** Rolling upland transitional between the gently rolling Till Plain and the hilly Glaciated Allegheny Plateau; mantled with thin to thick drift; elevation 800'-1400', moderate relief (100')	Medium- to low-lime Wisconsinan-age till over Mississippian-age shales and sandstones	North: limit of Berea Sandstone; west: Berea Escarpment; south and east: Allegheny Escarpment
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7. Maumee Lake Plains.** Flat-lying Ice-Age lake basin with beach ridges, bars, dunes, deltas, and clay flats; contained the former Black Swamp; slightly dissected by modern streams; elevation 570'-800', very low relief (5')	Pleistocene-age silt, clay, and wave-planed clayey till over Silurian- and Devonian-age carbonate rocks and shales	Northeast: Lake Erie; elsewhere: margin of highest Pleistocene lake
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7.1. Paulding Clay Basin.** Nearly flat lacustrine plain; most clayey of all Lake Plain subregions; low-gradient, highly meandering streams; easily ponded soils; elevation 700'-725', extremely low relief (less than 5')	Pleistocene-age lacustrine clay over clay till and Silurian-age dolomites	Northeast: subdued ("drowned") remnant of Defiance Moraine; elsewhere: limit of lacustrine clay
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7.2. Maumee Sand Plains.** Lacustrine plain mantled by sand; includes low dunes, inter-dunal pans, beach ridges, and sand sheets of glacial lakeshores; well to poorly drained; elevation 600'-800', very low relief (10')	Late Wisconsinan-age sand over clay till and lacustrine deposits; Silurian- and Devonian-age carbonate rocks and shales buried deeply.	Limit of sandy deposits and/or low dunes
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7.3. Woodville Lake-Plain Reefs.** Very low relief (10') lacustrine plain with low dunes and lake-margin features, punctuated by more than 75 ancient bedrock reefs rising 10' to 40' above the level of the plain and ranging in area from 0.1 to 3.0 square miles; the oblong reefs are thinly draped with drift; elevation 600'-775'	Thin to absent Wisconsinan-age wave-planed clay till, lacustrine deposits, and sand over Silurian-age reefal Lockport Dolomite	Limit of thinly mantled Lockport Dolomite (Bowling Green Fault to the west and the Defiance Moraine to the south)
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7.4. Findlay Embayment.** Very low relief (10'), broadly rolling lacustrine plain; embayment of ancestral Lake Erie in which relatively coarse lacustrine sediments collected; elevation 775'-800'	Silty to gravelly Wisconsinan-age lacustrine deposits and wave-planed clayey till over Silurian-age Lockport Dolomite	West: 775' beach ridge; north: Defiance Moraine; south: margin of highest Pleistocene lake level
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7.5. Fostoria Lake-Plain Shoals.** Portion of the Defiance Moraine lightly eroded by shallow Lake Maumee with low north-south trending hillocks and shallow, closed depressions; many sandy areas; elevation 750'-825', low relief, decreasing westward (10'-15')	Silty to gravelly Wisconsinan-age lacustrine deposits and wave-planed clay till over deeply covered Silurian-age dolomite	South and east: unmodified Defiance Moraine; elsewhere: very low-relief lake plain
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**7.6a and 7.6b. Bellevue-Castalia Karst Plain.** Hummocky plain of rock knobs and numerous sinkholes, large solution features, and caves; large springs; thinly mantled by drift; region straddles both Lake Plain (7.6a) and Till Plain (7.6b); 7.6a has greatest relief of any Lake Plain region (25'); elevation 570'-825'	Columbus and Delaware Limestones overlain by thin clay till in 7.6b, and thin silty and sandy Wisconsinan-age lacustrine deposits and wave-planed clay till in 7.6a	Limit of thinly mantled Columbus and Delaware Limestones, which is marked in the west by the Columbus Escarpment
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**8. Erie Lake Plain.** Edge of very low-relief (10') Ice-Age lake basin separated from modern Lake Erie by shoreline cliffs; major streams in deep gorges; elevation 570'-800'	Pleistocene-age lacustrine sand, silt, clay, and wave-planed till over Devonian- and Mississippian-age shales and sandstones	North: Lake Erie; south: margin of highest Pleistocene lake
INTERIOR PLAINS	CENTRAL LOWLAND	Huron-Erie Lake Plains	**8.1 Berea Headlands of the Erie Lake Plain.** Portion of the Erie Lake Plain underlain by resistant Berea Sandstone; several large sandstone headlands jut into the Ice-Age lake basin; contains several streamlined "whalebacks" of Berea Sandstone, 0.5 to 2.0 miles long, 20'-35' high; poorly drained; elevation 670'-800', very low relief (10')	Thin lacustrine deposits over thin, wave-planed, clayey, medium-lime Wisconsinan-age till; underlain by resistant Berea Sandstone	North: portion of Lake Plain underlain by soft shales; south: margin of highest Pleistocene lake
INTERIOR PLAINS	INT. LOW PLATEAUS	Bluegrass Section	**9. Outer Bluegrass Region.** Moderately high relief (300') dissected plateau of carbonate rocks; in east, caves and other karst features relatively common; in west, thin, early drift caps narrow ridges; elevation 455'-1120'	Ordovician- and Silurian-age dolomites, limestones, and calcareous shales; thin pre-Wisconsinan drift on ridges in west; silt-loam colluvium	Eastern segment: maximum glacial margin and high eastern ridges capped by noncarbonate rocks; connected by Ohio River bluffs to western segment which is bounded by nondissected till plain
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Glaciated Allegheny (Southern New York) Plateaus	**10. Killbuck-Glaciated Pittsburgh Plateau.** Ridges and flat uplands generally above 1200', covered with thin drift and dissected by steep valleys; valley segments alternate between broad drift-filled and narrow rock-walled reaches; elevation 600'-1505', moderate relief (200')	Thin to thick Wisconsinan-age clay to loam till over Mississippian- and Pennsylvanian-age shales, sandstones, conglomerates and coals	West and north: resistant sandstones of the Allegheny and Portage Escarpments; south and east: Wisconsinan glacial margin
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Glaciated Allegheny (Southern New York) Plateaus	**11. Akron-Canton Interlobate Plateau.** Hummocky area between two converging glacial lobes dominated by kames, kame terraces, eskers, kettles, kettle lakes, and bogs/fens; deranged drainage with many natural lakes; elevation 900'-1200', moderate relief (200')	Sandy Wisconsinan-age and older drift over Devonian- to Pennsylvanian-age sandstones, conglomerates and shales	Limit of common, sandy ice-contact features and deposits
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Glaciated Allegheny (Southern New York) Plateaus	**12. Illinoian Glaciated Allegheny Plateau.** Dissected, rugged hills; loess and older drift on ridgetops, but absent on bedrock slopes; dissection similar to unglaciated regions of the Allegheny Plateau; elevation 600'-1400', moderate relief (200')	Colluvium and Illinoian-age till over Devonian- to Pennsylvanian-age shales, siltstones and sandstones	North and west: Wisconsinan glacial margin; south and east: Illinoian (maximum) glacial margin
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Glaciated Allegheny (Southern New York) Plateaus	**13. Grand River Low Plateau.** Gently rolling ground and end moraine having thin to thick drift; poorly drained areas and wetlands relatively common; elevation 760'-1200', low relief (20') except near Grand River Valley (200')	Clayey, low-lime Wisconsinan-age till over deeply buried, soft Devonian-age shales and near-surface Mississippian-age sandstones and shales	North: Portage Escarpment; south and west: Defiance Moraine; southeast: increasing relief from proximity of buried Pennsylvanian-age sandstones
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Glaciated Allegheny (Southern New York) Plateaus	**13.1. Grand River Finger-Lake Plain.** Very low relief (10') lake deposits in steep-sided troughs (200' relief) within the Grand River Low Plateau; cut by glacial and stream erosion; extensive wetlands; elevation 800'-900'	Surficial lacustrine clay and drift over deeply buried, soft Devonian-age shales	Margins of steeply sloping troughs containing the Grand River and parts of Rock and Mosquito Creeks
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Allegheny (Kanawha) Plateaus	**14. Muskingum-Pittsburgh Plateau.** Moderately high to high relief (300'-600') dissected plateau having broad major valleys that contain outwash terraces, and tributaries with lacustrine terraces; medium-grained bedrock sequences coarser than those in Marietta Plateau (17) but finer than those in Ironton Plateau (16); remnants of ancient Teays-age drainage system uncommon; elevation 650'-1400'	Mississippian and Pennsylvanian-age siltstones, shales, sandstones and economically important coals and claystones; Wisconsinan-age sand, gravel, and lacustrine silt; silt-loam colluvium	North and west: maximum glacial margin; southeast: transition to finer grained bedrock; southwest: transition to coarser grained bedrock
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Allegheny (Kanawha) Plateaus	**15. Shawnee-Mississippian Plateau.** High relief (400'-800'), highly dissected plateau of coarse and fine grained rock sequences; most rugged area in Ohio; remnants of ancient lacustrine clay-filled Teays drainage system are extensive in lowlands, absent in uplands; elevation 490'-1340'	Devonian- and Mississippian-age shales, siltstones, and locally thick sandstones; Pleistocene-age sandy outwash in Scioto River; Teays-age Minford Clay; silt-loam and channery colluvium	North: Maximum glacial margin; west:: carbonate bedrock; east: limit of Mississippian-age bedrock
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Allegheny (Kanawha) Plateaus	**16. Ironton Plateau.** Moderately high relief (300') dissected plateau; coarser grained coal-bearing rock sequences more common than in other regions of the Allegheny Plateau; common lacustrine clay-filled Teays Valley remnants; elevation 515'-1060'	Pennsylvanian-age (Pottsville, Allegheny and Conemaugh Groups) cycles of sandstones, siltstones, shales and economically important coals; Pleistocene (Teays)-age Minford Clay; silt-loam and channery colluvium	West: limit of common Pennsylvanian-age bedrock; north and east: gradation to finer rock sequences
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Allegheny (Kanawha) Plateaus	**17. Marietta Plateau.** Dissected, high-relief (generally 350', to 600' near Ohio River) plateau; mostly fine-grained rocks; red shales and red soils relatively common; landslides common; remnants of ancient lacustrine clay-filled Teays drainage system common; elevation 515'-1400'	Pennsylvanian-age Upper Conemaugh Group through Permian-age Dunkard Group cyclic sequences of red and gray shales, and siltstones, sandstones, limestones and coals; Pleistocene (Teays)-age Minford Clay; red and brown silty-clay loam colluvium; landslide deposits	North and west: transition to medium-grained Lower Conemaugh rocks; east: Flushing Divide
APPALACHIAN HIGHLANDS	APPALACHIAN PLATEAUS	Allegheny (Kanawha) Plateaus	**17.1. Little Switzerland Plateau.** Highly dissected, high-relief (generally 450', to 750' along Ohio River) plateau; mostly fine-grained rocks; red shales and red soils relatively common; landslides common; high-gradient shale-bottomed streams subject to flash flooding; no remnants of ancient Teays drainage system; elevation 540'-1400'	Similar to Marietta Plateau but lacking Pleistocene (Teays)-age Minford Clay	North: transition to medium-grained rocks; west and south: Flushing Divide; east: Ohio River

