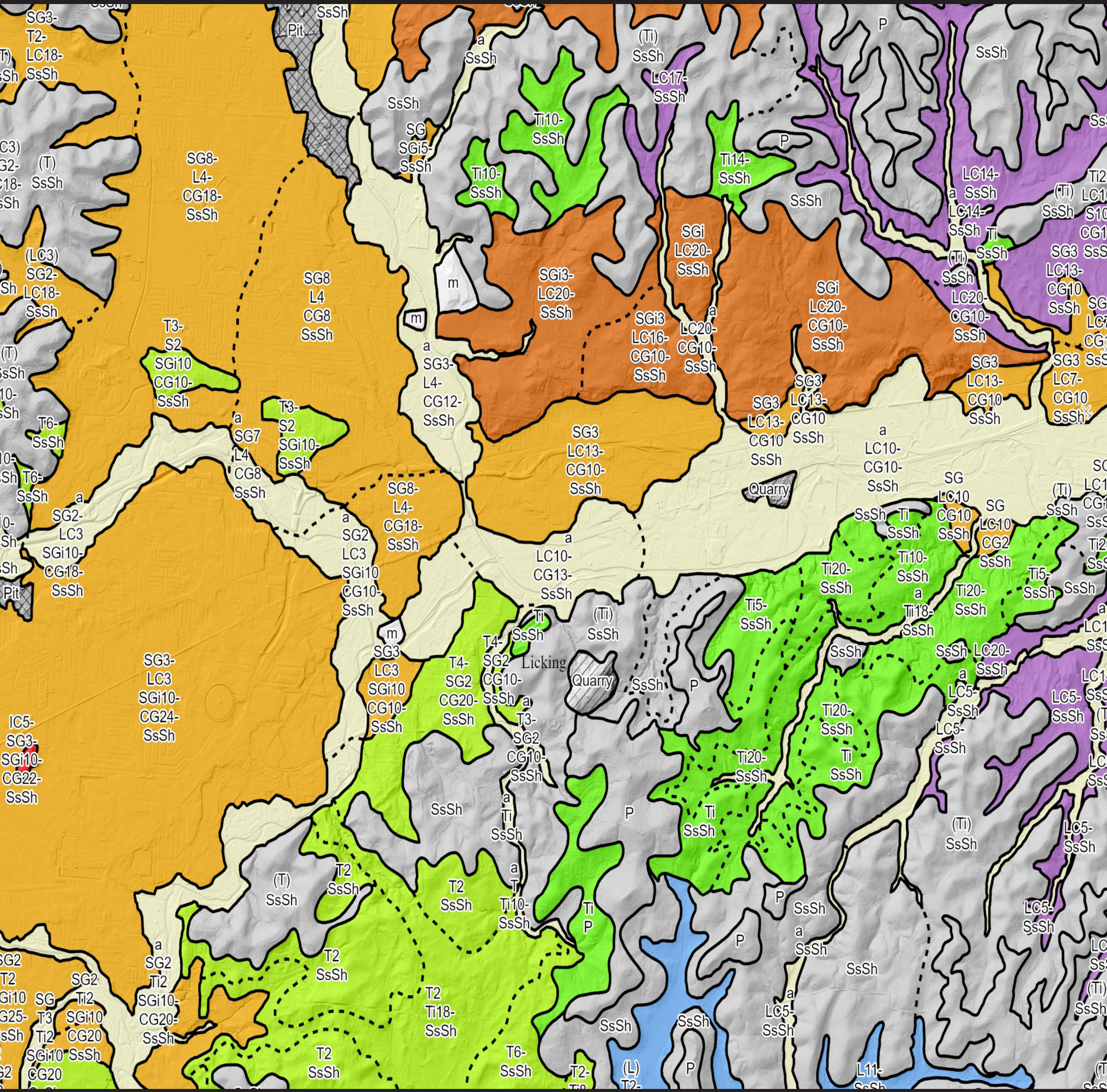
GUIDE TO THE SURFICIAL STACK DATABASE OF OHIO—MAPPING AND REVISIONS, 1997–2022

by Douglas J. Aden, T. Andrew Nash, and J. D. Stucker



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DEPARTMENT OF NATURAL RESOURCES

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FRONT COVER: Surficial geology stack map with hillshade for area located along the glacial margin in Newark, Ohio.

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PREFACE

This 2023 guide to the Surficial Stack Database of Ohio describes the mapping and revisions undertaken from 1997 to 2022 that resulted in a seamless, statewide surficial geology map database depicting the glacial materials of Ohio in three dimensions. The Surficial Stack Database is available as a downloadable dataset that will be updated regularly. This dataset is viewable through the Ohio Geology Interactive Map on the Survey's website at **ohiodnr.gov/ogim**. This interactive map includes viewable data, custom PDF outputs, and downloadable data. For questions, please contact the Ohio Department of Natural Resources, Division of Geological Survey at **geo.survey@dnr.ohio.gov**.

CONTENTS

FIGURES

TABLES

APPENDICES

ABBREVIATIONS USED IN THIS REPORT

Units of Measure

Feet . . . . . ft
Kilometers . . . . . km
Meters . . . . . m
Miles . . . . . mi

Other Abbreviations

Bedrock Topography . . . . . BT
Digital Elevation Model . . . . . DEM
Geographic Information System . . . . . GIS
Great Lakes Geologic Mapping Coalition . . . . . GLGMC
Light Detection And Ranging . . . . . LiDAR
Ohio Department of Transportation . . . . . ODOT
Ohio Environmental Protection Agency . . . . . OEPA
Ohio Geographically Referenced Imagery Program . . . . . OGRIP
Open File Report . . . . . OFR
Portable Document Format . . . . . PDF
Soil Survey Geographic Database . . . . . SSURGO
Surficial Geology . . . . . SG
Three Dimensional 3D
Transportation Information Mapping System . . . . . TIMS
Two Dimensional 2D
United States Geological Survey . . . . . USGS

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INTRODUCTION

Traditional surficial geology maps depict the sediments and rocks found on Earth's surface to a defined shallow depth, commonly 1.5 m (4.9 ft). These two-dimensional (2D) paper maps are important for understanding the areal extent of geologic units and how they relate to one another near Earth's surface. However, geologic units are three-dimensional (3D) in nature, and their full extents can be defined only by extending mapping into the subsurface. Practically, it is difficult to represent the 3D nature of geologic units on traditional 2D paper maps. However, various methodologies for producing surficial "stack" maps have been developed to overcome this issue, resulting in versatile maps that are beneficial for applications such as aquifer mapping, determining resource availability, and project design.

Surficial stack maps help scientists, hydrologists, engineers, consultants, and land-use planners determine the 3D extents of aquifers, the context of potential confining layers, the primary material of which an aquifer is composed, and the greater regional geologic context that created an aquifer. Groundwater-flow modelling relies on accurate measurements of these parameters to track point-source pollution and identify water quantity issues. Stack maps are also a useful tool for accurately creating volumetric estimates of natural resource reserves. Economically important unconsolidated resources, such as sand and gravel, clay, and peat, can be quantified using data presented in stack maps. These maps also include valuable information such as overburden thickness and unconsolidated resource composition, which may be used to determine the economic viability of extracting natural resources. Stack maps may also be used as a supplementary resource for determining depth to bedrock, calculating the total thickness of unconsolidated materials, or determining the materials needed to complete a well. Water well drillers can benefit from these maps by using them to better estimate the amount of casing and well screen needed to complete a well. Understanding the total thickness and extent of unconsolidated surficial sediments is fundamental when designing borings or wells and infrastructure, such as roads, bridges, buildings, pipelines, wind turbines, and solar farms. Having a single map product that includes unconsolidated thickness and lithology information helps all map users design and complete various projects and reduces cost by allowing for a more-targeted approach to subsurface data collection.

BACKGROUND

Within the Great Lakes region, stack maps have been adapted to represent the complex 3D nature of Quaternary-aged glacial deposits. The Illinois State Geological Survey created a preliminary version of a stack map as part of a study of the geology of Boone and Winnebago Counties (Berg and others, 1984, plate 1) , which would become the primary basis on which to model Ohio's stack map efforts. In Ohio, an early stack map was completed for the Superconducting Supercollider (SSC) project (1987) site in Delaware, Marion, and Union Counites, but it was not published or finalized. The SSC effort closely followed the format of the Berg and others (1984) report. In Illinois, continued implementation of digital mapping techniques and stack labeling culminated in the publication of the Paducah 1 x 2-degree Quadrangle (Berg and Greenpool, 1993). Berg and Greenpool (1993) used stacked labels, colors, and pattern overlays to depict the 3D framework of the surficial geology to a depth of 15 m (50 ft) in the Paducah Quadrangle. At the same time, Soller (1993) published a regional map depicting the thickness and character of Quaternary-aged sediments east of the Rocky Mountains using color intensity to define the thickness of three broad sediment texture categories. These examples of early stack maps were some of the first 3D representations of unconsolidated surficial materials in a 2D map format and provided inspiration and refinement for Ohio's first surficial stack maps.

The Ohio Department of Natural Resources, Division of Geological Survey (the Survey) has created stack maps (Appendix A) of the surficial materials of Ohio for over 25 years (table 1). In total, twenty-four of Ohio's thirty-four 30 x 60-minute quadrangles were published at the 1:100,000 scale. Each of these 1:100,000 scale publications were mapped over a specific, usually year-long, time period based on grant interval restrictions. The mapping projects were completed and published as independent products, leading to a patchwork of maps (fig. 1). Maps were published at 1:100,000 scale, but all the line work was completed at a more-detailed scale between 1:24,000 and 1:10,000.

