Potential Sand and Gravel Resources of the Mansfield, Ohio 30 x 60 Minute Quadrangle

POTENTIAL SAND AND GRAVEL RESOURCES OF THE MANSFIELD, OHIO 30 X 60 MINUTE QUADRANGLE

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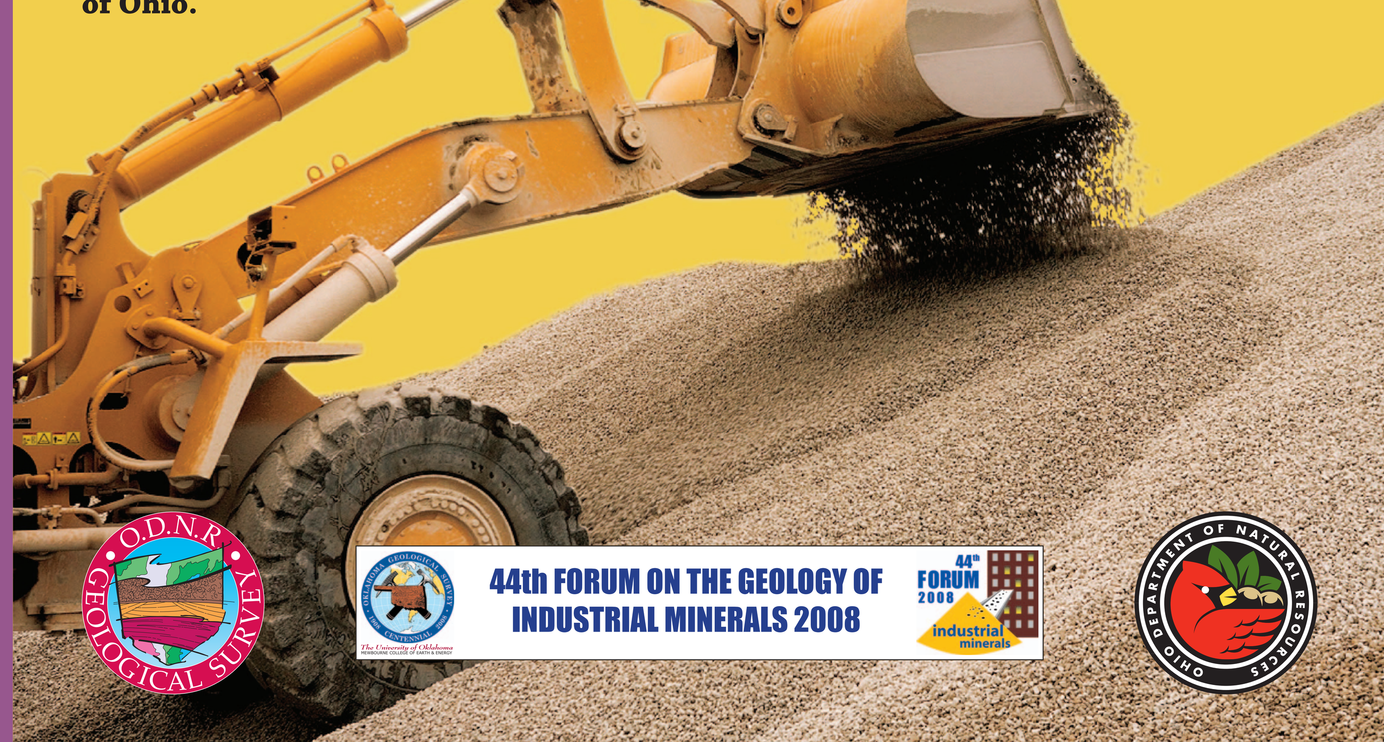
ABSTRACT

The Mansfield 30 x 60 minute quadrangle is located in north-central Ohio at the intersection of two major highway corridors: north-south Interstate 71 and east-west U.S. 30. Traffic on area highways exceeds 80,000 vehicles daily, including 20,000 trucks. Manufacturing and heavy industry provide significant employment for the more than 200,000 people that reside in the Mansfield quadrangle. Highway capacity enhancements and maintenance are crucial for the area's future economic viability. Aggregates represent 90% of the volume of asphalt, concrete, and road base needed for highway and building construction. More than 14 million tons of sand and gravel were produced in the Mansfield quadrangle from 1997 to 2006. Fifteen sand and gravel operations were active in 2006, including four new operations since 2002. It is essential to evaluate the location, quantity, and quality of potential sand and gravel resources in the Mansfield quadrangle, so that aggregates are available for future economic growth.