* Section names modified from Fenneman (1938, 1946).

STATE OF OHIO
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGICAL SURVEY
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DRAFT

SURFICIAL GEOLOGY OF THE DEFIANCE 30 X 60-MINUTE QUADRANGLE IN OHIO

by
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Map SG-2-DEF
Prepared in cooperation with
the United States Geological Survey,
National Cooperative Geologic
Mapping Program (STATEMAP)
Grant No. G10AC00415
9/2012

MAPPING CONVENTIONS

This map provides a three-dimensional framework of the area's surficial geology and depicts four important aspects of surficial geology:

1. Geologic deposits, indicated by **letters** that represent the major lithologies.
2. Thicknesses of the individual deposits, indicated by **numbers** and **modifiers**.
3. Lateral extent of the deposits, indicated by map-unit area boundaries.
4. Vertical sequence of deposits, shown by the stack of symbols within each map-unit area.

Figure 1 illustrates cross section A–A' and mapping conventions. Letters, numbers, and modifiers are arranged in stacks that depict the vertical sequence of lithologic units for a given map-unit area. A single stack of symbols occurs in each map-unit area and applies only to the volume of sediments within that particular map-unit area.

Letters represent geologic deposits (lithologic units) and are described in detail below. Lithologic units may be a single lithology, such as sand (S) or clay (C), or a combination of related lithologies that are found in specific depositional environments, such as sand and gravel (SG) or ice-contact deposits (IC). The bottom symbol in each stack indicates the bedrock lithologies that underlie the surficial deposits. The detailed lithologic unit descriptions below summarize:

1. Geologic characteristics, such as range of textures, bedding, and age.
2. Engineering properties or concerns attributed to the unit.
3. Depositional environment.
4. Geomorphology or geomorphic location.
5. Geographic location within the map area, if pertinent.

Numbers (without modifiers) that follow the lithology designators represent the average thickness of a lithologic unit in tens of feet (for example, *3* represents 30 ft). If no number is present, the average thickness is implied as *1* (10 ft). These unmodified numbers correspond to a thickness range centered on the specified value but may vary up to 50 percent. For example, *T4* indicates an average thickness of till in a map-unit area is 40 ft, but that thickness may vary from 20 to 60 ft.

Modifiers provide additional thickness and distribution information:

1. Parentheses indicate that a unit has a patchy or discontinuous distribution and is missing in portions of that map-unit area. For example, *(T2)* indicates that till with an average thickness of 20 ft is present in only part of that map-unit area.

2. A negative sign (-) following a number indicates the maximum thickness for that unit in areas such as a buried valley or ridge. Thickness decreases from the specified value, commonly near the center of the map-unit area, to the thickness of the same lithologic unit and vertical position specified in an adjacent map-unit area. For example, a *SG9-* map-unit area adjacent to a *SG3* area indicates a sand-and-gravel unit having a maximum thickness of 90 ft that thins to an average of 30 ft at the edge of the map-unit area. If the material is not present in an adjacent area, it decreases to zero at that boundary.

The small scale of this reconnaissance map generalizes the great local variability within surficial deposits. That variability is explained in the lithologic unit descriptions and by the use of thickness ranges. Some areas and lithologies are too small to delineate at 1:100,000 scale and have been included in adjacent areas. This map should serve only as a regional predictive guide to the area's surficial geology and not as a replacement for subsurface borings and geophysical studies required for site-specific characterizations.

DATA SOURCES

Data were collected from numerous sources (see "References"). The concentration of data was greatest near the surface and decreased with depth. County soil survey maps, which describe the top 5 feet of surficial materials, provided an initial guide to map-unit areas. These areas were modified through interpretation of local geomorphic settings and other data that indicated change of deposits at depth, such as water-well logs from the Ohio Department of Natural Resources (ODNR), Division of Water and oil-and-gas-well logs on file at the ODNR Division of Geological Survey (fig. 2); test-boring logs provided by the Ohio Department of Transportation and Ohio Environmental Protection Agency (EPA) and county engineers offices (fig. 3); theses; and published or unpublished geologic reports, maps, and field notes (on file at the ODNR Division of Geological Survey). These data also provided the basis for lithologic unit descriptions that summarize, as accurately as possible, recognized associations of genetically related materials. Total thickness of surficial deposits was calculated from ODNR Division of Geological Survey open-file bedrock topography maps, and bedrock units were summarized from ODNR Division of Geological Survey bedrock geology maps, all of which are available for each 7.5-minute quadrangle in the map area. Land-surface topography was derived from LiDAR data, collected as part of the Ohio Statewide Imagery Program, which were converted into a 12.5 x 12.5-ft-resolution digital elevation model (DEM) and shaded-relief model by the Ohio EPA. Detailed descriptions of 3-D mapping methods are described in Venteris (2007) and McDonald and others (2007).

LITHOLOGIC UNIT DESCRIPTIONS

SURFICIAL UNITS

m — **Made land.** Large areas of cut and fill, such as dams, landfills, and urban areas; may include reclaimed or active quarries or pits. Underlain by bedrock or other lithologic units.

a — **Alluvium (Holocene).** Includes a wide variety of textures from silt and clay to boulders; commonly includes organic material; generally not compacted. Rarely greater than 20 ft thick; unit considered to thin to zero at contact with adjacent polygons. Present in floodplains of modern streams throughout entire map area or in human-made water retention features. Mapped only where areal extent and thickness are significant.

o — **Organic deposits (Holocene).** Muck and peat, may contain clay at depth. Generally less than 20 feet thick; considered to thin to zero at contact with adjacent polygons. Formed in undrained depressions. Organic deposits too small to map at 100K scale indicated by an asterisk (*) and underlain by material shown in surrounding map-unit area. Occupies depressions on moraines, between beach ridges and dunes, and on the lacustrine plain; occurs throughout the map area and is common in areas formerly occupied by intermorainal marshes.