Beginning in 2015, surficial geology maps were published at the 1:24,000 and 1:62,500 scales but always digitized at the 1:10,000 scale. From 2015 to 2022, the Survey published 29 surficial geology 7.5-minute quadrangle maps at the 1:24,000 scale and three countywide surficial geology maps at the 1:62,500 scale. The remaining 188 7.5-minute quadrangles were completed as digital-only products and not published with a traditional map layout. Although these maps were not published, they underwent the same internal review process as published maps before being added to the digital database. In 2017, the Survey began a five-year process to complete the surficial mapping for the state and to correct inconsistences in the previous mapping, with the goal of creating a seamless, statewide surficial geology map database. Mapping methodologies, personnel, data sources, and software (e.g., LiDAR, ArcGIS®, geologic interpretations) have changed significantly in recent years, especially as advances in geographic information systems (GIS) and other mapping software have streamlined map production.

TABLE 1. ***Surficial geology stack maps produced at each scale for Ohio†***

Publication Scale	Map Size	Authoring Scale	Number of Mapping Projects
1:100,000	30 x 60 minute quadrangle	1:10,000–1:24,000	22
1:24,000	7.5 minute quad-rangle	1:10,000	29
1:62,500	Countywide	1:10,000	3
Digital only, no layout	7.5 minute quad-rangle	1:10,000	188

†See Appendix B for a full bibliography of published maps.

The Survey's published surficial geology maps can be categorized into three distinct phases (*original*, *born-digital*, and *seamless database*) based on the implementation of mapping methodologies and long-term strategic plans (fig. 2). During the *original phase*, which lasted from 1997 to 2008, maps were produced by hand on Mylar and later digitized into a GIS. This combination of traditional cartography and modern digital methods was typical during that time as the geologic mapping community was beginning to shift towards GIS formats. These maps were initially produced using 7.5-minute topographic contour base maps (1:24,000 scale) and published as 30 x 60-minute quadrangles (1:100,000 scale). Because these maps were treated as independent products, mapping methodologies evolved through time and thus varied from map to map with some adjacent quadrangles not being adequately edge matched. Inconsistent edge matching created topologic issues when these data were eventually digitized in a GIS.

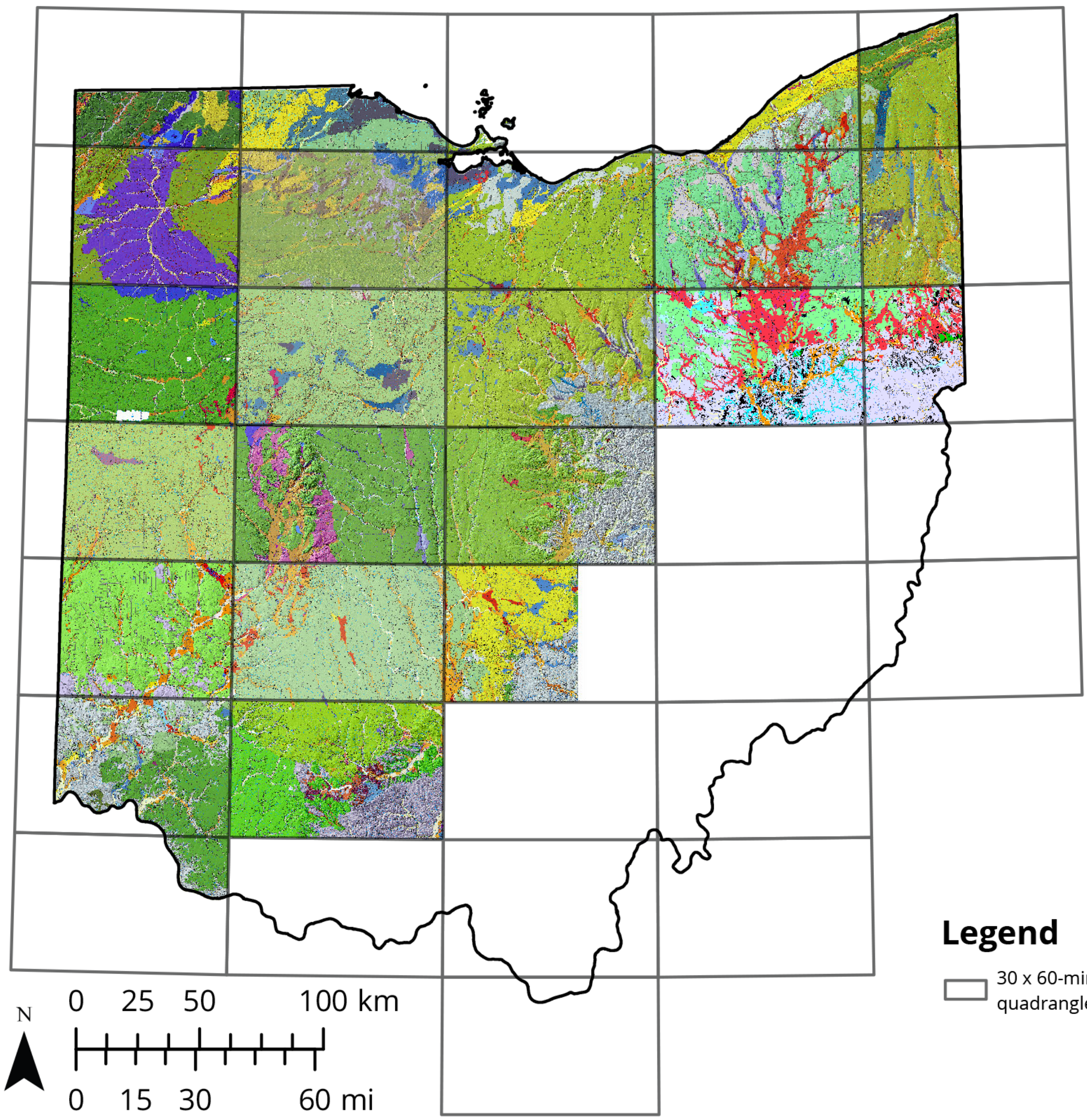

FIGURE 1. Patchwork of previously published 30 x 60-minute quadrangles in Ohio. The symbology and prevalence of each geologic unit vary dramatically from one mapping project area to the next, owing to different authorship and mapping methodologies.

The *born-digital* phase occurred from 2008 to 2017 and is defined by the drafting of surficial geology maps entirely in GIS formats at 1:10,000 scale but published at 1:100,000 scale. During this period, a statewide, 0.76-m (2.5-ft)-resolution digital elevation model (DEM) was used as the primary base map for delineating surficial geomorphic units. Maps produced during this phase attempted to edge match adjacent earlier mapping efforts, when possible, but this was not strictly enforced. Often, data discovered during new mapping would conflict with a previously mapped, adjoining area. Because there was typically no time budgeted, or method available, to edit preexisting maps, these new data often led to border discrepancies. Many of the publication methods and conventions established in the *original* phase were preserved during this *born-digital* phase, including publication of individual 30 x 60-minute quadrangles as 1:100-000 scale maps.

The *seamless database* phase began in 2017 when the Survey began the process of revising existing map data into a single seamless database and completing the statewide surficial geology stack map. During this phase, surficial geology maps were digitally authored at the 1:10,000 scale, but only some were formally published at the 1:24,000 or 1:62,500 scale. Most maps produced during this period were considered digital-only products and now exist as part of the seamless statewide database. During this period, edge matching was enforced during digital mapping to ensure no new topological errors were generated. Mapping during this phase was completed at a much quicker pace compared to previous phases. This expedited mapping was the result of several factors, including the introduction of additional mappers; prioritized internal funding; a lack of formally published products with cartographic layouts; and the absence of thick, complex unconsolidated deposits beyond the glacial margin. The conclusion of this third phase in 2022 culminated in the seamless, statewide surficial geology database, which exists as a living dataset and will be updated and versioned as new data are collected.

STACK MAPPING METHODOLOGY AND STATEWIDE REVISIONS

The primary data sources used to create stack maps remained consistent during all three mapping phases. Soil maps were a valuable data source for delineating surface lithology. Over the course of completing the statewide stack map, the primary methodology for accessing these soils maps transitioned from individual county surveys to digital data repositories that included updated data (SSURGO, 2022). The delineation of surficial geomorphic landforms for bounding the extents of certain lithologies likewise transitioned from paper 7.5-minute topographic quadrangles to a statewide 0.76-m (2.5-ft)-resolution DEM (OGRIP, 2006). To extend surficial lithologic units into the subsurface and create "stacks," geologists used thousands of manually verified water-well logs and tens of thousands of geocoded water-well logs (Ohio Geological Survey, 2022), geotechnical borings from the OEPA and the ODOT (TIMS, 2022), Survey core holdings, seismic-refraction profiles, aerial photography (OGRIP orthoimagery), past glacial mapping (Pavey and others, 1999), and field observations. Total stack thicknesses were derived from water wells, bedrock topography maps, and drift thickness mapping (Brockman and others, 2003; Powers and Swinford, 2004). Bedrock lithologies were derived from open-file bedrock geology maps and the *Bedrock Geologic Map of Ohio* (Slucher and others, 2006).