The surficial geology of the western and northern portions of the Mansfield quadrangle consists of glacially derived materials. Wisconsinan-age tills with high clay content predominate, particularly in upland areas. Potentially thick sand and gravel accumulations are associated with glacial outwash along major drainages or in highly variable ice-contact deposits that generally trend northwest-southeast in the northern portions of the map area. The surficial geology of the southeastern portion of the Mansfield quadrangle is primarily Mississippian- to Pennsylvanian-age sandstone, siltstone, and shale. In valleys, outwash deposits containing sand and gravel alternate with glacial lake deposits containing silt and clay.

The recently completed Mansfield 30 x 60 minute quadrangle map provides a three-dimensional framework of the area's surficial geology by using letters and numbers to represent lithologic units and average thicknesses from the surface to bedrock. These surficial units and corresponding thicknesses were queried within the map's GIS to produce a derivative map of potential sand and gravel resources. A mining ratio of 1:4, waste to resource, was used to delineate ice-contact and sand and gravel units as possible aggregate resources. Potential sand and gravel resources within municipal boundaries and public-owned areas were eliminated from the derivative map because of land-use conflicts. Organic deposits associated with sand and gravel were included because of the possibility of recovering peat and aggregates in a single operation. Preliminary results indicate that more than 3.5 billion tons of potential sand and gravel resources are located in the Mansfield quadrangle. Land uses such as municipal well fields, stream buffers, or existing infrastructure, as well as aggregate quality concerns due to shale content, will limit the potential of many sand and gravel deposits. The resulting map is meant as a general aggregate exploration or regional planning tool and demonstrates an important derivative product of the three-dimensional digital surficial mapping of Ohio.



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OHIO DIVISION OF GEOLOGICAL SURVEY
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INTRODUCTION

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

1) the geologic deposits, indicated by letters which represent the major lithologies;
2) the thickness of the individual deposits, indicated by numbers and modifiers;
3) the lateral extent of the deposits, indicated by map-unit area boundaries;
4) the vertical sequence of deposits, shown by the stack of symbols within each map-unit area.

In effect, each stack represents a generalized cross section for each 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 designator represent the average thickness of a lithologic unit in tens of feet (for example, 3 represents 30 feet). If no number is present, the average thickness is assumed to be 1 (10 feet). These unmodified numbers correspond to a thickness range centered on the specified value, but may vary up to 50 percent. For example, T4 indicates the average thickness of till in a map-unit area is 40 feet, but thickness may vary from 20 to 60 feet.

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 feet is present in only part of that map-unit area.

2) A minus 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, an SG9- map-unit area adjacent to an SG3 area indicates a sand and gravel unit having a maximum thickness of 90 feet that thins to an average of 30 feet 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.

These 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. Figure 1 illustrates mapping conventions.

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 described 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 which indicated change of deposits at depth, such as Ohio Department of Natural Resources water-well logs, Ohio Department of Transportation and Ohio EPA test-boring logs, theses, and published or unpublished geologic reports, maps, and field notes. These data also provided the basis for lithologic unit descriptions, which summarize, as accurately as possible, recognized associations of genetically related materials. The total thickness of surficial deposits was calculated from Division of Geological Survey open-file bedrock-topography maps, which are available for each 7.5-minute quadrangle in the map area. The bedrock units were summarized from Division of Geological Survey bedrock-geology maps, also available for each 7.5-minute quadrangle. Land-surface topography shown on the basemap was prepared largely from data derived from the U.S. Geological Survey's National Elevation Dataset (30 meter grid spacing).

LITHOLOGIC UNIT DESCRIPTIONS

Unit descriptions represent an amalgamation of those for the Lorain/Put-in-Bay, Canton, Newark, and Bellefontaine 100,000-scale surficial geology maps. Map-specific units noted in the individual descriptions.
***Bold units are those used for the GIS query.**

SURFICIAL UNITS

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

o — Organic deposits, Holocene age. Muck and peat, may contain clay at depth. Generally less than 20 feet thick. Formed in undrained depressions. Organic deposits too small to map at 1:100,000 scale indicated by an asterisk [*] and underlain by material shown in surrounding map-unit area. Present also on outwash trains, ice-contact areas, and hummocky moraines throughout the map area.

a — Alluvium, Holocene age. Includes a wide variety of textures from silt and clay to boulders; commonly includes organic material; generally not compact; rarely greater than 20 feet thick. Present in floodplains of modern streams throughout entire map area. Mapped only where areal extent and thickness are significant.