At — **Alluvial terraces (Wisconsinan).** Old floodplain remnants along streams that flowed into high, proglacial lakes. Highly variable textures; commonly present tens of feet above modern floodplains.

C — **Clay (Wisconsinan).** Massive to laminated; may contain interbedded silt and fine sand; clay content can exceed 80 percent. Laminated clay commonly contains thin silt or sand partings. Carbonate-cemented concretions occur in some areas. Associated with the deep water deposits of high, proglacial predecessors of Lake Erie.

LC — **Silt and clay (Wisconsinan).** Laminated to interbedded, may contain thin, fine sand or gravel layers. Present as thick, deltaic deposits; outwash deposits in upland depressions; and intermorainal lake deposits. Associated with deep water and deltaic deposits of high, proglacial predecessors of Lake Erie.

L — **Silt (Wisconsinan).** Massive or laminated, commonly contains thin sand partings. Carbonate-cemented concretions occur in some areas. May contain localized clay, sand, or gravel layers. Associated with moderate-depth water and deltaic deposits of high, proglacial predecessors of Lake Erie.

S — **Sand (Wisconsinan).** Contains minor amounts of disseminated gravel or thin lenses of silt or gravel; grains well to moderately sorted, moderately to well rounded; finely stratified to massive, may be cross bedded; locally may contain organics. In deep buried valleys, may be older than Wisconsinan age. Present in association with deltaic deposits, finer-grained ice-contact deposits, and as nearshore dune and beach ridge deposits of proglacial predecessors of Lake Erie.

SG, SGg — **Sand and gravel, (generally Wisconsinan).** Intermixed and interbedded sand and gravel commonly containing thin, discontinuous layers of silt and clay; grains well to moderately sorted, moderately to well rounded; finely stratified to massive, may be cross bedded; locally may contain organics. In deep buried valleys, may be older than Wisconsinan age. Present as valley wall terraces and in buried valleys throughout the map area and as beach ridge deposits of proglacial predecessors of Lake Erie. SGg units contain patchy gas (fig. 4).

IC — **Ice-contact deposits (Wisconsinan).** Highly variable deposits of poorly sorted gravel and sand; silt, clay, and till lenses common; may be partially covered or surrounded by till. Deposited directly from stagnant ice as kame or esker landforms. Commonly associated with large, deep buried valleys.

T, Tg — **Till (Wisconsinan).** Unsorted mix of silt, clay, sand, gravel, and boulders. Variable carbonate content, fractures common. May contain silt, sand, and gravel lenses. Deposited directly from several separate ice advances. Undifferentiated and nonspecified age in buried valleys or where separated by intervening nontill units from an overlying, designated till. Surface may be wave planed or modified by lacustrine erosion and deposition. Tg units contain patchy gas (fig. 4).

CG — **Clay to Gravel.** Complexly interbedded deposits of clay, silt, sand, gravel, and till in deeper parts of buried valleys; unspecified age. Unit identified from well logs; data insufficient for more detailed differentiation or age assignment.

G — **Gravel.** Generally Wisconsinan age. Contains minor amounts of disseminated sand and thin, discontinuous lenses of silt and thicker, more continuous beds of sand; unit well to poorly sorted, angular to well rounded; may be massive, cross bedded, or horizontally bedded. Clasts vary in lithology. In deep buried valleys, may be older than Wisconsinan age. Gg units contain patchy gas (fig. 4).

BEDROCK UNITS

Sh — **Shale.** Coldwater, Sunbury, Bedford, and Antrim Shale. Coldwater Shale (Lower Mississippian), shades of gray to greenish black; clayey; calcareous; carbonate nodules at base. Sunbury and Bedford Shales, undivided (Lower Mississippian and Upper Devonian). Sunbury Shale: brownish black to greenish black; carbonaceous; pyritic. Bedford Shale, shades of gray to olive green; silty to clayey. Antrim Shale (Upper Devonian): brownish black; carbonaceous. Units not exposed, occur beneath undifferentiated Quaternary and Neogene(?) deposits in northwestern Ohio; data from core holes.

D — **Dolomite.** Stratigraphic names in descending stratigraphic order; predominantly dolomites: Traverse Group, Dundee Limestone, Detroit River Group, and Salina Group undifferentiated. Traverse Group (Middle Devonian): Ten Mile Creek Dolomite and Silica Formation; undivided dolomite, limestone, and shale. Ten Mile Creek Dolomite: gray; contains some nodules of chert. Silica Formation: calcareous clayey shale and limestone; bluish gray; highly fossiliferous. Dundee Limestone (Middle Devonian): blue, gray, and brown; upper is highly fossiliferous; lower contains cherty dolomite. Detroit River Group (Middle and Lower Devonian): dolomite, sandstone, and shale. Unit consists generally of three formations, in descending order: Lucas and Amherstburg Dolomites and Sylvania Sandstone. Lucas and Amherstburg Dolomites: brown to gray; mostly medium to thick beds; carbonaceous laminae. Sylvania Sandstone: white; fine grained; quartzose grains well rounded; locally dolomitic. Salina Group undifferentiated (Upper and Lower Silurian): shades of gray and brown; very finely crystalline; mostly thin to medium beds and laminae; locally includes shale, anhydrite, and/or gypsum beds and laminae.

EXPLANATION OF MAP SYMBOLS

* Small area of organic deposits.

× Quarry, mine, or strip mine; floored in bedrock; may contain reclaimed areas.

× Sand-and-gravel pit. Pit bottom generally underlain by unconsolidated lithologic units of surrounding polygon(s). May contain reclaimed areas.

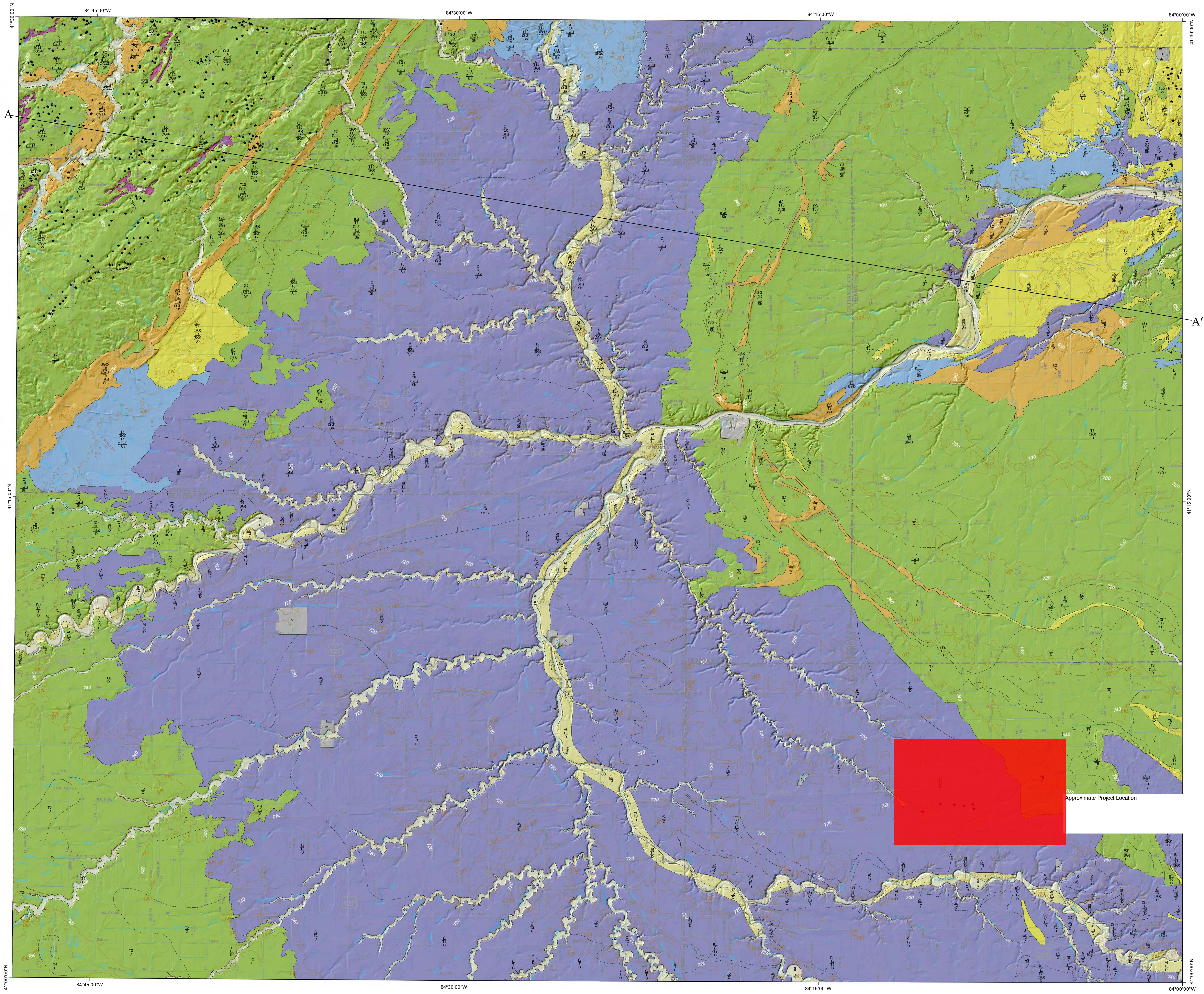
—— Boundary between map-unit areas having different uppermost, continuous lithologies or significant bedrock lithology change; underlying lithologies may or may not differ.