The Survey's stack maps are composed of four feature classes, each of which are used during map digitization or display (table 2). Recognizing the feature types, purposes, and relationships is important to understand the revisions that were made to the statewide dataset. Additional detailed mapping conventions can be found in Appendix A.

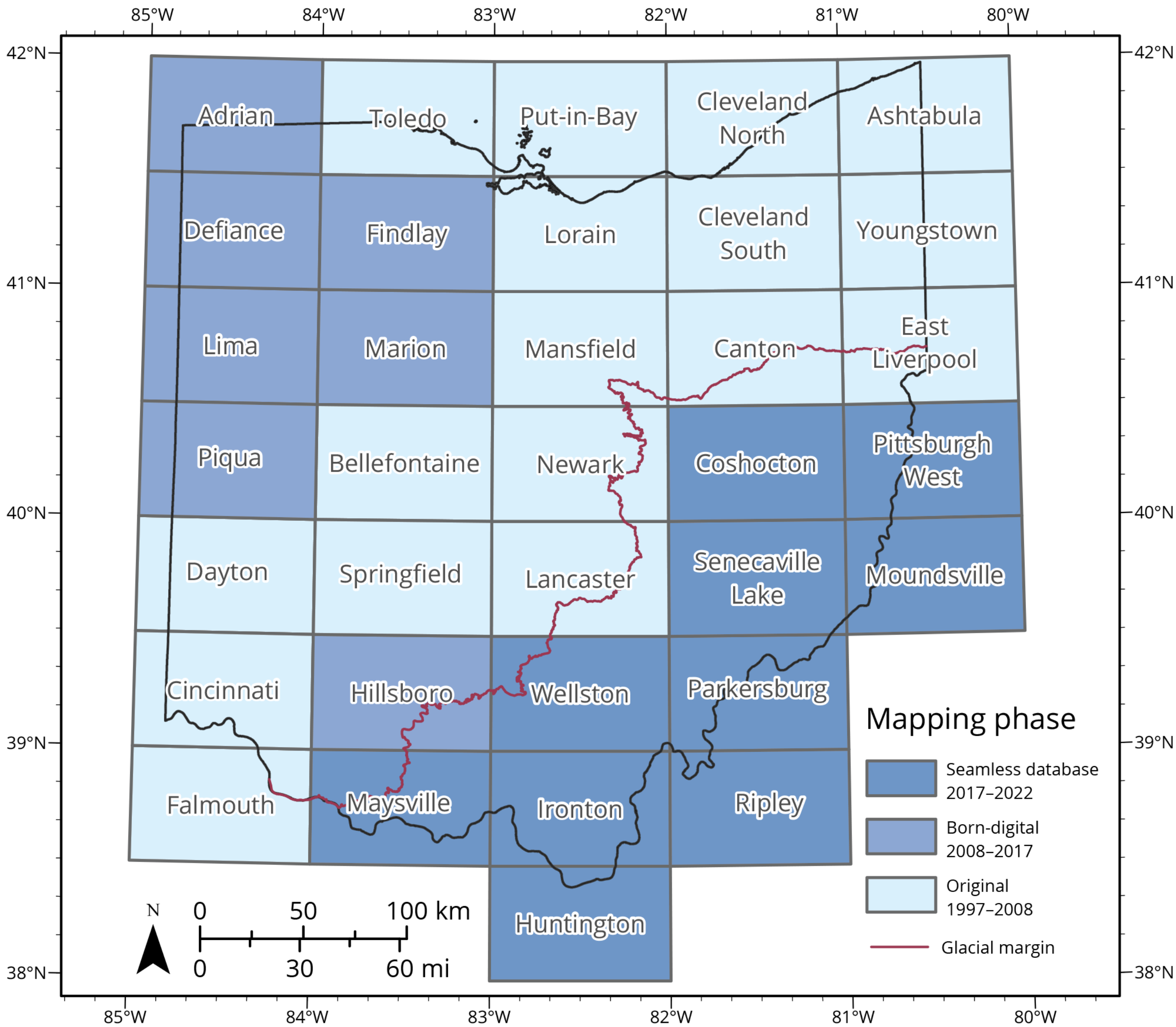

FIGURE 2. Ohio 30 x 60-minute quadrangles and phases in which they were mapped. The *original* phase refers to a period when maps were primarily produced by hand and then later digitized into a GIS and published as 30 x 60-minute quadrangle maps at 1:100,000 scale. The *born-digital* phase refers to a period when maps were fully produced in GIS and then published as 30 x 60-minute quadrangle maps at 1:100,000 scale. The *seamless database* phase refers to a period when GIS map data was created digitally, and the stack map digital database was considered the primary authoritative source. Some 7.5-minute quadrangle maps were published at a 1:24,000 scale during the *seamless database* phase, but no 1:100,000 scale maps were formally published with layout. All originally published paper maps from this 25-year time span have been archived in the Survey library and are available upon request.

TABLE 2. ***Statewide surficial stack map feature class types and purposes***

Feature Description	Feature Type	Feature Purpose
Unit Contacts	Line	Solid and dashed lines that represent lateral changes in unit lithology.
Primary Label	Point	Unit stack labels, which identify lithologies present in an area and their approximate thicknesses and distribution.
Quarry/Pit/Organic	Point	Depicts quarries, pits, and organic deposits too small to be delineated by a polygon.
Unit Areas	Polygon	Generated from unit contact lines and attributed using primary label points. Symbology determined by uppermost continuous primary label unit. Displayed overlain by unit contacts, primary labels, and quarry/pit/organic points to produce final digital map view.

Methodology revisions

Before the seamless surficial stack database could be completed and compiled, many revisions needed to be made to existing mapped areas. Historically, final map products were published as PDFs at 1:100,000 scale for each 30 x 60-minute quadrangle, and in some cases, edits were made to final PDFs but not to the supporting GIS data. To compare the two, published PDFs were georeferenced, examined in GIS, and used to update the digital data where needed.

To account for digital map products, such as an online interactive map, a more dynamic labeling system was needed. Static annotation was replaced by real-time labeling of polygon features, so that a label would always be visible for each polygon, regardless of where a user panned or zoomed on the interactive map or within GIS.

Across the 22 published 1:100,000 scale stack maps, the usage of lithologic units varied as map authors and regional geology varied and methods evolved. This created a situation where unconsolidated deposits within the same lithologic category, and with similar properties, were classified as different units. For example, Wisconsinan-aged glacial till (**T**) was split by early authors into eight different lithologic units (see Appendix C) based on slight regional differences. On a statewide scale, these subtle variations were not well-defined and not consistent enough to justify that level of differentiation. In addition, these units were only differentiated at the land surface and subsurface till units were not differentiated, making those distinctions less useful. Therefore, groups of overly differentiated units were consolidated into a single, universal unit that could be applied consistently throughout the state. In total, 65 statewide unit descriptions were consolidated to 35 (Appendix C). This simplified lithologic framework ensures that each lithology is applied consistently throughout the state.

Many polygons contained unnecessarily complex labels that needed simplification. Some of these labels contained as many as ten stacked units, excessive use of modifiers, or were overly thick based on the known thickness for unconsolidated sediments in that area. Unit labels were reviewed and limited to no greater than seven stacked units, a maximum of one modifier per layer, and total thicknesses were reevaluated, within the confines of the established stack-mapping parameters (Appendix A). Units shown in parentheses (patchy units) were reevaluated if thicker than 6 m (20 ft), and stacks were adjusted to include only the uppermost bedrock unit as the bottom of the stack. In 2022 alone, more than 8,000 of the 53,000 total label points were adjusted.

Quarry, pit, and organic deposit points often conflicted with the polygons they overlapped. For example, where a pit point and quarry polygon overlapped, the area was reviewed and corrected. Furthermore, clusters of points were examined to determine if they could be simplified into polygons (fig. 3).