Ac — Alluvium and alluvial terraces, combined. Shown in areas where insufficient space is available to delineate separate units.

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

C — Clay, Wisconsinan age. Massive to laminated; may contain interbedded silt, and fine sand; clay content can exceed 80%. Laminated clay commonly contains thin silt or sand partings. Carbonate-cemented concretions occur in some areas. Commonly contains fractures 6 to 12 inches apart. Distributed throughout map area as lowland surface deposits, terraces, and as deep-water deposits of proglacial lakes.

CG — 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. Present in deeper buried valleys throughout the area.

IC — Ice-contact deposits, Wisconsinan age. 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 deep buried valleys.

L — Silt, Wisconsinan age. Massive or laminated, commonly contains thin sand partings. Carbonate-cemented concretions occur in some areas. May contain localized clay, sand, or gravel layers. Clay content commonly increases with depth. Present throughout the map area as lowland surface deposits, terraces, and thick, deltaic deposits of proglacial lakes.

LB — Backwater lake deposits, Wisconsinan age. Mostly lacustrine silt and clay in tributary valleys south of the glacial border. Commonly interfingered with alluvium, alluvial fans, and debris flows from surrounding steep-walled tributary and main valleys.

LC — Silt and clay, Wisconsinan age. Laminated to interbedded, may contain thin fine sand or gravel layers. Occurs as thick lacustrine valley fill deposits of high, proglacial predecessors of lakes and as thick, deltaic deposits of proglacial and as thick, deltaic deposits, outwash deposits in upland depressions and proglacial lake deposits. Present as terraces along the Clear, Jerome, Lake, Muddy, and Rocky Forks of the Mohican River.

S — Sand, Wisconsinan age. 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 terraces and buried valleys throughout the map area, and in association with deltaic deposits or outwash.

SG — Sand and gravel, generally Wisconsinan age. Intermixed and interbedded sand and gravel commonly containing thin, discontinuous layers of silt, clay, and till. 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 terraces along valley walls and in buried valleys throughout the map area.

SGD — Sand and gravel, undifferentiated. Outwash sand and gravel over ice contact or outwash units of mostly sand and gravel, or deeply buried units of predominantly sand and gravel. Data insufficient for more detailed differentiation. Present in buried valleys along the eastern edge of the southeast corner of map.

SGi — Sand and gravel, Illinoian age. Properties similar to unit SG above, except upper part of unit is deeply weathered and leached where near surface. Present under areas mapped as Ti in the south-central area of the map.

GA — Basal gravel. Highly variable, poorly sorted gravel and sand, with significant amounts silt and clay. Present in the northwest part of the map area; deposited at or near the front of the ice sheet directly on bedrock. Presumably of Wisconsinan age, but may be older.

T — Unsorted mix of silt, clay, sand, gravel, and boulders, fractures/joints common, Wisconsinan age when at surface. May contain silt, sand, and gravel lenses. Deposited directly from several separate ice advances. Undifferentiated and non-specified age in buried valleys or where separated by intervening non-till units from an overlying designated till. Most common surficial material in the map area.

Ti — Loam till, Illinoian age. May be overlain by up to 3 feet of loess. Till contains silt, sand, and gravel lenses; unit deeply weathered and leached to 6 feet; fractures/joints common. Deposited by direct lodgement or meltout from glacial ice. Widespread in the eastern map area as a surface and buried unit.

BEDROCK UNITS

P — Vertically and horizontally variable sequences of sandstone, shale, siltstone, claystone, limestone, and coal bedrock, including associated colluvium of the Middle and Lower Pennsylvanian age Allegheny and Pottsville Groups undivided. Sandstone nonbedded to massive; may be conglomeratic in basal portion and interbeds of shale, sandstone, siltstone, clay, coal, and limestone common in upper portion of unit. The Lower Pennsylvanian age Pottsville Group is the most commonly encountered, composed of primarily of sandstone and conglomerate, with subordinate amounts of shale, siltstone, clay, and coal is mapped in the southeastern portion of map area. The basal portion of the Pottsville Group is predominantly a very light- to light-gray, medium to coarse grained, nonbedded to massive sandstone with abundant rounded quartz pebbles and quartz pebble conglomerate unit known as the Sharon Sandstone and conglomerate (it may sometimes designated as Ss, not P) that forms resistant hills and cliffs.