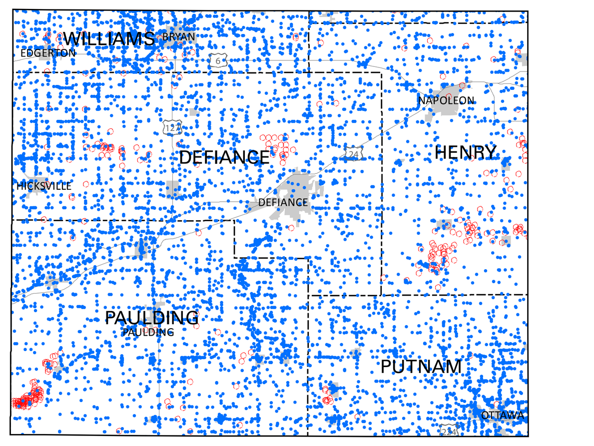
------- Boundary between map-unit areas having the same uppermost, continuous lithology but different

KEY TO LITHOLOGIC COLORS*

- Made land, quarries, mines or large pits
- Alluvium (Halocene)
- Organic deposits (Halocene)
- Alluvial terraces (Wisconsinan)
- Clay (Wisconsinan)
- Silt (Wisconsinan)
- Sand (Wisconsinan)
- Sand and gravel (generally Wisconsinan)
- Till (Wisconsinan)

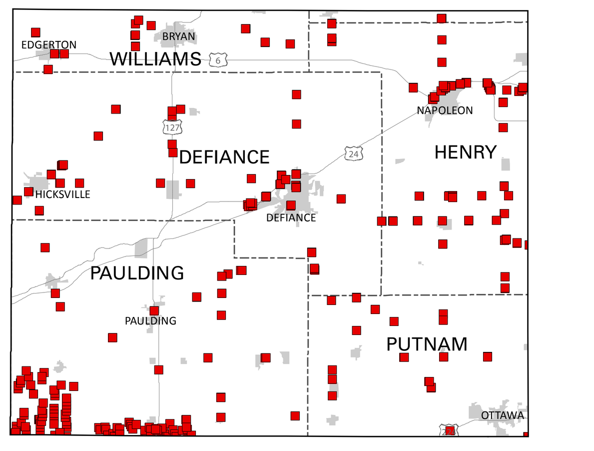
* The colors on the map correspond to the uppermost continuous map units and serve to assist in visualizing the geology of the area. Discontinuous units (in parentheses) and subsurface-only units are not assigned colors.





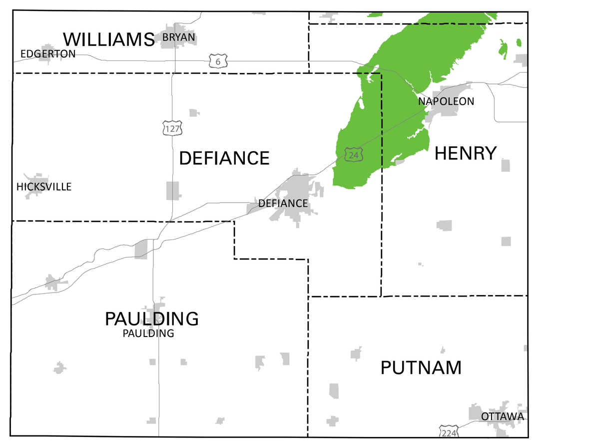
Oil & gas wells   Water wells

FIGURE 2.—Plot of oil-and-gas wells and water wells in the Ohio portion of the Defiance 30 X 60-minute quadrangle. Oil-and-gas well logs on file at ODNR Division of Geological Survey. Water-well logs on file at ODNR Division of Soil and Water Resources.



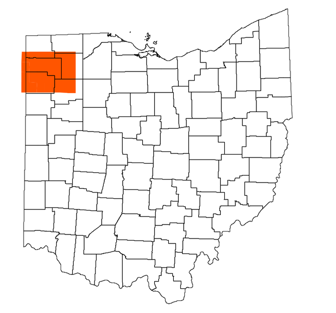
Soil borings

FIGURE 3.—Plot of soil boring locations in the Ohio portion of the Defiance 30 X 60-minute quadrangle. Test-boring logs provided by Ohio Department of Transportation, Ohio Environmental Protection Agency, and county engineers offices.



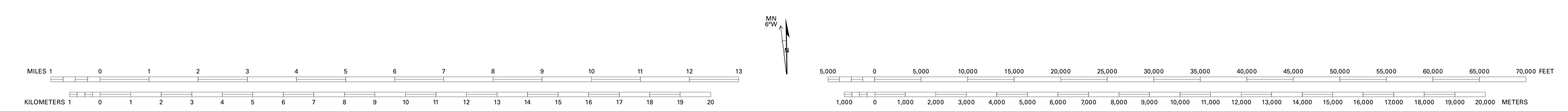
Area of occuring natural gas

FIGURE 4.—Natural gas may occur in various units and at depths of 30 feet or greater, sometimes in multiple horizons. The gas is thought to result either from the decay of buried organic deposits (ancient soils or bog deposits), or, in areas underlain by Antrim shale, migration out of the bedrock and into the overlying glacial deposits. Gas may be encountered in tills and gravels just above the bedrock surface, or it may be found well above the bedrock interface.

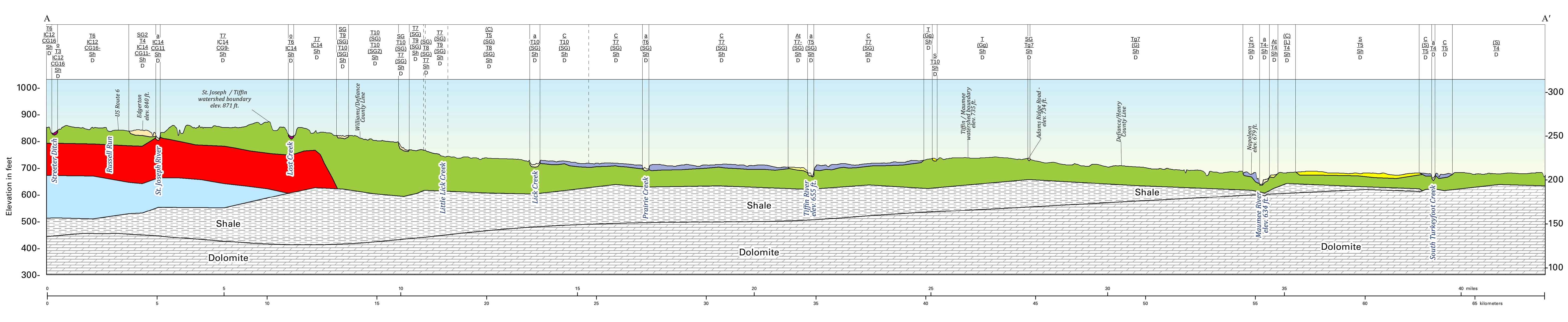


Location of the Defiance
30 X 60-minute quadrangle

Base map derived from Ohio Department of Transportation data sets. Projection of data is Ohio coordinate system, south zone, North American Datum, 1983.