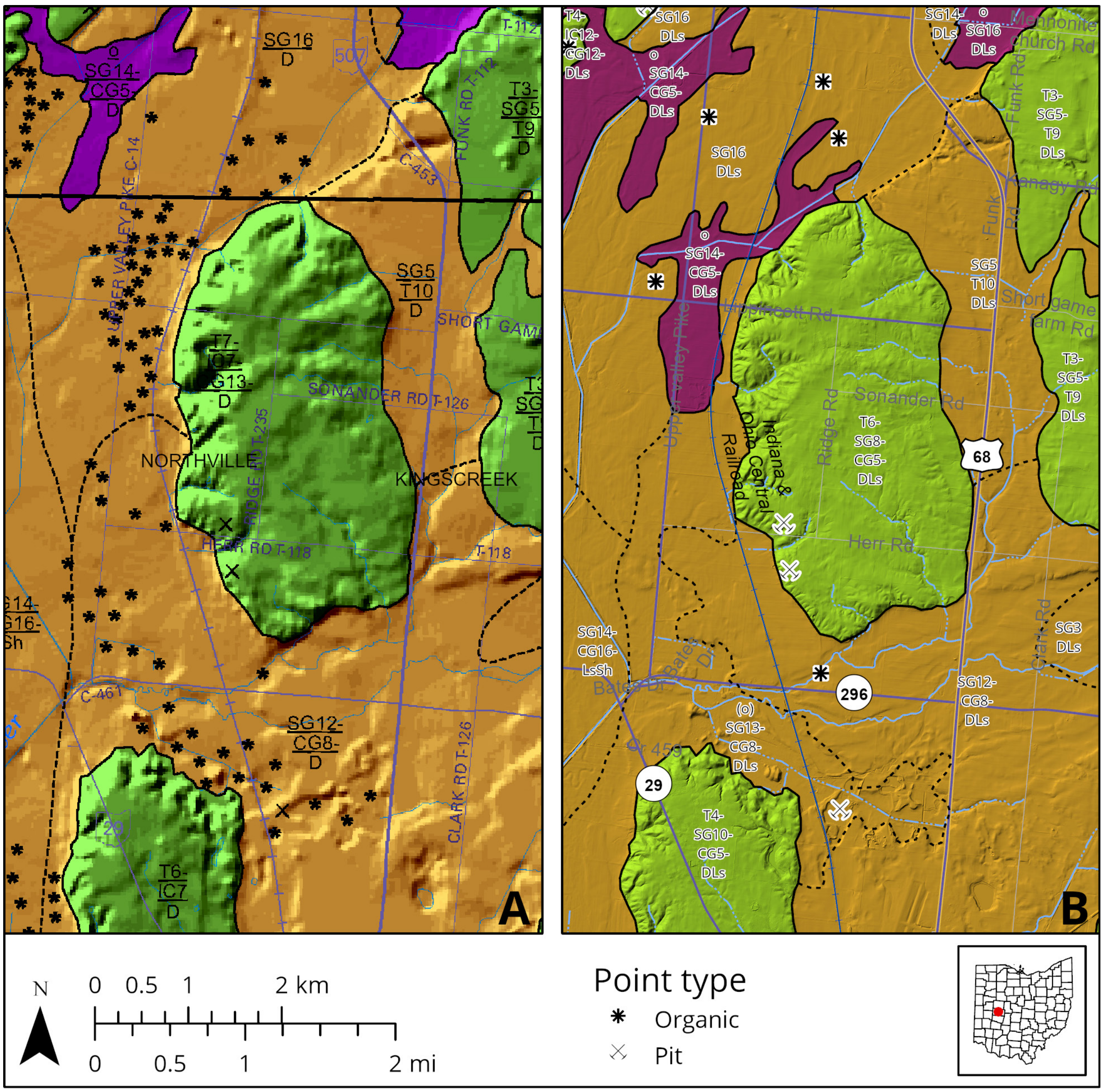

FIGURE 3. (A) Original georeferenced, published PDF map. (B) Clusters of organic points from original PDF map incorporated into two adjacent polygons in the updated stack map database, owing to their number and density.

Geologic interpretation revisions

Polygons smaller than thirty acres (twelve hectares) and with greater than seven stack layers were considered too complex for the purposes of this map database. These polygons were merged into adjacent, similar polygons or simplified by grouping layers. For example, a stack of **T/(SG)/T/Sh** could be simplified to **T2/Sh**, since the definition of **T** (till) technically includes patchy **SG** (sand and gravel).

Each layer of a stack label contains a material type, a thickness, and in some cases a modifier. In order to validate the stack labels, an ArcGIS model was created that splits every label into its component parts. These split fields were checked for typos, missing values, and duplicated units. Prior to this, there was no systematic way to assess the individual parts of a given stack, and extensive manual review was needed. Furthermore, layer thickness fields were summed to calculate the total estimated thickness of surficial materials for each polygon. These values were compared to the existing statewide drift thickness data to create a difference map, which highlighted discrepancies between these datasets. Areas that differed by greater than 15 m (49 ft) were prioritized for review and adjusted where needed, using the best available data for the area.

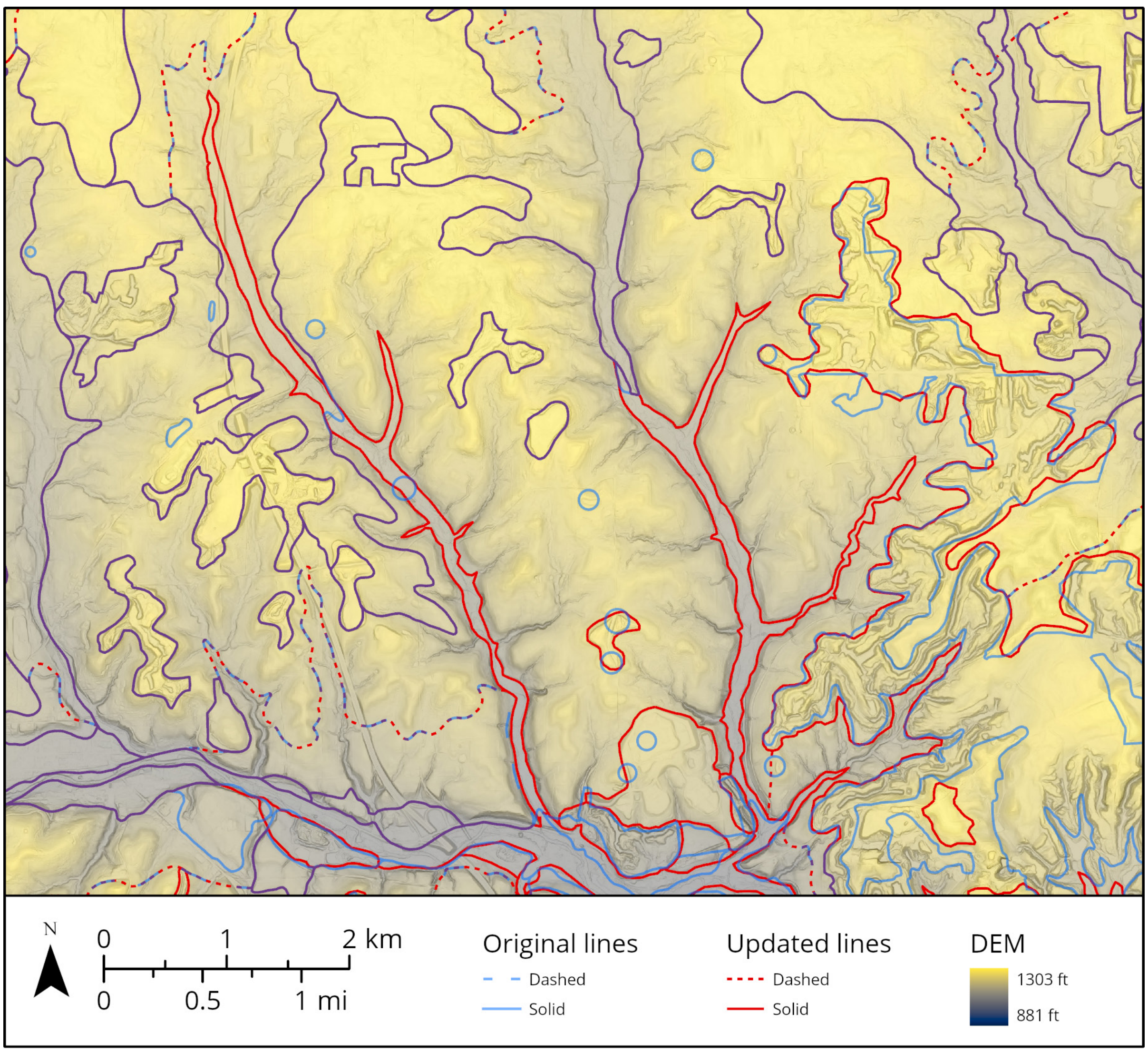

FIGURE 4. Map showing new long, narrow alluvial valleys that have been added where they were previously unmapped. Original lines in blue, new lines in red, and purple where they overlap. Glacial sediments have been remapped in valleys, and small quarries drawn as blue circles have been converted to symbol points (not shown) or merged into larger polygons. DEM base map shows elevation decreasing from yellow to blue (high to low).

With the implementation of technological advancements like GIS and DEMs, line features from older maps were noticeably less accurate than modern lines drawn with the enhanced resolution of these technologies. Features that change over time, such as quarries, pits, and made land, were remapped with more accuracy upon review (fig. 4). The delineation of alluvium was also improved using new soil data and updated DEMs (fig. 4). Many lines were added and revised in older mapping areas where alluvium was not originally digitized. Numerous human-made reservoirs were also delineated for the first time during statewide revisions. About 30,000 lines—nearly half of all the lines created before 2017—were corrected or updated during the review and remapping of the *original* phase and *born-digital* phase data (fig. 5). During 2022, all quadrangles underwent a final quality assessment and were remapped where needed for final database release (Appendix D).