SSh — The dominant basal stack unit over the eastern three-quarters of the map area. Variable sequences of sandstone, conglomerate, shale, and siltstone. The following stratigraphic units may be mapped as Ssh: Mississippian Logan and Cuyahoga Formations undivided, Sunbury Shale, Devonian Bedford and Berea undivided.
Logan and Cuyahoga Formations undivided (Upper and Lower Mississippian age), sandstone, conglomerate, shale, and siltstone. Logan Formation, sandstone and siltstone; shades of gray, yellow, and brown. Sandstone, mainly silty to medium grained, locally contains lenses and beds of coarse sand grains to fine-pebble conglomerate; siltstone, clayey to sandy; locally contains shale interbeds and partings; locally fossiliferous. Cuyahoga Formation mainly shades of gray, olive, brown, and yellow sandstone, siltstone, and shale. Sandstone, silty to conglomeratic, occurs in thin to massive beds. Siltstone and shale occur in thin to thick beds; shale locally black and carboniferous; locally fossiliferous; unit lithologies commonly intertongued and intergraded. SSh may also be used in map areas comprised of the colluvium derived from sandstone and shale bedrock associated with the Mississippian age Logan and Cuyahoga Formations.
Sunbury and Bedford Shales undivided. Sunbury Shale, Upper Devonian to Lower Mississippian age, present in a north to south band in the western quarter of the map area, is brownish black to greenish black; carbonaceous; pyritic. Bedford Shale, shades of gray to olive green; silty to clayey. Both stratigraphic units can have lesser amounts of sandstone and siltstone.
Designation may also be used where the Berea Sandstone and Bedford Shale are not divided. Berea Sandstone, a resistant unit that forms a north to south escarpment of hills and cliffs in the western quarter of map area is light gray to shades of brown; medium to fine grained to silty, and thin to massive bedded. Unit is generally 40 to 60 feet thick. Bedford Shale is predominantly soft, red, clay shale that grades downward into gray shale. Thick siltstone lentils are present. Bedford Shale ranges from 0 to 150? feet in thickness.

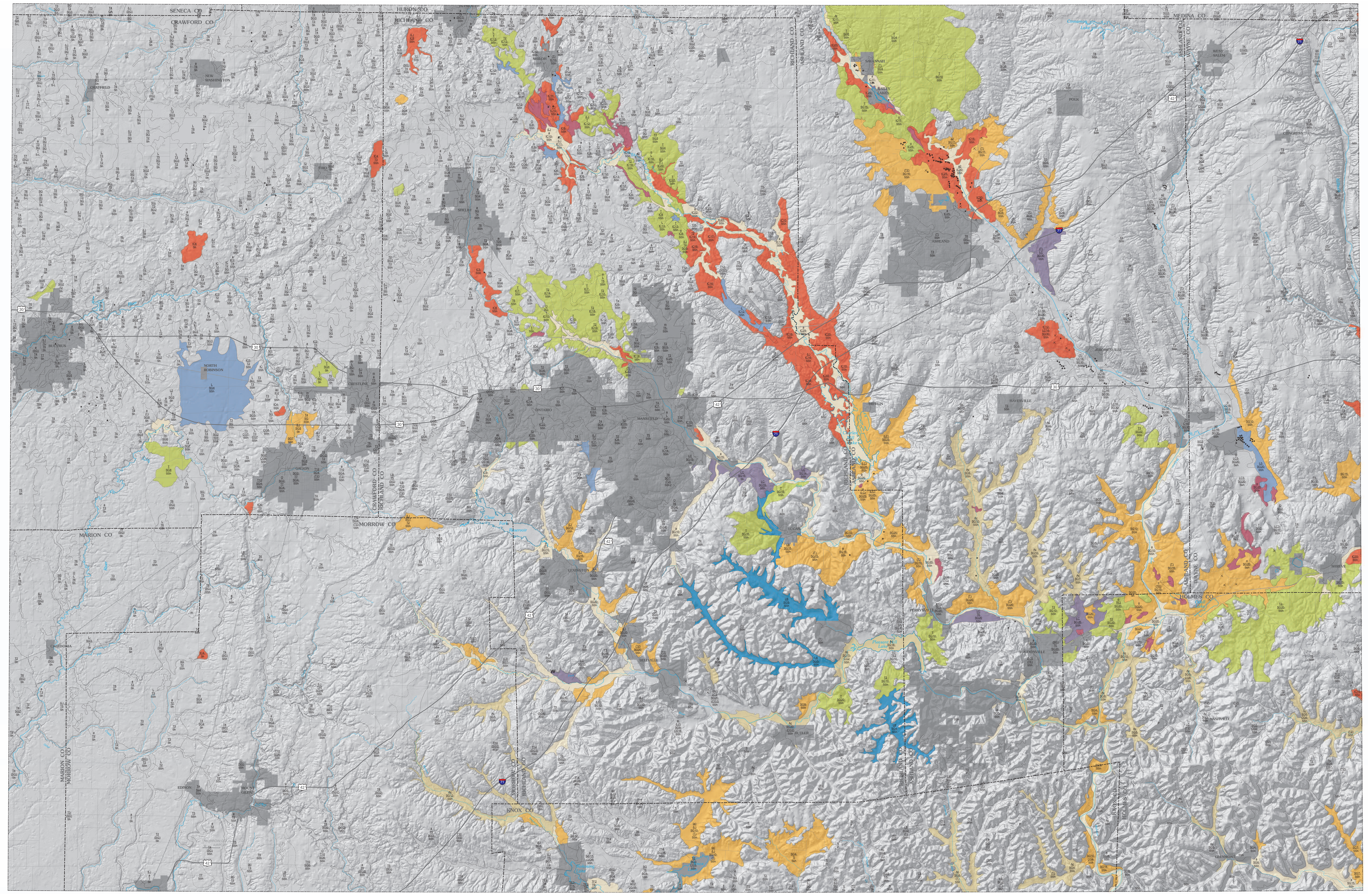
Sh — Designation used in western quarter of map area primarily to denote areas underlain by black shale. Key stratigraphic units broken out in descending stratigraphic order.
Sunbury Shale (Lower Mississippian)—Shale, brownish black; carbonaceous; pyritic, present in a north to south belt from Plymouth to Mount Gilead. Unit thickens northward, intertongues and intergrades with undifferentiated Cuyahoga Formation.