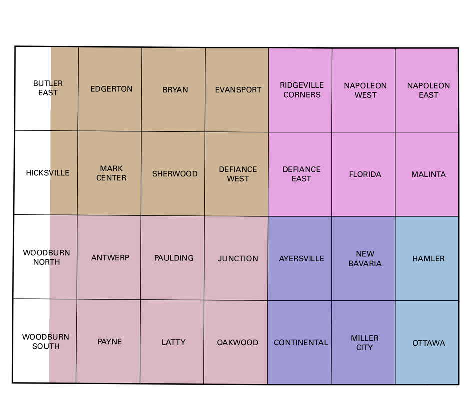
SCALE 1:100 000



KEY TO CROSS SECTION UNITS

- Alluvium (Halocene)
- Organic deposits (Halocene)
- Alluvial terraces (Wisconsinan)
- Clay (Wisconsinan)
- Clay to gravel
- Ice contact
- Sand (Wisconsinan)
- Sand and gravel (generally Wisconsinan
- Till (Wisconsinan)
- Shale
- Dolomite

FIGURE 1.—Cross section of the Surficial Geology of the Defiance 30x60-Minute Quadrangle in Ohio. See key to cross section units for explanation of symbols. Solid-line boundaries separate map-unit areas having different lithologic units at the surface; underlying lithologic units may or may not differ. Dashed-line boundaries separate map-unit areas having the same surface lithologic unit but different thickness or different underlying lithologic units. The cross section illustrates thickness and mapping conventions. Thickness values are in tens of feet. Values are gross averages that can vary up to 50 percent, except (1) those followed by a minus sign (-), which represent the maximum thickness of a thinning trough- or wedge-shaped sediment body, or (2) units in parentheses ( ), which indicate a discontinuous distribution of that unit. Precise surface topography can be determined from topographic maps that are available from the ODNR Division of Geological Survey at several scales; bedrock-surface topography and bedrock geology are available from the ODNR Division of Geological Survey as 1:24,000 scale quadrangle maps.



AUTHOR INDEX
- ADEN
- ADEN/ANGLE
- ANGLE
- JONES
- PAVEY

Mapping responsibility and index to the 7.5-minute (1:24,000-scale) quadrangles in the Ohio portion of the Defiance 30 X 60-minute quadrangle. Mapping completed in 2011.

ACKNOWLEDGMENTS

The geologists of the ODNR Division of Geological Survey, Mapping and Industrial Minerals Group used data from records obtained from the Ohio Department of Transportation, Office of Geotechnical Engineering Geotechnical Document Management System, available online at <http://www.dot.state.oh.us/Divisions/Engineering/Geotechnical/Pages/GDocMS.aspx#GRSR>.

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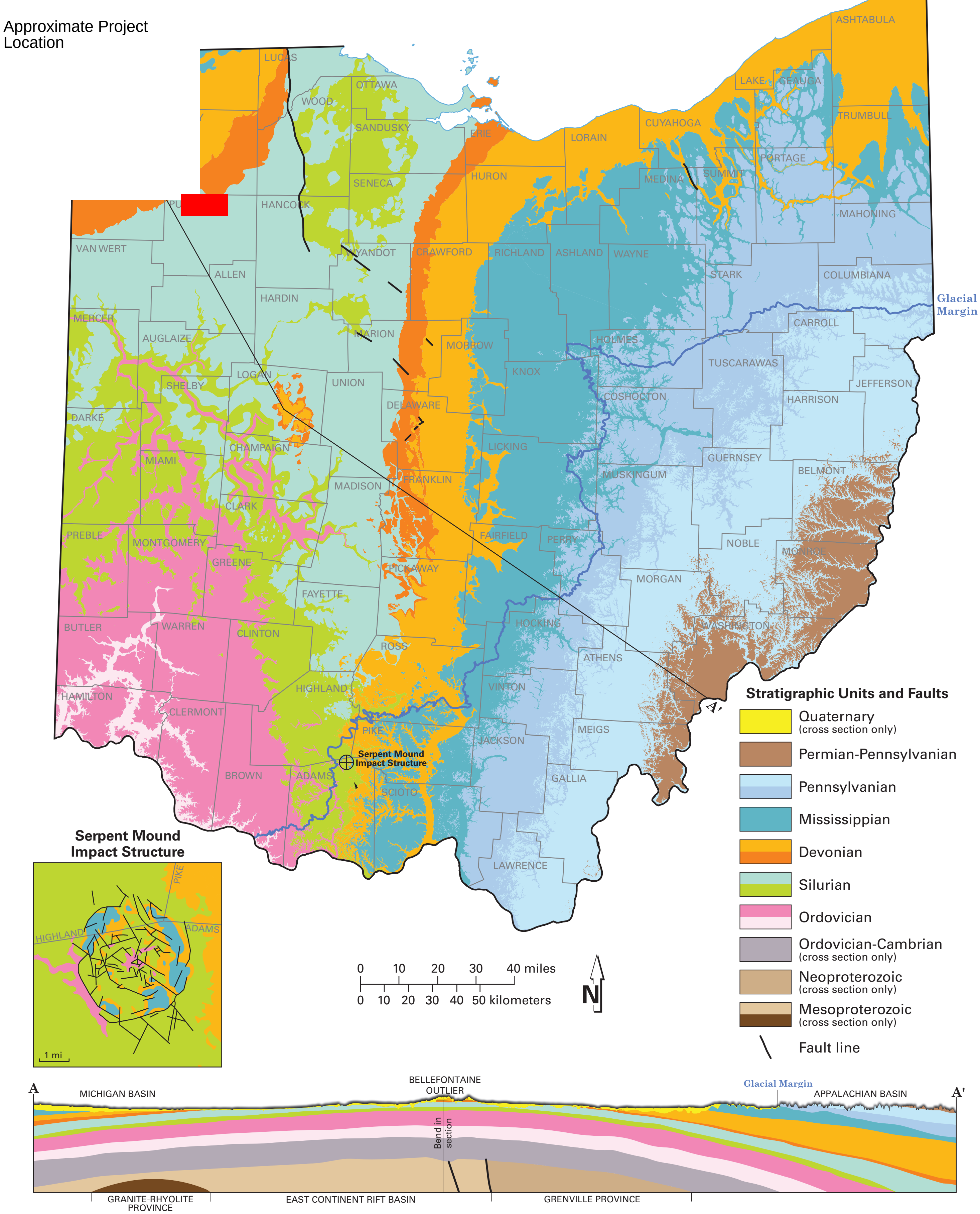
Recommended Bibliographic Citation for this map:

Aden, D.J., Pavey, G.E., Jones, D.M., and Angle, M.P, with GIS production and cartography by Martin, D.R., and Wells, J.G., 2012, Surficial geology of the Defiance 30 x 60-minute quadrangle in Ohio: Columbus, Ohio Department of Natural Resources, Division of Geological Survey Map SG-2-DEF, scale 1:100,000.

BEDROCK GEOLOGIC MAP OF OHIO



Recommended citation: Ohio Division of Geological Survey, 2006, Bedrock geologic map of Ohio: Ohio Department of Natural Resources, Division of Geological Survey Map BG-1, generalized page-size version with text, 2 p., scale 1:2,000,000. [Revised 2017.]

This map is a generalization of the *Bedrock Geologic Map of Ohio* (Slucher and others, 2006)—the first statewide 1:500,000-scale bedrock-geology map compiled by the ODNR Division of Geological Survey since 1920 and the first to properly portray the bedrock geology that exists beneath the extensive deposits of Quaternary sediments that cover much of the bedrock in the state[1]. Overall, the bedrock geology of Ohio consists of flat-lying to gently dipping carbonate, siliciclastic, evaporite, and organoclastic strata of sedimentary origin that range in age from Upper Ordovician to Upper Carboniferous-Lower Permian. As illustrated in the cross section, older sedimentary, igneous, and metamorphic rocks occur at depth and range from Lower Ordovician to Mesoproterozoic in age. At the surface, an irregular veneer of mainly unconsolidated Quaternary sediments conceal most bedrock units occurring northward and westward of the glacial margin.

Strata of the Ordovician System are the oldest exposed rocks in Ohio and consist mainly of alternating shale and limestone sequences. Silurian System strata are mostly dolomites with lesser amounts of shale. Rocks of the Devonian System consist of two contrasting types. Lower and Middle Devonian-age strata are mainly carbonate rocks, whereas Upper Devonian-age rocks consist mostly of clastic rocks. In Champaign and Logan Counties, Devonian-age rocks occur on a small erosional remnant referred to by geologists as the Bellefontaine Outlier. Coincidentally, the highest topographic point in Ohio (Campbell Hill at 1,549 feet above sea level) occurs also in this area.