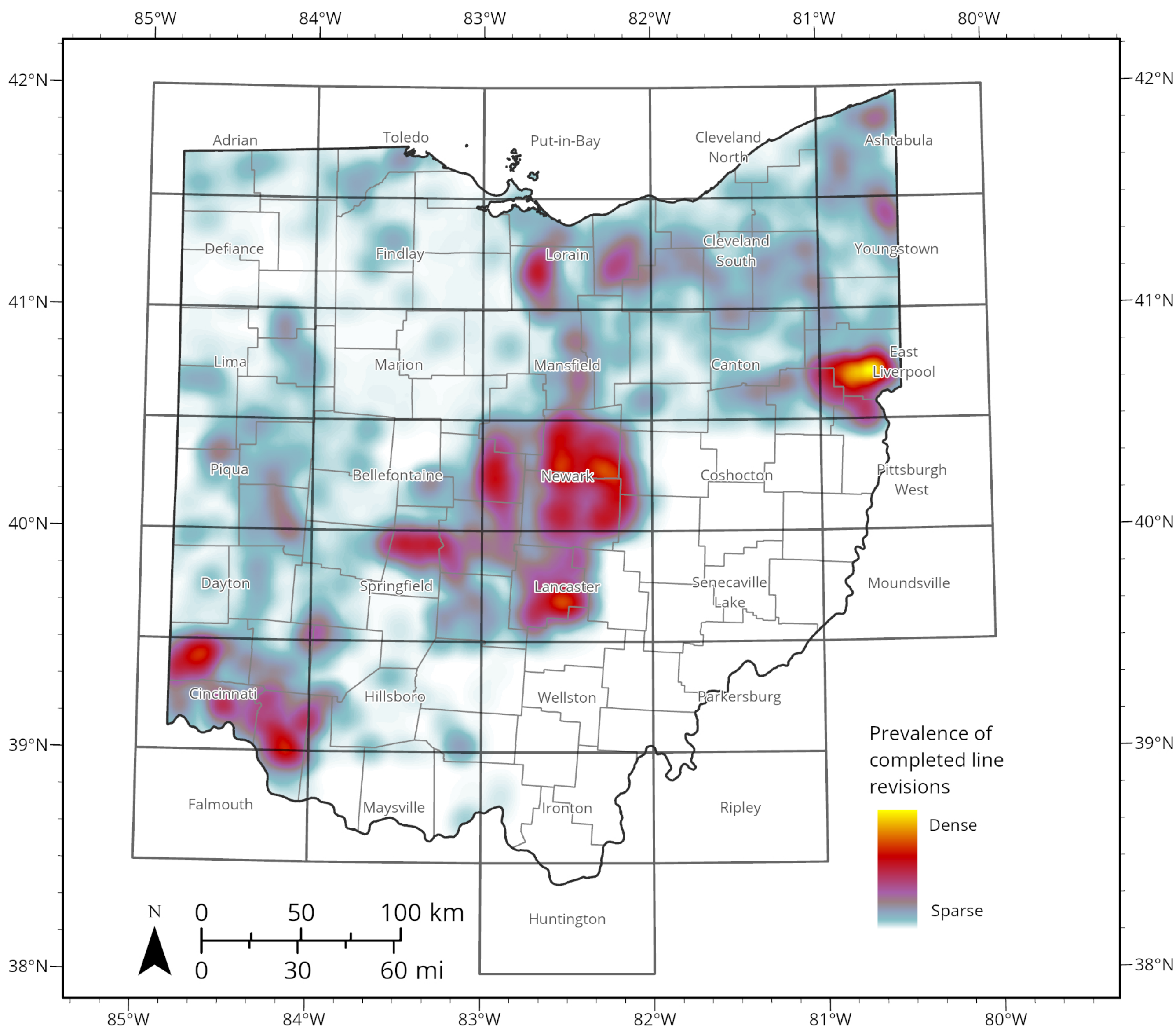

Figure 5. Heat map of Ohio showing 30 x 60-minute quadrangles and areas where the most line corrections were made between 2017 and 2022.

Topological revisions and database normalization

Areas across the state with topological errors were located using topology rules for geologic lines as defined by GeMS (*Ge*ologic *M*ap *S*chema; USGS NCGMP, 2020), three rounds of visual inspection, and analysis of the attribute tables. Every 7.5-minute quadrangle boundary was inspected to determine if lines and lithologic units matched. Incongruities were discovered and corrected on about one-third of the borders mapped prior to the *seamless database* phase (fig. 6). Topological rules were verified on all point, line, and polygon feature classes stored in the map database and corrected during final map compilation.

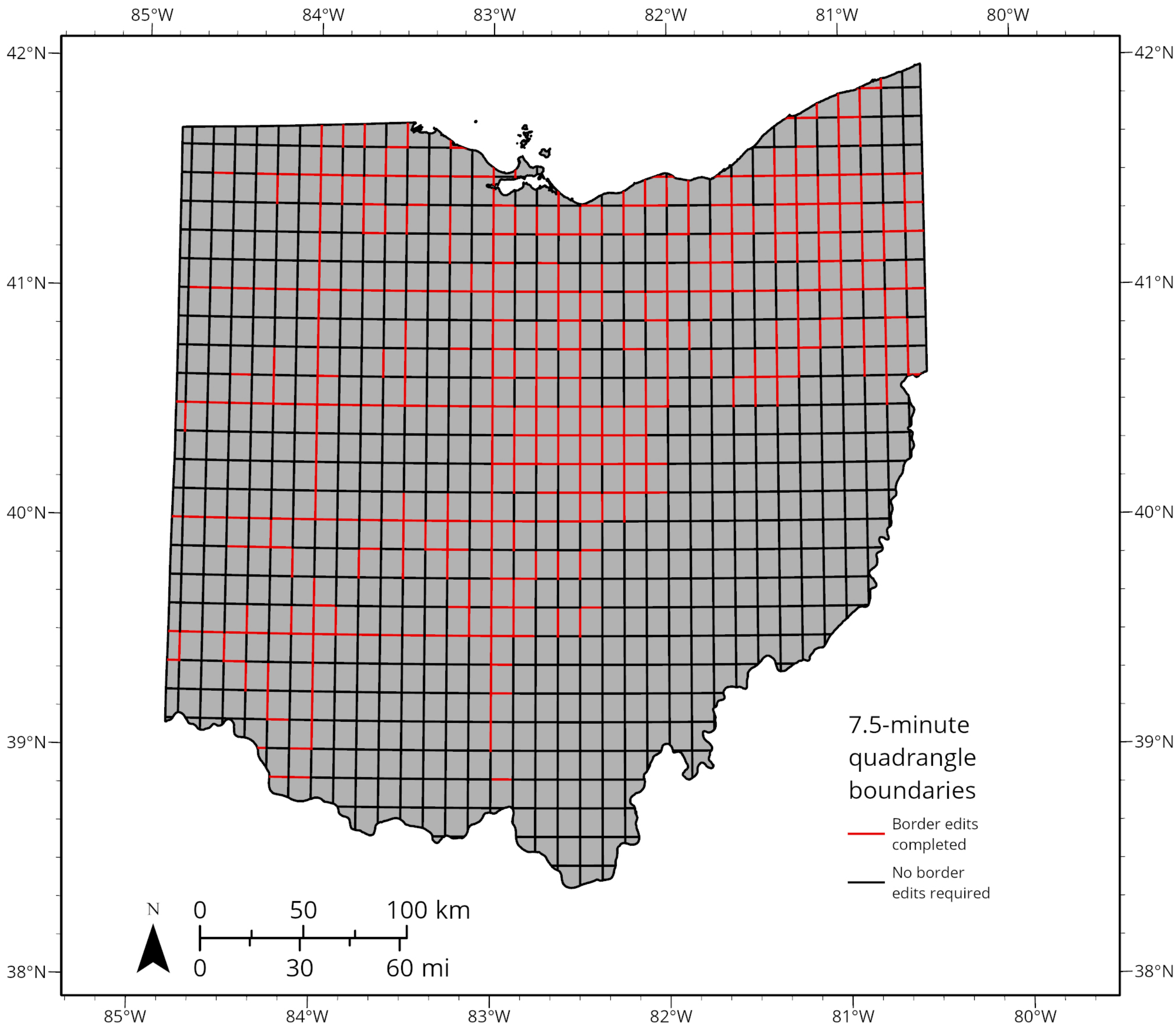

FIGURE 6. Red lines show Ohio 7.5-minute quadrangle borders that were not edge matched during initial mapping; these were corrected at the start of the seamless database phase in 2017. Border corrections were not needed in southeastern Ohio because edge matching was enforced during that phase of mapping.

The statewide line feature class contained some nongeologic lines, such as relic quadrangle boundaries, that needed to be removed. There were also numerous capitalization and spelling errors. Statewide, topologic rules were used to identify overlapping, dangling (fig. 7), and incorrectly snapped lines (fig. 8), which were then systematically remapped. For all point feature classes, a “must be disjoint” topological rule was used to ensure no labels overlapped. In some past cases, not all labels were updated when a polygon was edited, resulting in conflicting labels. Other times, polygons were split into multiple parts and not completely labeled; this commonly occurred when mapping long alluvial valleys that split many polygons.

