STATE OF OHIO
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DEPARTMENT OF NATURAL RESOURCES
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Potential for Mineable Bedrock in the Findlay 30 x 60 minute quadrangle

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DRAFT

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INTRODUCTION AND PURPOSE

The Ohio Department of Natural Resources (ODNR), Division of Geological Survey has completed a reconnaissance map showing areas of mineable bedrock, including shale, limestone, and dolomite, likely covered by thin surficial materials (glacial drift) in the Findlay, Ohio, 30 x 60 minute (scale 1:100,000) quadrangle. The main purpose of this map was to create a reconnaissance-level map that shows the potential for mining carbonate and shale bedrock in this quadrangle. We sought to create this map from many existing ODNR Division of Geological Survey maps and GIS datasets as possible. The map shows areas of surficial materials in increments of 10 feet (ft) and totaling less than 40 ft overlying Silurian- and Devonian-age dolomite and limestone, and it also shows a limited area in the southeastern most portion of the quadrangle where surficial materials (totaling less than 20 ft) overlay potential Devonian-age shale resources.

The Findlay map is a derivative map based directly from the ODNR Division of Geological Survey SG-2 series map, *Surficial Geology of the Findlay 30 x 60 Minute Quadrangle* (Venteris and others, 2009). The SG-2 series features maps based upon polygons that represent a "stack" of mapped unit lithologies and thicknesses. A set of queries were run in ESRI ArcGIS® to illustrate the range of thicknesses of the surficial materials overlaying the topmost bedrock units. The goal is to target areas where the glacial surficial materials are relatively thin, making quarrying the underlying bedrock economically viable. A secondary goal is to use the SG-2 series of surficial geology "stack maps" as the basis for creating a number of easy-to-construct, reconnaissance-scale derivative maps that allow the user to quickly determine the thickness and nature of the drift and the underlying bedrock for a variety of uses, including the potential for mineable bedrock, sand and gravel aggregate resources, and solid waste disposal sites. The "Mapping Conventions" section below describes surficial mapping units and bedrock units and includes a brief discussion of the potential mineable resources of the bedrock units. A more detailed discussion of the data sources and techniques used for creating the original SG-2 map, *Surficial Geology of the Findlay 30 x 60 Minute Quadrangle*, can be found in Venteris and others (2009).

In addition to the main "stack map"-based derivative map, this publication includes three useful, smaller-scale inset maps. The first inset map (fig. 1) shows the location of both bedrock quarries and sand-and-gravel pits located in the Findlay 30 x 60 minute quadrangle (Wolfe, 2009). The second inset map (fig. 2) shows the bedrock geology of the Findlay 30 x 60 minute quadrangle derived from the *Bedrock Geologic Map of Ohio* (Slucher and others, 2006). Map-unit symbols used for this inset map appear in bold in the "Bedrock Units" section below. The third inset map (fig. 3) depicts the drift thickness map of the Findlay 30 x 60 minute quadrangle based upon the *Shaded Drift Thickness Map of Ohio* (Powers and Swinford, 2004).

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 4 illustrates 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). 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 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 the average thickness of till in a map-unit area is 40 ft, but 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 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, 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.

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.

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; 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 ft 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 between beach ridges, dunes, and on the lacustrine plain; occurs throughout the map area; very prevalent in marshy, estuarine areas flanking Sandusky Bay.

Af — **Alluvial terraces (Wisconsinan).** Old floodplain remnants along streams that flowed into high, proglacial lake predecessors of Lake Erie. Highly variable textures; commonly positioned tens of feet above modern floodplains. Unit considered thinning to zero at contact with adjacent polygons.

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. Distributed throughout the Findlay map area as lowland surface deposits, terraces, and as deep-water 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. Present throughout the map area as lowland surface deposits; terraces; and thick, deltaic deposits of proglacial predecessors of Lake Erie.

SL — **Sandy silt (Wisconsinan to Holocene).** Massive or laminated; commonly contains thin sand partings. Present throughout the map area in depressions, as beach deposits, drapes on flanks of beach ridges and dunes, and capping deltaic deposits.

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 as terraces, in buried valleys, as nearshore dune and beach ridge deposits of proglacial predecessors of Lake Erie, and in association with deltaic deposits or outwash throughout map area.

SG — **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.

G — **Gravel (Wisconsinan).** Contains intergranular sand, some sand and silt beds or lenses; unit well to moderately sorted, subangular to well rounded; may be massive, crossbedded, or horizontally bedded. Larger clasts and majority of gravel are of variable lithology but are commonly derived from bedrock within the immediate area. In deep buried valleys, may be older than Wisconsinan age. Mapped only near the border with the Lorain/Put-in-Bay quadrangle.