The Carboniferous System is divided into two Subsystems, the Mississippian and Pennsylvanian. Mississippian-age strata are mostly shales and sandstones that occur locally in various proportions. Pennsylvanian-age strata consist mainly of a diverse array of alternating sandstones, siltstones, shales, mudstones, limestones, and underclays; economic coal beds occur also in portions of this sequence. The youngest interval of sedimentary rocks in Ohio, the Dunkard Group, occurs only in southeastern Ohio and consists of strata similar in composition to the underlying Upper Pennsylvanian-age rocks; however, the age of the Dunkard Group has been debated since the late 1800s. Dunkard strata contain a well-studied late Pennsylvanian-age assemblage of plant fossils with infrequent early Permian-age forms. Yet, fossil plant spores found in coal beds in the interval only support a late, but not latest Pennsylvanian age. Thus until more definitive fossils are found, geologists are unable to determine the exact age of the Dunkard Group beyond a combined Permian-Pennsylvanian age assignment.

In west-central Ohio, the ancient Teays River system extended across much of Ohio during the late Neogene to early Quaternary Periods and sculptured an extensive network of deeply dissected valleys into the bedrock surface. The spatial configuration of many geologic units on this map clearly reflects the major channel networks of these former drainage systems. Also, four major regional structural geology elements affect the spatial distribution of rocks in Ohio: the Appalachian and Michigan Basins and the Cincinnati and Findlay Arches, which occur between the two basins. Locally, several high-angle normal faults displace rocks in the state.

The Serpent Mound Impact Structure in southern Ohio is a circular area of deformed and broken rocks that is approximately nine miles in diameter. Recent investigations indicate the feature is the result of a meteorite or comet impact believed to have occurred between 256 and 330 million years ago.

Cross section A–A' traverses Ohio from the northwest to the southeast and intersects the southern portion of the Michigan Basin, the area between the Cincinnati and Findlay Arches, and the western Appalachian Basin, respectively. The stratigraphic units shown in this profile illustrate the broad, arching geometric distortion to the bedrock in Ohio, created mainly by periods of tectonic subsidence within these regional structural basins. For specific details on the various rock units, economic commodities, and geologic hazards within Ohio, see the large-format *Bedrock Geologic Map of Ohio* (Slucher and others, 2006), available for purchase by contacting the ODNR Geologic Records Center at 614-265-6576 or geo.survey@dnr.state.oh.us.

1 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.

Quaternary (about 1.8 million years ago to present). Unconsolidated sediments: till, gravel, sand, silt, clay, and organic debris. Continental origin. (Shown in cross section only)

Period of widespread erosion

Permian and Pennsylvanian (about 298 to 302 million years ago). Sedimentary rocks: mainly shale, sandstone, siltstone, mudstone, and minor coal. Continental origin.

Pennsylvanian (about 302 to 307 million years ago). Sedimentary rocks: mainly shale, sandstone, siltstone, mudstone, limestone, and some coal. Continental and marine origin.

Pennsylvanian (about 307 to 318 million years ago). Sedimentary rocks: mainly sandstone, siltstone, shale, and conglomerate, with some coal and limestone. Deltaic and marine origin.

Period of widespread erosion

Mississippian (about 322 to 359 million years ago). Sedimentary rocks: sandstone, shale, siltstone, conglomerate, and minor limestone. Marine to marginal marine origin.

Devonian (about 359 to 385 million years ago). Sedimentary rocks: mainly shale and siltstone with some sandstone. Marine to marginal marine origin.

Devonian (about 385 to 407 million years ago). Sedimentary rocks: mainly limestone and dolomite with some shale, and minor sandstone. Marine and eolian origin.

Period of widespread erosion

Silurian (about 416 to 423 million years ago). Sedimentary rocks: dolomite, anhydrite, gypsum, salt, and shale. Marine and restricted marine origin.

Silurian (about 423 to 435 million years ago). Sedimentary rocks: dolomite and shale with some limestone. Marine origin.

Period of widespread erosion

Ordovician (about 446 to 450 million years ago). Sedimentary rocks: shale and limestone. Marine origin.

Ordovician (about 450 to 460 million years ago). Sedimentary rocks: limestone and shale. Marine origin.

Period of widespread erosion

Ordovician and Cambrian (about 486 to 510 million years ago). Sedimentary rocks: mainly dolomite, sandstone, shale, with minor limestone. Marine origin. (Shown in cross section only.)

Period of widespread erosion

Neoproterozoic (between 900 million and 1 billion years ago). Metamorphic rocks: gneiss, schist, amphibolite, and marble; and igneous rocks: granite. Form during collision of tectonic plates. (Shown in cross section only.)

Mesoproterozoic (between 1.0 and 1.2 billion years ago). Sedimentary rocks: sandstone and siltstone; and igneous rocks: basalt and rhyolite. Form during rifting of continental landmass. (Shown in cross section only.)

Period of widespread erosion

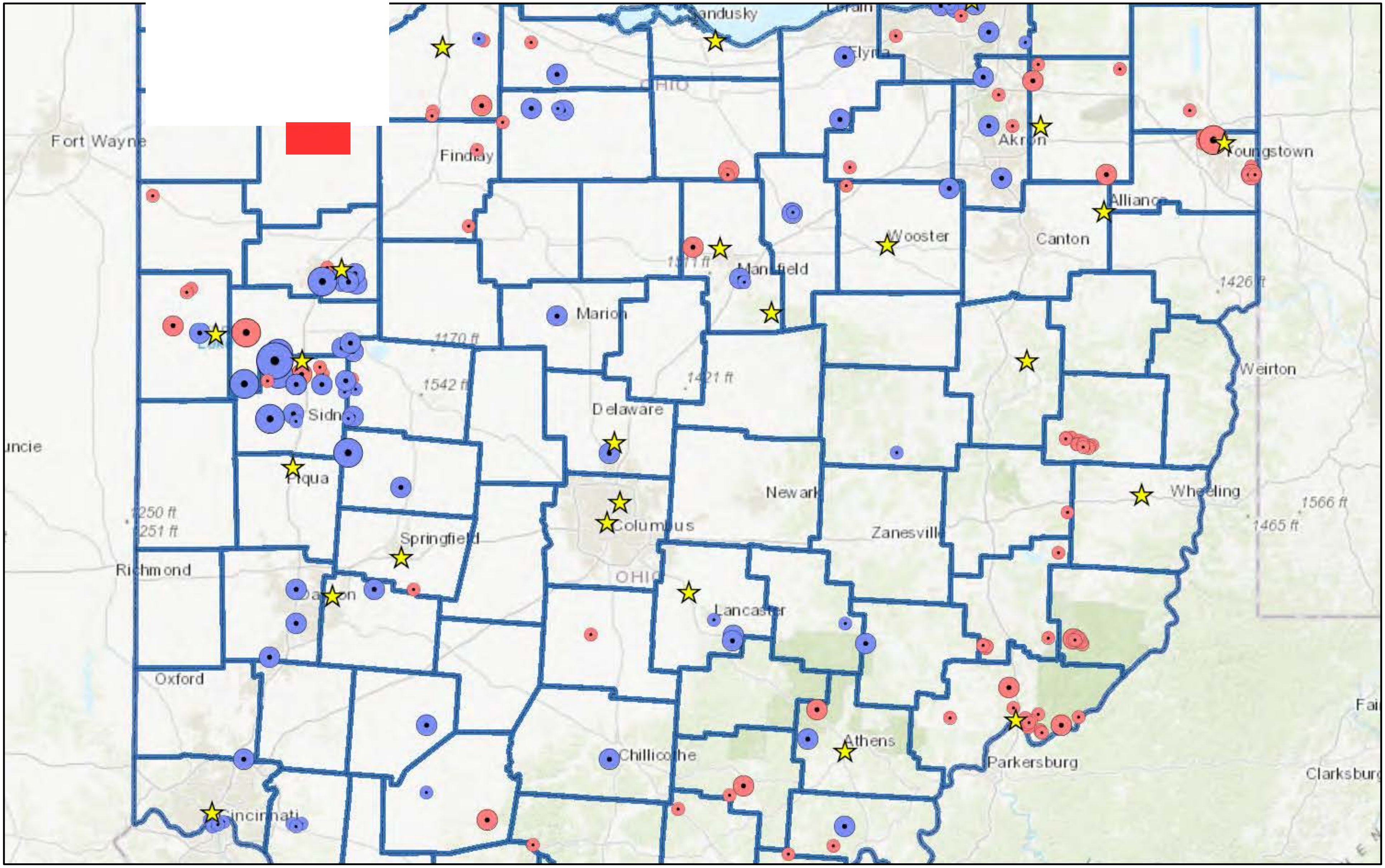
Mesoproterozoic (between 1.45 and 1.52 billion years ago). Igneous rocks: granite and rhyolite. Formed during crustal evolution and differentiation. (Shown in cross section only.)