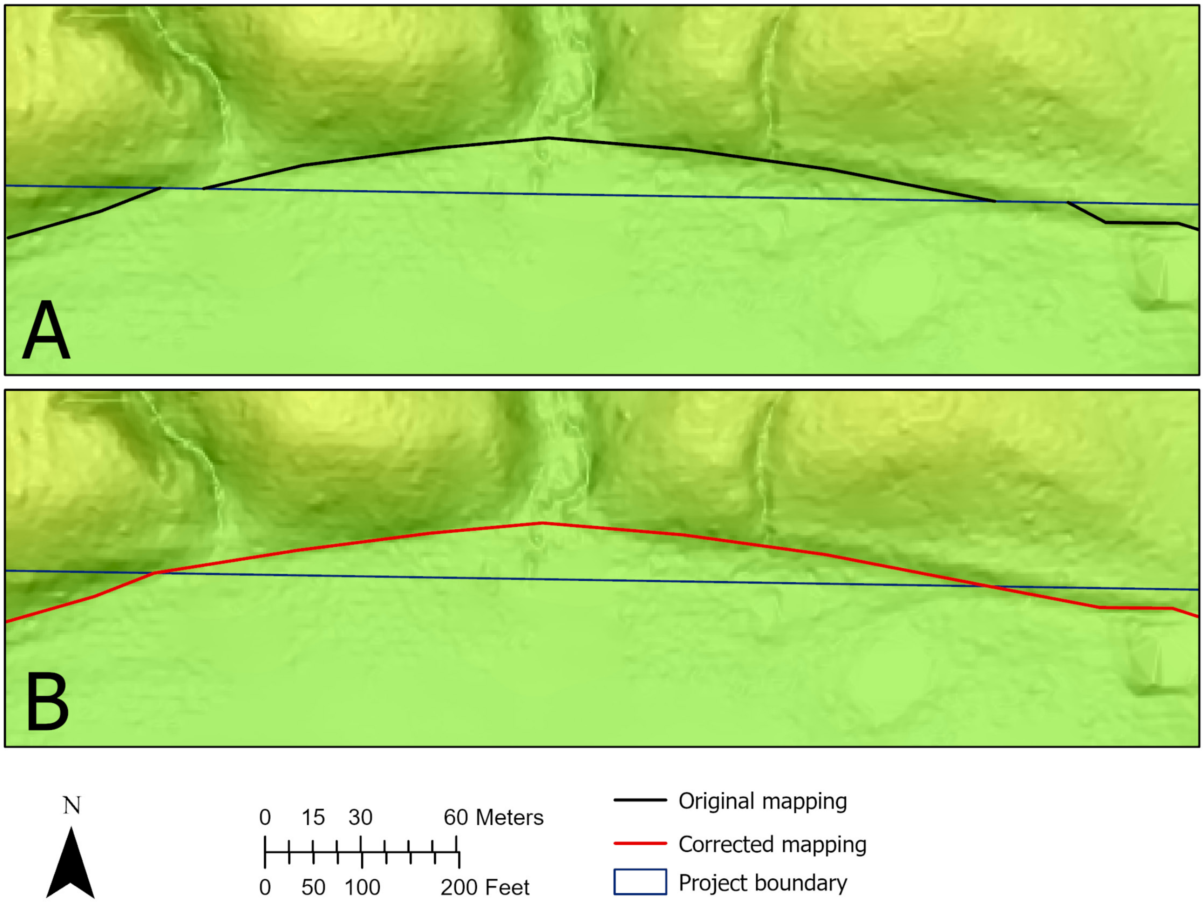

FIGURE 7. (A) Example of mismatched line (black) at quadrangle boundary (blue), one of many errors of this type discovered during a query for topological inconsistencies. This is likely the result of varying base map resolution between the quadrangles. (B) Corrected line (red).

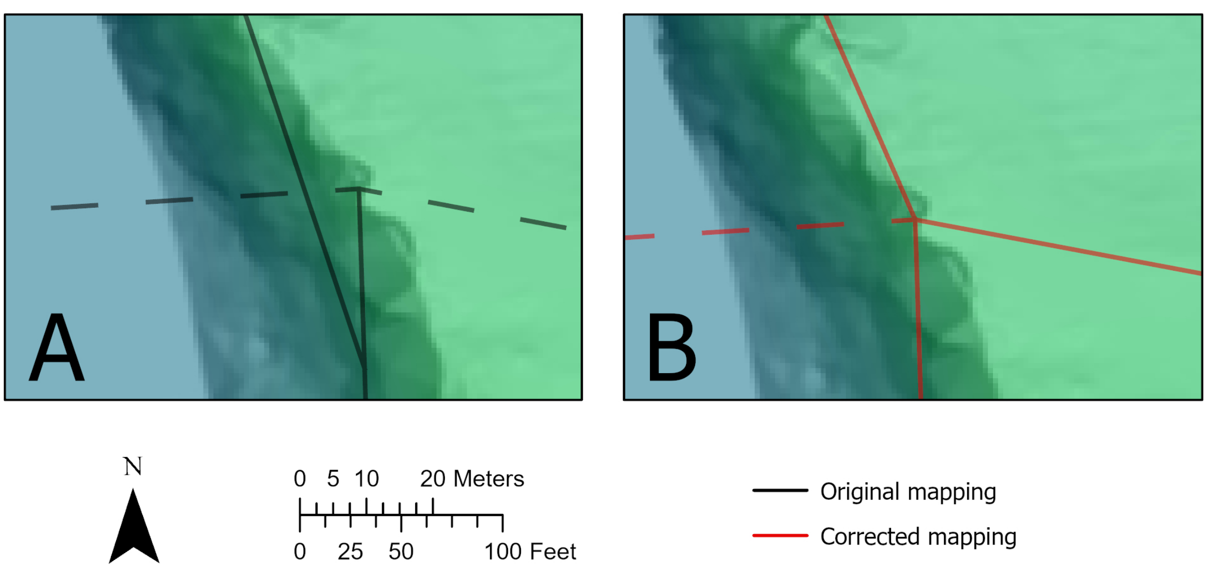

FIGURE 8. (A) Example of an incorrectly snapped line (solid black). This creates a small, unattributed triangular area. (B) Corrected line (solid red) with correct snapping applied.

A time-intensive step of map review was verifying the correct usage of solid and dashed line types. Traditionally, mapping geologists spent hours inspecting each line forming the boundary between every pair of adjacent polygons and determining if the line should be solid or dashed with a simple visual inspection. In most cases, solid lines indicate that the topmost lithologies between two adjacent polygons are different, whereas dashed lines indicate that the topmost lithologies are the same. This visual inspection was viable for a project encompassing a 30 x 60-minute quadrangle but too laborious for a statewide assessment. A Python script was written to review line types, which identified that about 1% of the lines needed to be assessed and corrected.

USING THE SURFICIAL STACK MAP DATABASE

The completed seamless stack database consists of a geodatabase of four feature classes and a layer file, which provides the recommended symbology (fig. 9). Each feature class contains a set of fields designated to attribute a map, perform calculations, and track edits. The critical fields of each feature class are described in Appendix E. Detailed stack mapping conventions, including an explanation of the types of line and point features, are provided in Appendix A. Users can find additional detailed explanations of stack mapping conventions in previously published reports (Swinford and others, 2007; Venteris, 2007; McDonald and others, 2008).

The stack map database is intended to be used at a regional level to establish foundational knowledge about a region's surficial geology, at approximately a 1:24,000 scale (or greater). It is primarily focused on material type and grain size more than depositional mechanisms or stratigraphic nomenclature. It is not intended to replace site-specific investigations, and while it contains limited bedrock information, users interested in bedrock geology, bedrock topography, or drift thickness, are advised to use this map in conjunction with the other map products specifically designed for those purposes.

Estimating aggregate resources

Understanding where key mining opportunities exist can inform companies, zoning boards, and planners about how to best account for aggregate resources and manage their future sustainable development. Stack maps help provide estimates of sand-and-gravel deposit locations, volumes, and suitability. Stack units may be queried to determine where sand or gravel deposits are present close enough to the surface to make mining them economically viable. The estimated thicknesses of these deposits are easy to calculate based on the given thickness values for each lithology in each stack. The ratio of pure sand or gravel to other undesired materials can also be calculated. The considerable focus on grain size to characterize many of the established statewide stack units (Appendix C) makes this database ideal for identifying areas of high aggregate potential.

Characterizing unconsolidated aquifers

Unconsolidated groundwater aquifers are important sources of water and are especially vulnerable to contamination, owing to their frequently unconfined nature (Nelson and Valachovics, 2022). These aquifers exist within the units defined by the surficial stack map database, which provides information on the aquifers' extents and thicknesses. These parameters can be used to support groundwater flow models (Langevin and others, 2017), which can be used to estimate maximum aquifer yield or assist in contamination remediation. Complex, 3D groundwater models require data on subtle geologic changes in the subsurface that the stack map database can provide. Using a stack map to define the extent and thickness of an aquifer can provide a more complete model than simply relying on point data from monitoring wells or other water wells (fig. 10).