Ohio Shale, including associated colluvium, Devonian age, black to brown, silty, organic-rich, carbonaceous, fissile parted shale, which contains beds of gray to greenish-gray, soft, clay shale. Dominant basal stack unit within a north to south belt along the western edge of map area.

Olentangy Shale (Upper and Middle Devonian)—Shale; upper portion greenish gray, lower portion gray; clayey; disseminated pyrite; locally contains lenses and nodules of limestone. Contains thin, brownish-black shale beds in upper portion. Unit mapped only in very northwestern corner of map area, may also be included with the Ohio Shale.

Ls — Limestone, Devonian age. Delaware and Columbus Limestones, present as a basal bedrock designation only in the extreme northwest corner of map area. Delaware Limestone is medium brown, fine to medium crystalline, fossiliferous, cherty limestone containing shale laminae. Columbus Limestone is light to medium gray to brown, fine to coarse crystalline, fossiliferous, and cherty in the upper portion.

S-L — Shale and limestone, Devonian age. Olentangy Shale and Delaware Limestone, present as an undifferentiated basal stack unit in the northwestern corner of map. Data insufficient to clearly distinguish between formations.



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EXPLANATION

- × Sand and gravel pit. Pit bottom generally underlain by unconsolidated lithologic units of surrounding polygon(s). May contain reclaimed areas.
- * Small area of organic deposits
- ⌘ Quarry, mine, or strip mine; floored in bedrock; may contain reclaimed areas
- Boundary between map-unit areas having different uppermost continuous lithologies; underlying lithologies may or may not differ
- Boundary between map-unit areas having the same uppermost continuous lithology but different thickness or different underlying lithologies
- Municipal / state-owned land boundaries

KEY TO LITHOLOGIC COLORS*

Surficial Units

- m — made land, larger pits, quarries, or mines
- a — alluvium
- o — Organic deposits
- Ac — Alluvium and alluvial terraces, combined
- At — Alluvial terrace
- IC — Ice-contact deposit, Wisconsinan age
- L — Silt, Wisconsinan age
- LB — Backwater lake deposit
- LC — Silt and clay, Wisconsinan age
- S — Sand, Wisconsinan age
- SG — Sand and gravel, Wisconsinan age
- T — Till
- Ti — Loam till, Illinoian age
- Not a viable sand and gravel mining area

* The colors on this map depict the uppermost continuous unit and are intended to assist in visualizing the geology of the area. Discontinuous units (in parentheses) and subsurface-only units are excluded in colors assignments.