GA — **Basal gravel.** Highly variable, poorly sorted gravel and sand with significant amounts of silt and clay. Deposited at or near the front of the ice sheet directly on bedrock. Presumably of Wisconsinan age. Mapped only in the southeast corner of map.

T — **Unsorted mix of silt, clay, sand, gravel, and boulders (Wisconsinan).** 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.

BEDROCK UNITS*

*Bedrock unit symbols in bold appear in the legend for the second inset map entitled Bedrock Geology of the Findlay, Ohio, 30 x 60 Minute Quadrangle (fig.2).

Potential Shale Resources

Sh — **Shale.** Upper Devonian Antrim Shale (**Da**). Brownish black, dark brown to black, carbonaceous. Present in the northwest corner of map area. Unit not exposed; occurs beneath undifferentiated Quaternary and Neogene (?) deposits. Data from core holes. Limited to the northwestern corner of the Findlay quadrangle, less than 100 ft thick.

SH — **Interbedded shale and limestone.** Shale dominant. Mapped only in the very southeastern corner of the Findlay Quadrangle to indicate the Olentangy Shale (**Do**). Middle and Upper Devonian age, greenish-gray, calcareous, sparsely fossiliferous, clay shale; disseminated pyrite; locally contains lenses and nodules and layers of limestone. Thickness less than 100 ft, thickens to the east.

Potential Carbonate Rock Resources

Ls — **Limestone.** Used to designate the Devonian-age Delaware and Columbus Limestones, present in the southeast corner of the map area, and the Devonian Silica Formation and Dundee Limestone, present in the northwest corner of the map area. Delaware Limestone (**Dd**): Middle Devonian age; medium-brown, fine- to medium-crystalline, fossiliferous, cherty limestone containing shale laminae. Columbus Limestone (**Dc**): Middle Devonian age; light to medium gray to brown, fine to coarse crystalline, fossiliferous, and cherty in the upper portion; sparsely fossiliferous and contains quartz grains in the lower portion. This unit is susceptible to dissolutioning and contains significant areas of well-developed karst topography. Unit thins to the east. Dundee Limestone (**Du**): Middle Devonian age; shades of blue, gray, and brown; occurs in thin to massive beds; upper part very fossiliferous; lower part contains cherty dolomite. The Silica Formation (**Dts**): Middle Devonian age; a calcareous, clayey shale and limestone; bluish gray; very fossiliferous. The Dundee and Silica have a combined maximum thickness of just over 100 ft and thin towards the west.

D — **Dolomite.** Dominant bedrock stack unit present in the map area except in northwest and southeast corners. Stratigraphic names of the dolomites in descending stratigraphic order: Ten Mile Creek Dolomite (note the Ten Mile Creek Dolomite and Silica Formation are typically mapped together), Detroit River Group, the Salina Group undifferentiated, Tymochtee and Greenfield Dolomites, and Lockport Dolomite. Ten Mile Creek Dolomite (**Dts**): Middle Devonian age; shades of gray; mostly in thin to medium beds; contains some irregular layers and nodules of chert. Detroit River Group (**Ddr**) Middle and Lower Devonian-age; consists generally of three formations, in descending stratigraphic order—Lucas Dolomite, Amherstburg Dolomite, and Sylvania Sandstone. These formations tend to thin to the west and may exceed 100 ft. Salina Group undifferentiated (**Ss**): Upper and Lower Silurian age; comprised of dolomite; shades of gray and brown; very finely crystalline; mostly in thin to medium beds and laminae; locally includes shale, anhydrite, and/or gypsum beds and laminae; this unit thickens to the west. Tymochtee and Greenfield Dolomites undivided (**Stg**): Upper and Lower Silurian-age; dolomite and shale. Tymochtee Dolomite, shades of gray and brown; very finely crystalline; occurs in thin to massive beds with carbonaceous shale laminae and beds. Greenfield Dolomite, shades of gray and brown; very finely to coarsely crystalline; vuggy intervals, brecciated zones; occurs as massive beds to laminae; argillaceous; locally brecciated in lower portion. These units tend to thicken to the west and will exceed 100 ft. Lockport Dolomite (**Sl**): Upper and Lower Silurian-age; variegated white to shades of gray; finely to coarsely crystalline; mostly in medium to massive beds; fossiliferous; vuggy; locally cherty in lower portion of unit. This unit typically exceeds 100 ft in thickness and tends to thin to the northwest. Local reef development may be encountered.