Appendix B

ODNR Location Data Maps

Approximate Project Location

Ohio Earthquake Epicenters



March 27, 2020

☆ OhioSeis Seismic Stations

N

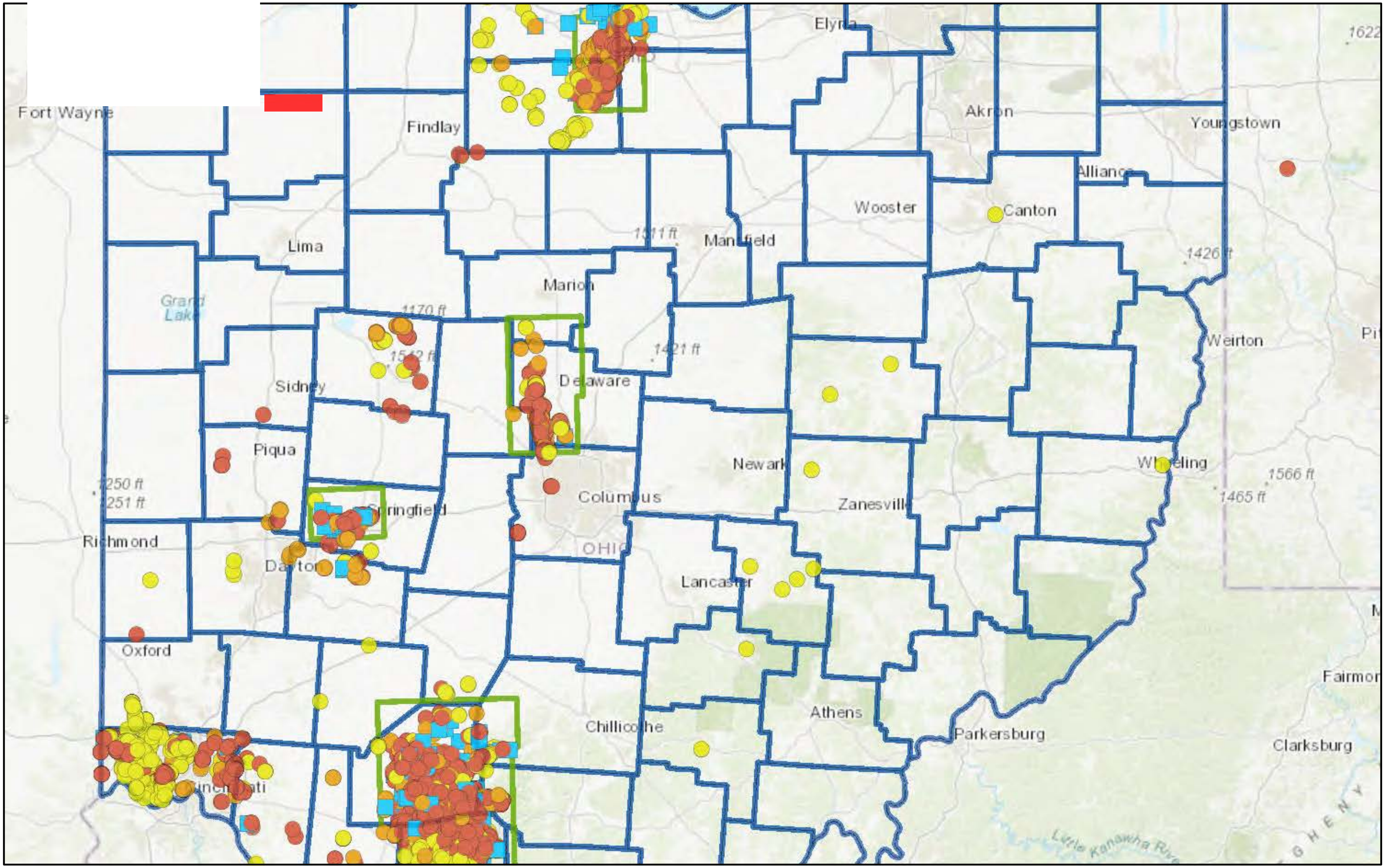
0 20 40 80 mi

0 30 60 120 km

1:2,311,162

ODNR - Div. of Geosurvey

Karst Map



March 27, 2020

Karst Points

- Karst - Field Verified
- Karst - Suspect - Field Visited
- Karst - Suspect - Not Visited
- Spring