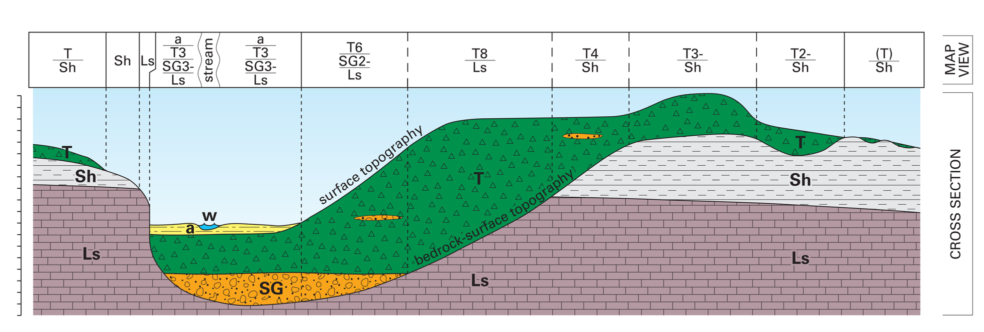
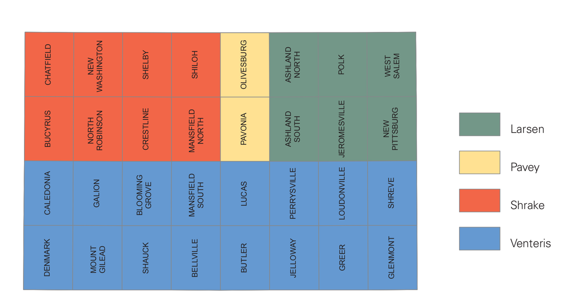
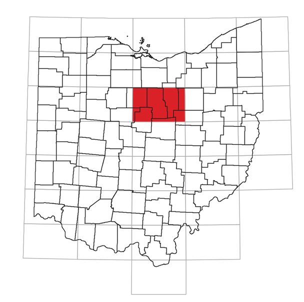


FIGURE 1. – Map view and cross section of a hypothetical stack-unit map. See lithologic-unit descriptions for explanation of symbols. In the map view (top), solid-line boundaries separate map-unit areas having different lithologic units at the surface; underlying lithologic units may or may not differ. 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 Division of Geological Survey at several scales; bedrock-surface topography and bedrock geology are available from the Division of Geological Survey as 1:24,000-scale quadrangle maps.



Mapping responsibility and index to 7.5-minute (1:24,000-scale) quadrangles in the Ohio portion of the Mansfield 30 x 60 minute quadrangle. Mapping completed in 2007.



Location of the Mansfield 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.

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REFERENCES

Alkire, R.L., 1952, Part 1: Oil and gas well drilling statistics for 1951; Part 2: Oriskany sand study, by J. F. Hall; Canton gas pool, by Henry Belden; Wells drilled in Ohio, 1888-1951, Oil and gas production charts, Well sample cuttings index; and Excerpts from previous reports: Ohio Division of Geological Survey Report of Investigation 13, 99 p.

Brant, R.A., 1954, The Lower Kittanning No. 5 coal bed in Ohio: Ohio Division of Geological Survey Report of Investigation 21, 59 p. Reprinted 1965.

Brockman, C.S., 1992, A "rock city" in Richland County, Ohio-An indication of possible periglacial environment: Program of Abstracts, 101 St Annual meeting of the Ohio Academy of Science, Ohio Journal of Science, v. 92, p. 19.

Bureau, M.F., Graham, T.E., and Scherzinger, R.J., 1984, Soil survey of Wayne County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 201 p.

Carlson, E.H., 1991, Minerals of Ohio: Ohio Division of Geological Survey Bulletin 69, 155 p.

Coffey, G.N., 1930, proglacial, Interglacial and Postglacial Changes of Drainage in Northeastern Ohio with Special Reference to the Upper Muskingum Drainage Basin: The Ohio Journal of Science, v. 30, n. 6, p. 373-384.

Collins, H.R., 1976, Coal production in Ohio--1800-1974: Ohio Division of Geological Survey Information Circular 44, 33 p.

Conrey, G.W., 1921, Geology of Wayne County: Ohio Division of Geological Survey Bulletin 24, 155 p.

DeLong, R.M., 1965, Geology of the Malvern quadrangle, Ohio: Ohio Division of Geological Survey Report of Investigations 57, map (scale 1:24,000) with text.