BEDROCK GEOLOGY AND MINING POTENTIAL

Bedrock geology in the Findlay quadrangle ranges from the Lower Silurian-age Lockport Dolomite to the Upper Devonian-age Antrim Shale (Shrake, 1997). Stith and Wolfe (2006) and Shrake (1997) showed that five units have potentially economic-quality carbonate rock occurring under thin cover. These units are, in ascending order, Lockport Dolomite, Greenfield Dolomite, Tymochtee Dolomite, Salina Group undifferentiated, and the Columbus Limestone. Small areas of the Delaware Limestone with minimal overburden may be available to mine but would be of a thickness that is not economically viable unless produced in conjunction with the underlying Columbus Limestone. Most of the carbonate rocks in the Findlay quadrangle are considered good to fair in quality for the production of aggregates or other commercial uses, such as fluxstone, extenders or fillers, and agricultural lime. Limestone and dolomite production in 2008 from quarries located in the Findlay quadrangle was more than 7.3 million tons, which is approximately 12.8 percent of the state's total annual crushed stone production (Wolfe, 2009).

The Devonian Antrim Shale and Olentangy Shale units may locally be of some value as a light aggregate material. Historically, these units have been mined in Ohio to produce clay for the ceramic drainage tile and brick industries.

The Findlay map is intended as a general guide to exploration for potential crushed stone resources. The map also may be useful for land-use planning and zoning. Because the Findlay map is based on reconnaissance-level bedrock-topography and bedrock-geology maps, it should not be used for resource leasing purposes. A more detailed geologic and engineering investigation utilizing soils maps, additional water well data, drilling, and laboratory testing of chemical and physical properties would be needed to delineate and evaluate the economic viability of the carbonate resource. Additional studies of possible detrimental geologic conditions, such as karst known to exist in the northernmost region of the Findlay quadrangle, reefal structures prevalent in the Lockport Dolomite, shale interbeds, or the effect of mapped faults on quarrying procedures, also would need to be completed before making mining decisions.

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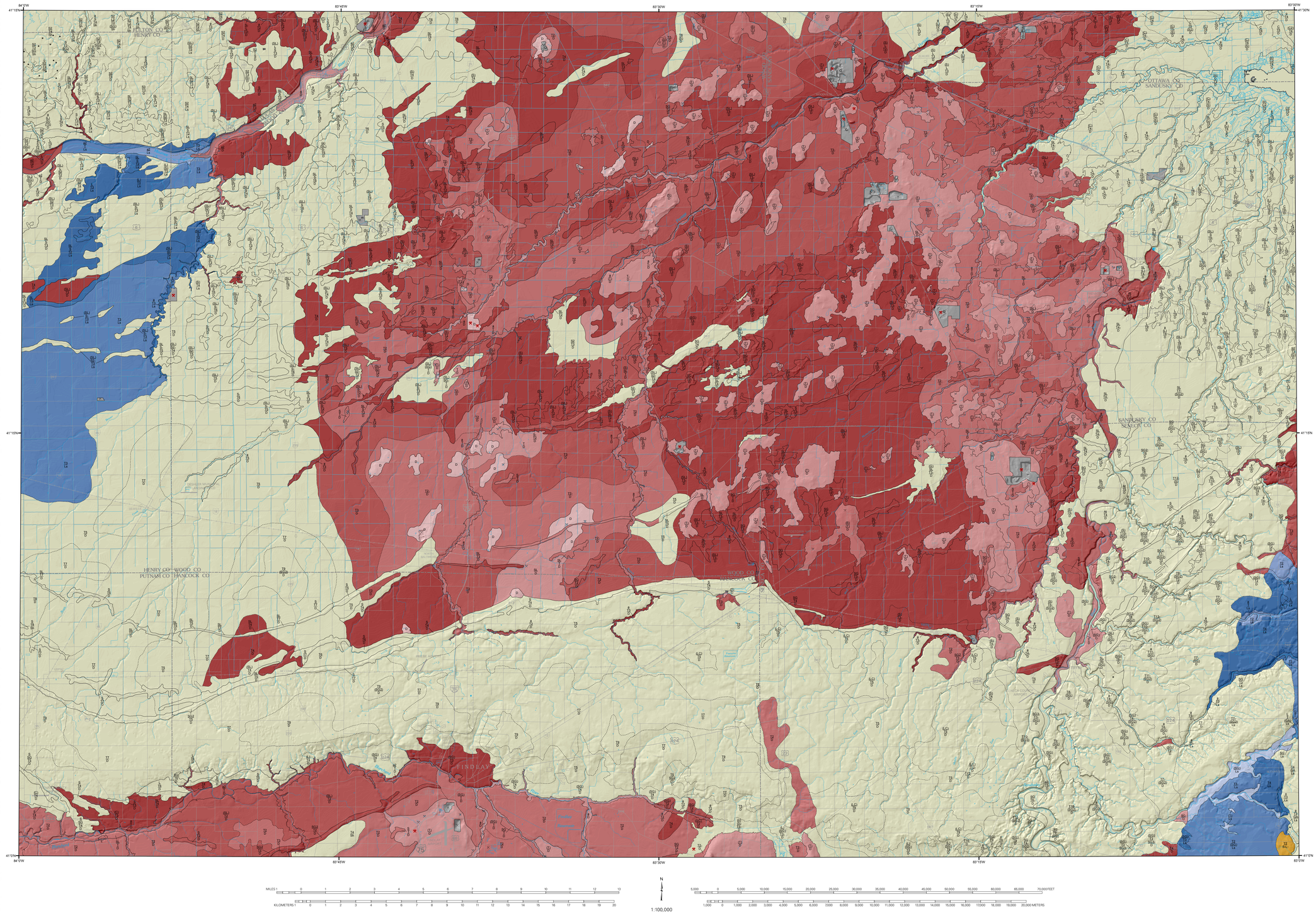