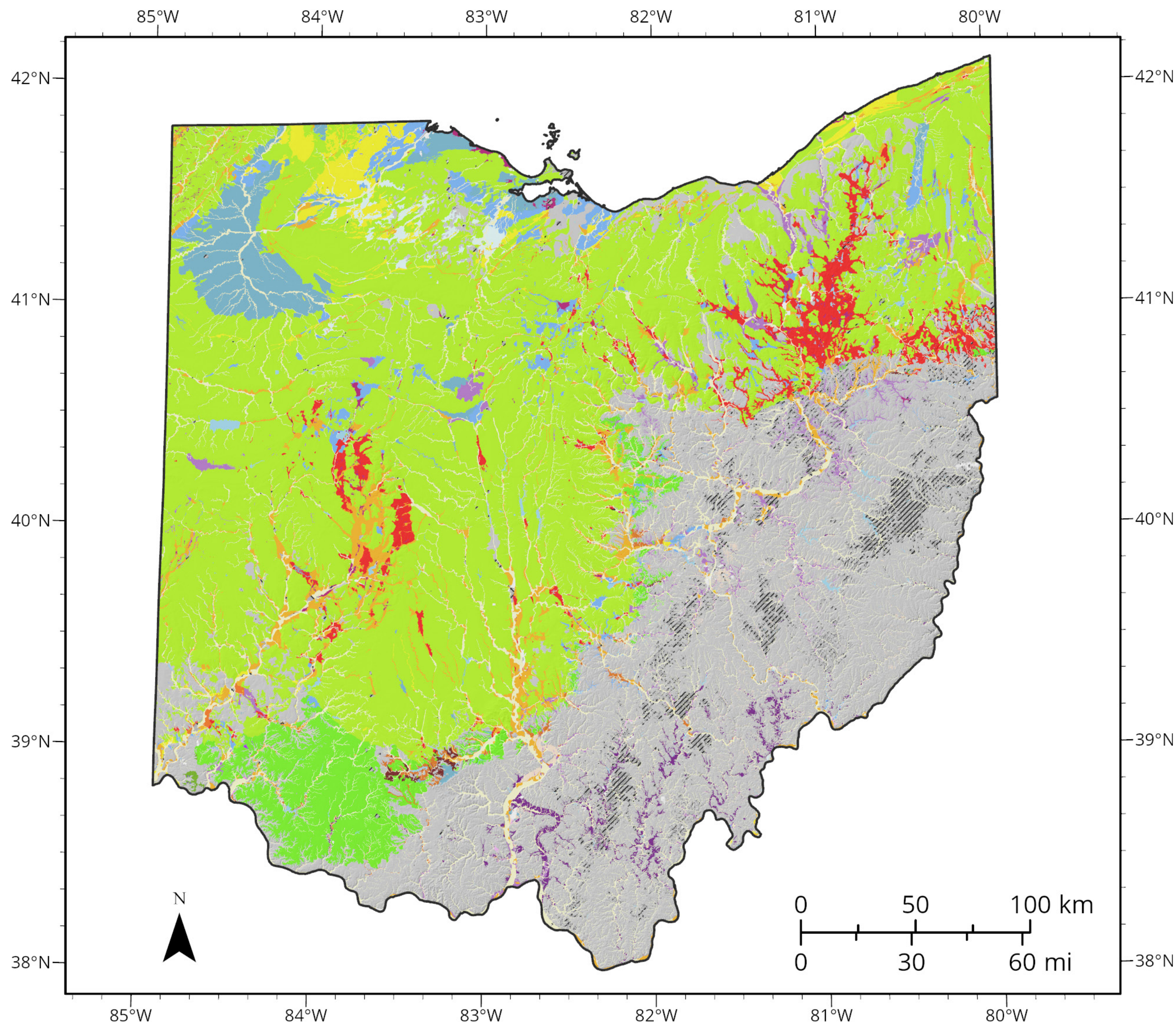

FIGURE 9. Completed stack map of Ohio with seamless polygons. Points, lines, and labels are not shown at a statewide scale. Gray portions of eastern and southern Ohio represent unglaciated areas dominated by bedrock at or near the surface.

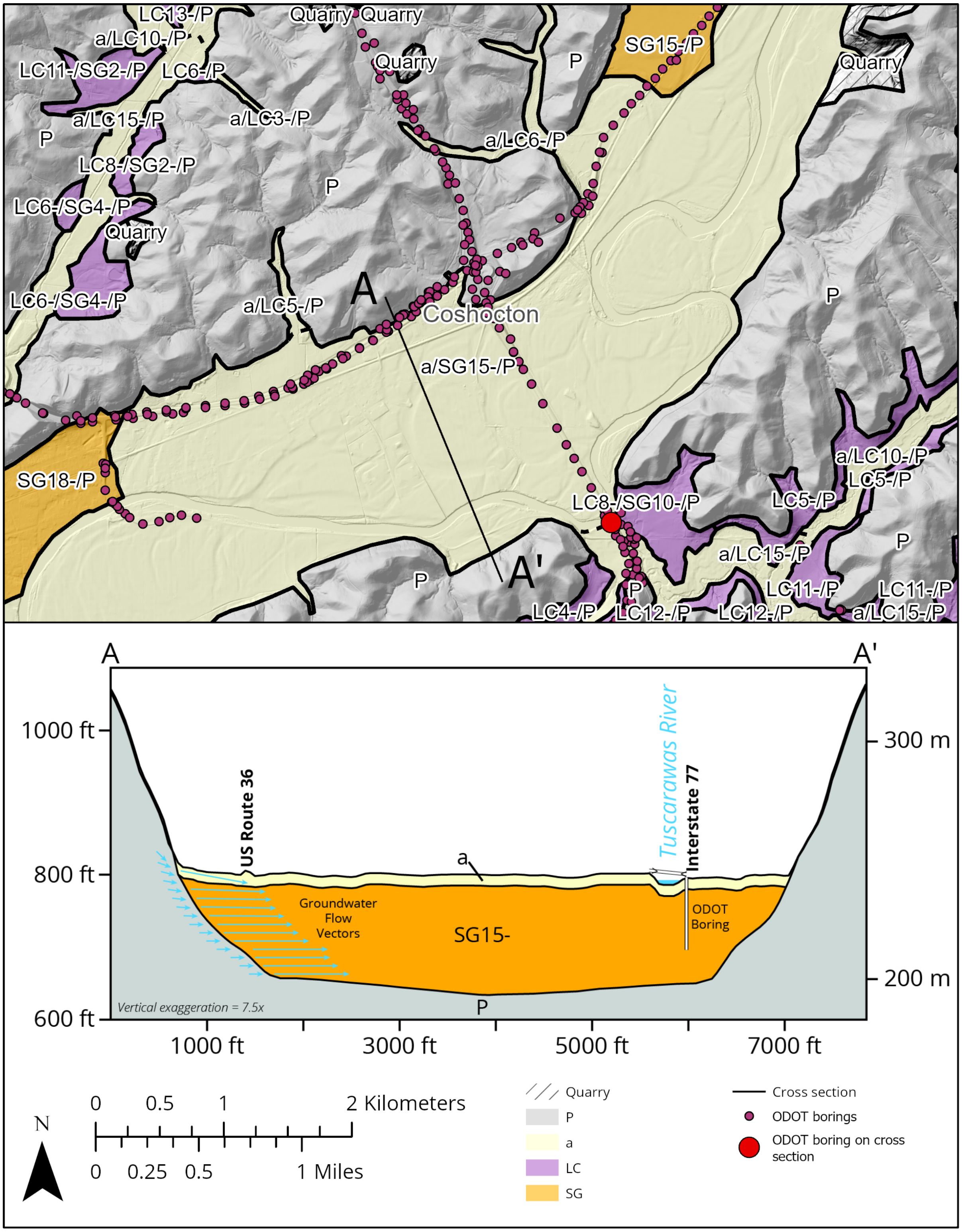

FIGURE 10. Map view and cross section of stack map in a large aquifer in the Coshocton 30 x 60-minute quadrangle of Ohio and adjacent ODOT TIMS boring data.

Construction planning

Extensive construction projects frequently require widespread exploratory borings to provide an understanding of the geologic framework of consolidated materials. Stack maps can be a valuable tool for reducing the number of exploratory borings required for individual projects by providing these 3D geologic data with little investment of time and money. Without these data, additional boreholes would be required to approximate important criteria like piling length or the characteristics of unconsolidated materials. The estimated cost of site excavation is reduced based upon the expected materials that may be encountered.

Stack maps can be a valuable tool for reducing project costs. The data stored in each map polygon, including unit lithology, thickness, and 3D extent, can provide a greater understanding of the geologic framework of surficial and unconsolidated sediments. Without these maps, more exploratory borings would be required to interpret that framework on a site-by-site basis. For example, if a bridge is being constructed over a river and the specifications call for pilings to be set into consolidated material, the stack map can be used to estimate the height of the piling necessary, the type of unconsolidated material surrounding the borehole/piling, and the consolidated material into which the piling would be set (fig. 10).

FUTURE WORK AND REVISIONS

Although the statewide revisions to the seamless stack map database are considered complete, more work can be done to refine the geologic framework. Geomorphic landforms are transitory, and landscapes change over time, sometimes rapidly, with prolonged periods of erosion and land-use change. Even stable geomorphic landforms can be mapped with higher precision as new elevation data in the form of LiDAR-derived DEMs are produced at increasingly higher resolutions. As stewards of geological data, the Survey will update the surficial stack map database when new data become available or are collected. For example, long-term plans to remap the bedrock topography on a statewide scale could require remapping of the existing stack mapping by altering the mapped course of large subsurface features, such as buried valleys.

Future additions and revisions of the stack map database will be triggered by updates to other associated maps and databases. As other datasets (e.g., bedrock topography, drift thickness, and the water-well log database) are updated, the need for updating the surficial stack map database will be periodically evaluated. Updates to the statewide database will be published on the Survey website and interactive map. Versions of the database will be numbered (see DDF-8, Ohio Geological Survey and Aden 2023) to ensure the authoritative version is easily recognizable. Whenever a new version of the database is released, a document that records the changes made will accompany the database release and will be available on the Survey website.

ACKNOWLEDGMENTS

This seamless database is the result of 25 years of surficial stack mapping and would not have been possible without the dozens of mappers who contributed both within the Ohio Geological Survey and as collaborators. Appendix B contains the full list of authors. Special thanks to Paul Spahr for his contributions; Nate Erber, who created the scripts used to validate this mapping; and Alexis Lanier, who updated the Python scripts for ArcGIS® Pro. This manuscript was improved after peer-reviewed comments from Survey retirees Michael P. Angle, E. Mac Swinford, and C. Scott Brockman.