______, 1957, Coal resources of the lower part of the Allegheny formation in Ohio: Ohio Division of Geological Survey Report of Investigations 31.

Ernst, J.E., and Martin, N.H., 1994, Soil survey of Huron County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 184 p.

______, Miller, K.E., and Hunter, R.L., 1980, Soil survey of Seneca County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 143 p.

Fernandez, R.L., 1986, Glacial geology of Seneca County, Ohio: Field maps (scale 1:24,000) on file at the Ohio Division of Geological Survey.

Gehring, R.M., McClure, D.N., and Hacker, S.C., 1993, Soil survey of Morrow County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 160 p.

Granchi, J.A., 1958, Coal resources of the Pottsville formation: Ohio Division of Geological Survey Report of Investigation 36, 53 p.

Gray, J.D., Struble, R.A., Carlton, R.W., Hodges, D.A., Honeycutt, F.M., Kingsbury, R.H., Knapp, N.F., Majchszak, F.L., and Stith, D.A., 1982, An integrated study of the Devonian-age black shales in eastern Ohio: Ohio Division of Geological Survey, 168 p.

Hall, J.F., and Alkire, R.L., 1956, The economic geology of Crawford, Marion, Morrow, and Wyandot Counties: Ohio Division of Geological Survey Report of Investigation 28, 43 p.

Heiskanen, W.A., and Uotila, U.A., 1956, Gravity survey of the State of Ohio: Ohio Division of Geological Survey Report of Investigation 29, 34 p. Reprinted 1968. Superseded by U.S. Geological Survey Map GP-962.

Hayhurst, E.N., Milliron, E.L., and Steiger, J.R., 1977, Soil survey of Medina County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 119 p.

Hildenbrand, T.G., and Kucks, R.P., 1984, Complete Bouguer gravity anomaly map of Ohio: U.S. Geological Survey Geophysical Investigations Map GP-962.

Hoover, K.V., 1960, Devonian-Mississippian Shale Sequence in Ohio: Ohio Division of Geological Survey Information Circular 27, 154 p.

LaRocque, Aurèle, 1966, Pleistocene Mollusca of Ohio, Introduction, geologic setting, and paleoecology: Ohio Division of Geological Survey Bulletin 62, Part 1, 111 p.

______ 1967, Pleistocene Mollusca of Ohio, Naiades and Sphaeriidae: Ohio Division of Geological Survey Bulletin 62, Part 2, 243 p.

______, 1968, Pleistocene Mollusca of Ohio, Freshwater Gastropoda: Ohio Division of Geological Survey Bulletin 62, Part 3, 196 p.

______, 1970, Pleistocene Mollusca of Ohio, Terrestrial Gastropoda: Ohio Division of Geological Survey Bulletin 62, Part 4, 196 p., 246 p.

Lord, R.C., 1936, The Black Hand Formation in North Central Ohio: The Ohio Geological Survey, v. 36, n.3, p. 124-129.

Miller, K.E., Martin, N.H., and Bonet, N.A., 1989, Soil Survey of Marion County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 152 p.

Multer, H.G., 1967, Bedrock geology of Wayne County, Ohio: Ohio Division of Geological Survey Report of Investigations 61, map (1:62,500) with text.

Norris, S.E., 1979, Hydraulic properties of a limestone-dolomite aquifer near Marion, north-central Ohio: Ohio Division of Geological Survey Report of Investigation, 110, 23 p.

Pavey, R.R., Goldthwait, R.P., Brockman, C.S., Hull, D.N., Swinford, E.M., and Van Horn, R. G., 1999, Quaternary geology of Ohio: Ohio Division of Geological Survey Map No. 2., scale 1:500,000.

Powers, D.M., Laine, J.F., and Pavey, R.R., 2002 (revised 2003), Shaded elevation map of Ohio: Ohio Division of Geological Survey Map MG-1, scale 1:500,000.

Read, M.C., 1878, Report on the Geology of Huron County: Ohio Division of Geological Survey, v. 3, p. 289-309.

______, 1878, Report on the Geology of Richland County: Ohio Division of Geological Survey, v. 3, p. 310-324.

______, 1878, Report on the Geology of Knox County: Ohio Division of Geological Survey, v. 3, p. 519-528.

______, 1878, Report on the Geology of Ashland County: Ohio Division of Geological Survey, v. 3, p. 519-528.

______, 1878, Report on the Geology of Wayne County: Ohio Division of Geological Survey, v. 3, p. 539-561.

______, 1878, Report on the Geology of Holmes County: Ohio Division of Geological Survey, v. 3, p. 520-539.

______, 1871, Sketches of the Geology of Geauga and Holmes Counties: Ohio Division of Geological Survey Report of Progress 1870, Pt. VI, p. 463-484.