KEY TO DRIFT THICKNESS COLORS

Thin Drift above Dolomite
- 0 ft.
- 0 – 10 ft.
- 10 – 20 ft.
- 20 – 30 ft.
- 30 – 40 ft.

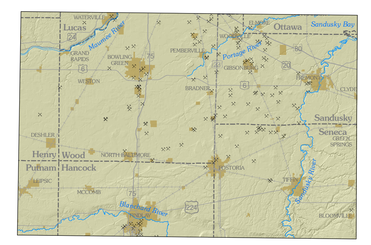
Thin Drift above Limestone
- <10 ft.
- 10 – 20 ft.
- 20 – 30 ft.
- 30 – 40 ft.

Thin Drift above Shale
- <20 ft.

Other Areas
- surficial materials (drift) >40 ft.
- made land, quarries, mines, or large pits

MAP SYMBOLS

- Small area of organic deposits
- Quarry, mine, or strip mine; floored in bedrock; may contain reclaimed areas (Symbols highlighted in red were active in 2009)
- Sand and gravel pit. Pit bottom generally underlain by unconsolidated lithologic units of surrounding polygon(s). May contain reclaimed areas. (Symbols highlighted in red were active in 2009)
- 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



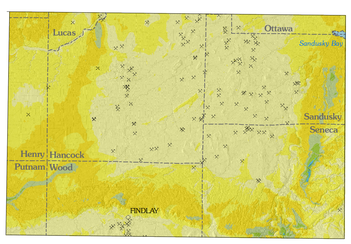
× Pit × Quarry Urban Areas

FIGURE 1.—Pits and quarries located in the Findlay, Ohio, 30 X 60 minute quadrangle.

Description of Map Units

- Da — Devonian Antrim Shale
- Dc — Devonian Columbus Limestone
- Dd — Devonian Delaware Limestone
- Ddr — Devonian Detroit River Group
- Ddu — Devonian Dundee Limestone
- Do — Devonian Olentangy Shale
- Dts — Devonian Ten Mile Creek Dolomite and Silica
- Ss — Silurian Salina Group
- Stg — Silurian Tymochtee and Greenfield Dolomites
- Sl — Silurian Lockport Dolomite
- × Pit
- × Quarry
- Fault

FIGURE 2.—Bedrock geology of the Findlay, Ohio, 30 X 60 minute quadrangle.



Thickness in Feet

- 0 – 30
- 31 – 60
- 61 – 100
- No Data
- 10 – 130
- 131 – 160
- 161 – 225
- 226 – 300
- 301 – 360
- 361 – 460
- 461 – 723
- × Pit
- × Quarry

FIGURE 3.—Drift thickness of the Findlay, Ohio, 30 X 60 minute quadrangle.

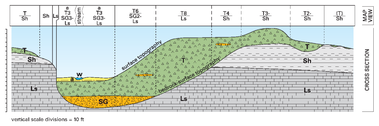


FIGURE 4.—Map view and cross section of a hypothetical stack-unit map. See lithologic unit descriptions for explanation of symbols. In the map view (top), solid-line boundaries separate map-unit areas having different lithologic units at the surface; underlying lithologic units may or may not differ. 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 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.

Location of the Findlay 30 x 60 minute quadrangle

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

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