N

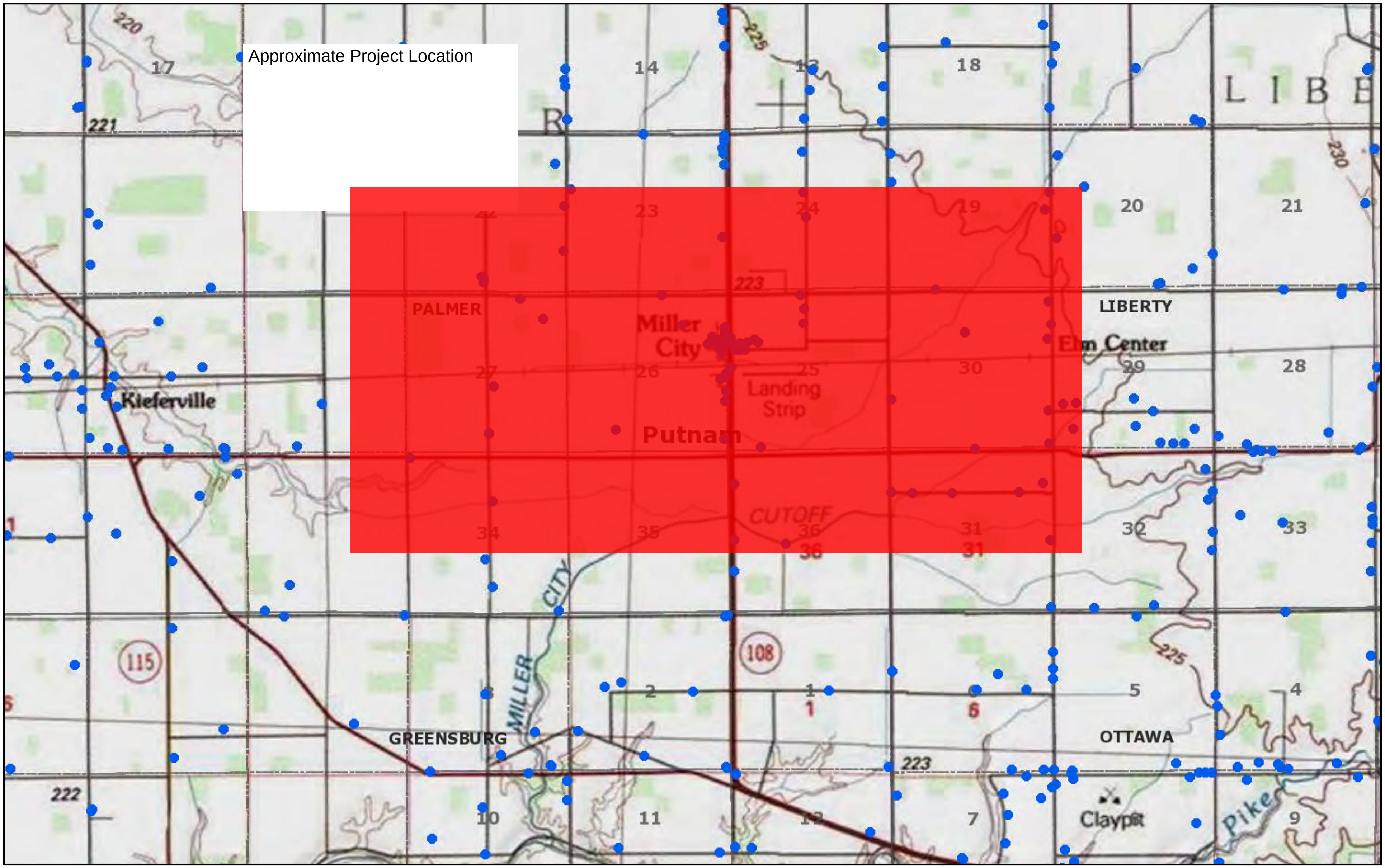
0 20 40 80 mi

0 30 60 120 km

1:2,311,162

Ohio Dept. of Natural Resources

Ohio Water Wells



March 27, 2020

- Water Wells
- Counties
- Current Township
- Land Subdivision

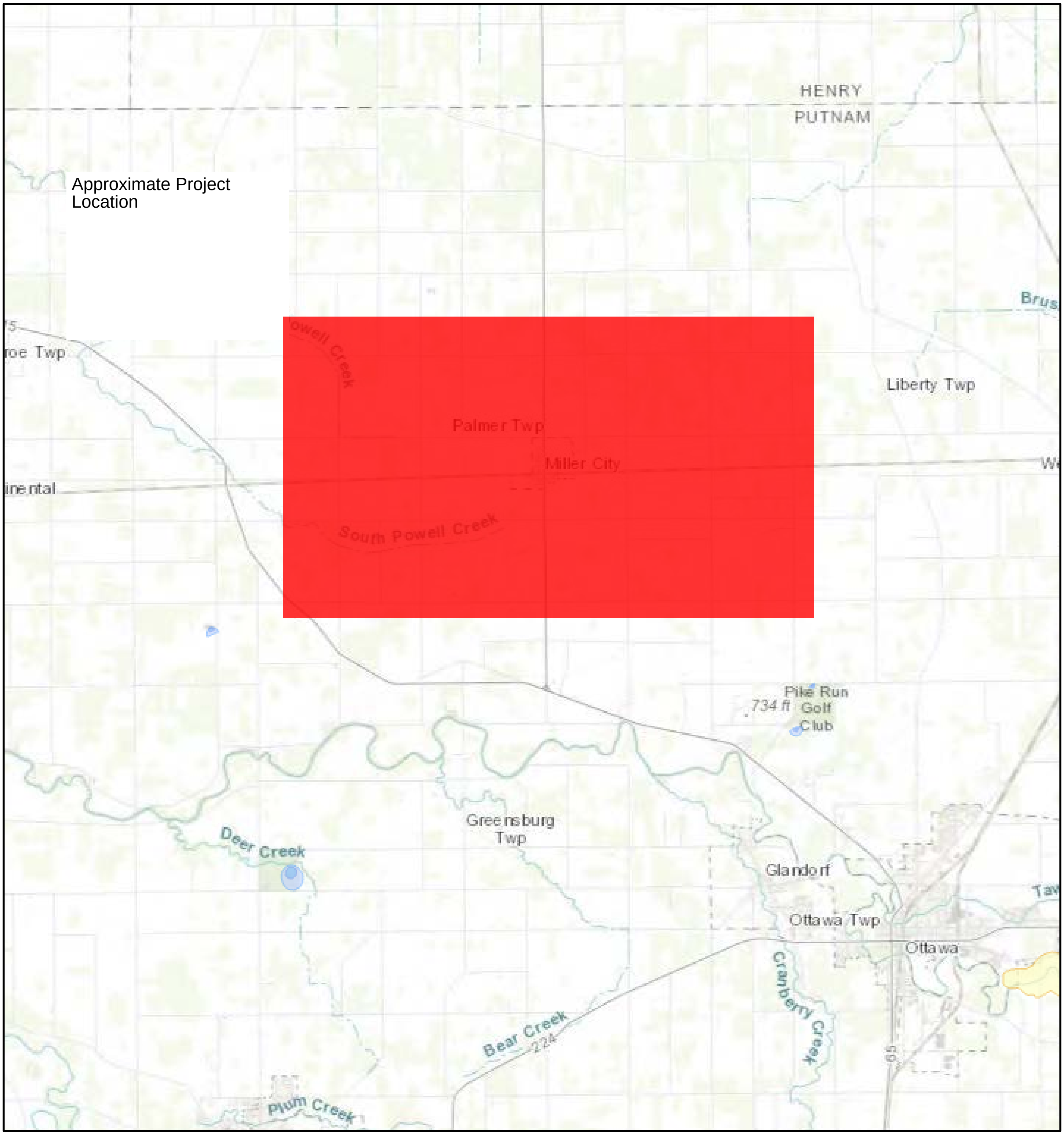
N

0 0.5 1 2 mi

0 1 2 4 km

1:72,224

Drinking Water Source Protection Areas



3/27/2020, 11:17:00 AM

1:144,448

0 0.75 1.5 3 mi

0 1.5 3 6 km

Ohio River (surface water)

- Ohio River-Zone of Critical Concern
- Ohio River-Zone of High Concern

Lake Erie (surface water)

- Lake Erie-Critical Assessment Zone
- Lake Erie-Potential Influence Zone

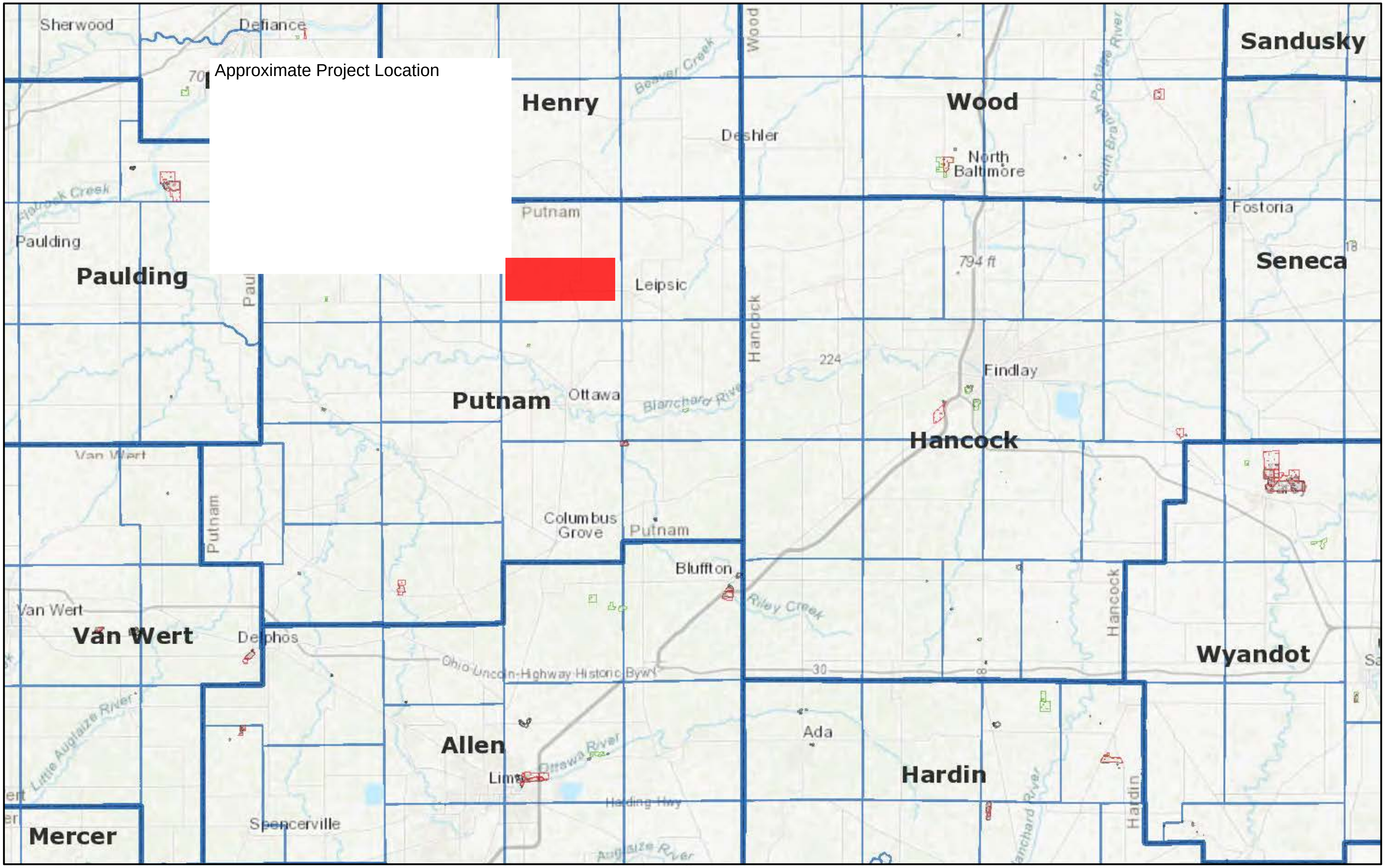
Inland (surface water)

- Emergency Management Zone
- Corridor Management Zone
- Source Water Protection Area
- Inner Management Zone

Division of Drinking and Ground Waters, Ohio EPA, Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User

Ohio EPA
Division of Drinking and Ground Waters

Mines of Ohio



March 27, 2020

Surface Affected Area

Current

C Law (1976 - 1981)

D Law (1982 - Present)

Historic - From Topo Maps

Proposed

Original Application

Adjacent Area Application

Past

A Law (1965 - 1972)

B Law (1972 - 1975)

N

0 5 10 20 mi

0 5 10 20 km

1:577,791

Ohio Dept. of Natural Resources