Redmond, C.E., and Graham, T.E., Brown, D.L., 1980, Soil survey of Knox County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 213 p.

______, and Brown, D.L., 1980, Soil survey of Ashland County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 179 p.

______, Brug, W.H., Vann, J.R., and Milliron, E.L., 1975, Soil Survey of Richland County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 132 p.

Risser, M.L., 1981, Sand and gravel resources of Medina County, Ohio: Ohio Division of Geological Survey Report of Investigations 119, map (scale 1:62,500) with text.

______, 1987, Surficial materials of Medina County, Ohio: Ohio Division of Geological Survey Report of Investigations 133, map (scale1:62,500) with text.

Root, S.I, Rodriguez, Joaquin, and Forsyth, J.L., 1961, Geology of Knox County: Ohio Division of Geological Survey Bulletin 59, 232 p.

Seaholm, J.E., and Graham, T.E., 1998, Soil survey of Holmes County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 281 p.

Shearrow, G.G., 1958, 1957 Oil and gas developments in Ohio: Ohio Division of Geological Survey Report of Investigation, 36, 27 p.

Shafer, W.E., ed., 1994, The Ohio Geological Society anthology, the Morrow County, Ohio "oil boom" 1961-1967 and the Cambro-Ordovician reservoir of central Ohio: Ohio Geological Society, 452 p.

Shrake, D.L., 1997, Regional bedrock geology of the Marion, Ohio, 30 x 60 minute quadrangle: Ohio Division of Geological Survey Map 9, scale 1:100,000.

Smith, W.H., 1949, Sand and gravel resources in northern Ohio: Ohio Divison of Geological Survey Report of Investigation 6, 24 p., map. Reprinted 1968.

Steiger, J.R., Brug, W.H., Parkinson, R.J., LeMaster, D.D., and Plunkett, M.K., 1979, Soil Survey of Crawford County, Ohio: U.S. Department of Agriculture, Soil Conservation Service, 141 p.

Stout, W., Ver Steeg, K., and Lamb, G.F., 1943, Geology of Water in Ohio: Ohio Division of Geological Survey Bulletin 44, 694 p.

Totten, S.M., 1989, Glacial geology of Huron County, Ohio: Manuscript map (scale 1:62,500) on file at the Ohio Division of Geological Survey.

______, 1988, Glacial geology of Medina County, Ohio: Ohio Division of Geological Survey Report of Investigations 141, 38 p., map (scale 1:62,500).

______, 1973, Glacial geology of Richland County, Ohio: Ohio Division of Geological Survey Report of Investigations 88, 55 p., map (scale 1:62,500).

Ver Steeg, K., 1934, The buried topography of north-central Ohio and its origin: Journal of Geology, v. 42, p. 602-620.

Wheat, A.W., 1878, Report on the geology of Medina County: Ohio Division of Geological Survey, v. 3, p. 362-380.

White, G.W., 1982, Glacial geology of northeastern Ohio: Ohio Division of Geological Survey Bulletin 68, 75 p., map (scale 1:250,000).

______, 1977, Glacial geology of Ashland County, Ohio: Ohio Division of Geological Survey Report of Investigations 101, Map (scale 1:62,500) with text.

______, 1973, Glacial geology of Holmes County, Ohio: Ohio Division of Geological Survey Report of Investigations 91, map (scale 1:62,500) with text.

______, 1967, Glacial geology of Wayne County, Ohio: Ohio Division of Geological Survey Report of Investigations 62, 39 p.

______, 1949, Geology of Holmes County: Ohio Division of Geological Survey Bulletin 47, 373 p. Glacial geology superseded by Report of Investigations 91.

Winchell, N.H., 1874, Report on the geology of Crawford County: Ohio Division of Geological Survey v. 2, pt.1, Geology, p. 236-252.

______, 1874, Report on the geology of Morrow County: Ohio Division of Geological Survey v. 2, pt.1, Geology, p. 253-271.

______, 1873, Report on the geology of Seneca County: Ohio Division of Geological Survey v.1, pt.1, Geology, p. 612-624.

______, Report on the geology of Marion County: Ohio Division of Geological Survey v.1, pt.1, Geology, p. 636-645.

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