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APPENDIX A

Surficial 'stack' mapping conventions, cross section, and unit descriptions

ODNR Division of Geological Survey "stack" mapping provides a three-dimensional framework and depicts four important aspects of an area's surficial geology (refer to the sample cross section below fig. A1-1):

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

Letters represent geologic deposits (lithologic units) and are described in detail on the following pages. 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 (IC) deposits. The bottom symbol in each stack indicates the bedrock lithologies that underlie the surficial deposits.

Numbers (without modifiers) that follow the lithology designators represent the average thickness of each 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). Each unmodified number corresponds to a thickness range centered on the specified value but may vary ±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:

- Parentheses indicate that a unit has a patchy or discontinuous distribution and is missing in portions of that map-unit area. For example, **(T)** indicates that till with an average thickness of 10 ft is present in only part of that map-unit area.
- A negative sign (**-**) following a number indicates the maximum thickness for that unit in an area, 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 **SG3-** map-unit area adjacent to a **SG2-** area indicates a sand-and-gravel unit having a maximum thickness of 30 ft that thins to an average of 20 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.

Boundary types reflect the relationships among uppermost continuous lithologies only, not patchy, discontinuous lithologies (in parentheses). 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 on the map.

- A **solid line** indicates a boundary between map-unit areas having different uppermost, continuous lithologies or significant bedrock lithology change; underlying lithologies may or may not differ.
- A **dashed line** boundary between map-unit areas having the same uppermost, continuous lithology but different thicknesses or underlying lithologies.

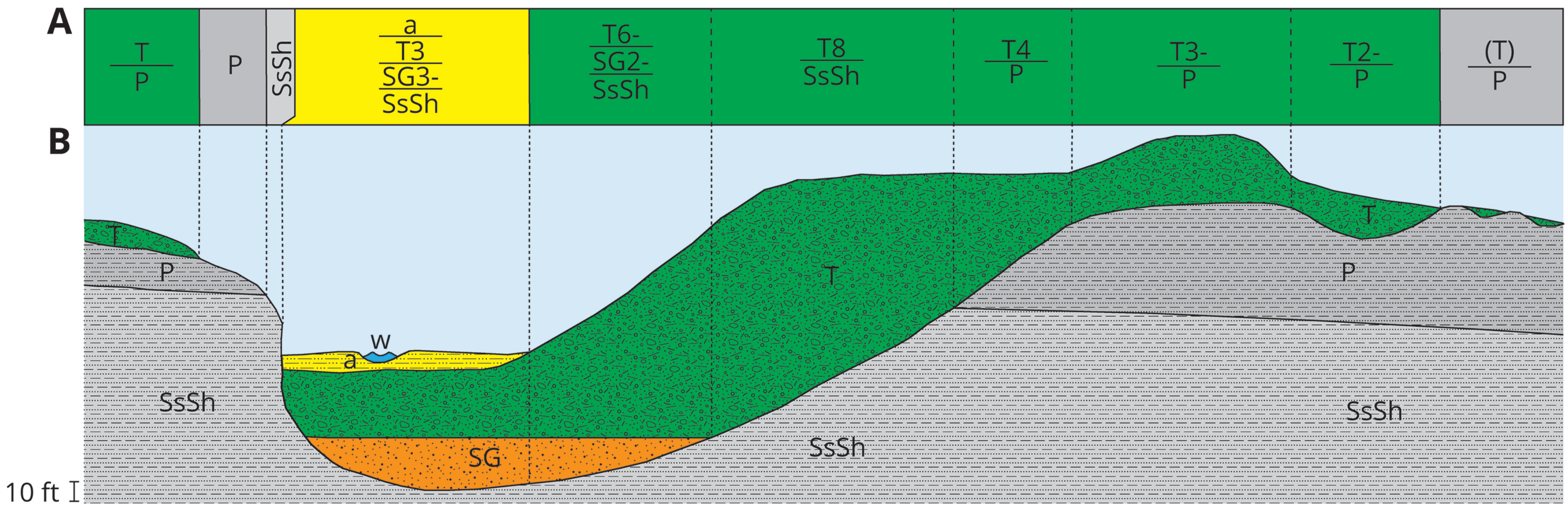

FIGURE A1. (A) Representation of stacks as they appear in the statewide surficial geology database. (B) Sample cross section.

Geologic Mapping Unit Descriptions

Surficial Units

w — **Water.** Lakes generally larger than 20 acres and not appearing on the base map.

m — **Made land.** Large areas of cut and fill, such as dams, landfills, and urban areas.

o — **Organic deposits (Holocene).** Muck and peat; may contain clay at depth. Formed in undrained depressions. Occurs on outwash trains, ice-contact areas, and hummocky moraines. Small areas are indicated with an asterisk (✱). Marl deposits also present in the Lorain 30 x 60-minute quadrangle.

Pit — **Sand-and-gravel pit.** Pit bottom generally underlain by surrounding unconsolidated lithologic units. May contain reclaimed areas. Small areas indicated by a crossed- shovels symbol (⚔).

Quarry — **Quarry.** Floored in bedrock; may contain reclaimed areas. Includes strip mine benches. Small areas indicated by a crossed-picks symbol (⚒).

a — **Alluvium (Holocene).** Includes a wide variety of textures from silt to clay to boulders. Commonly includes organic material; generally, not compact. Occurs in floodplains of modern streams and mapped only where areal extent and thickness are noteworthy. Also includes alluvial terraces, old floodplain remnants that are positioned tens of feet above modern floodplains.

C — **Clay (predominantly Wisconsinan).** Massive to laminated; may contain interbedded silt and fine sand. May include till and be older than Wisconsinan-age in deep buried valleys.

Ci — **Clay (predominantly Illinoian).** Properties similar to unit C except upper part of unit deeply leached and more deeply jointed where near surface.

Ck — **Clay in Teays-age valleys (predominantly pre-Illinoian).** May contain interbedded silt and fine-sand deltaic deposits where main trunk valley joins tributary valleys. Lacustrine deposits occur only in the subsurface in the largest, deeply buried valleys of the classical Teays Valley System. Minford Clay.

CG — **Complexly interbedded deposits of clay, silt, sand, gravel (unspecified age).** Can include till in deeper parts of buried valleys.

E	**Eolian silt (loess) and fine sand (unspecified age).** Deposited by wind, generally on bedrock and Illinoian till-capped ridges. Mapped where thickness and areal extent noteworthy.
G	**Gravel (predominantly Wisconsinan).** Contains minor amounts of disseminated sand and thin, discontinuous lenses of silt and thicker, more continuous beds of sand. Well to poorly sorted, angular to well rounded. May be massive, cross bedded, or horizontally bedded. May be older in deep buried valleys. May contain gas in the Defiance 30 x 60-minute quadrangle.
Gi	**Gravel (predominantly Illinoian).** Occurs in subsurface only. Properties similar to unit G, except upper part of unit is deeply weathered and leached where near surface.
IC	**Ice-contact deposits (predominantly Wisconsinan).** Highly variable deposits of poorly sorted gravel, sand, silt, and clay. Till lenses common, may be partially covered or surrounded by till.
ICi	**Ice-contact deposits (predominantly Illinoian).** Properties similar to unit IC, except upper part of unit is deeply weathered and leached where near surface.
L	**Silt (predominantly Wisconsinan).** Massive or laminated, commonly contains thin sand partings. May contain localized clay, sand, or gravel layers. Clay content commonly increases with depth. Frequently occurs in lowland surface deposits, in terraces, and as deposits of glacial lakes.
Li	**Silt (predominantly Illinoian).** Properties similar to unit L, except upper part of unit is deeply leached and more deeply jointed where near surface.
Lk	**Silt and clay (Minford silt) (predominantly pre-Illinoian).** Present on high terraces or as eroded remnants of lacustrine clays and silts. Finely laminated. Often covered with loess and/or colluvium; sometimes underlain by sand and gravel.
LC	**Silt and clay with occasional sand-and-gravel interbeds (unspecified age).** Present as deltaic deposits, outwash, deposits in upland depressions, intermorainal lake deposits, and backwater lake deposits.
S	**Sand (predominantly 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; may contain organic material. May be older in deep buried valleys.
SL	**Sand and silt (unspecified age).** Massive or laminated, commonly contains thin sand partings. May contain sand or gravel layers. Present as beach deposits, drapes on flanks of beach ridges and dunes, and capping deltaic deposits.

Si	**Sand (predominantly Illinoian).** Properties similar to unit S, except upper part of unit is more deeply weathered and leached where near surface. Unit occurs in high- level terraces and buried valleys.
Sk	**Sand (predominantly pre-Illinoian).** Clayey to pebbly, weathered, and leached. Overlain by loess with sand- to pebble-sized nodules of iron oxide and manganese oxide concentrate near loess/sand contact. Sand mostly quartz and other resistant lithologies. Erodes easily when vegetation removed. Unit fluvial (deposited in high- level "Teays-age" paleovalleys) and eolian (loess and sheet sands in uplands).
SG	**Sand and gravel (predominantly Wisconsinan).** Intermixed and interbedded sand and gravel commonly containing thin, discontinuous layers or silt, clay, and till. Grains well to moderately sorted, moderately to well rounded; finely stratified to massive, may be cross bedded; locally, may contain organic material. Widespread fluvial deposits in terraces and buried valleys. May be older in deep buried valleys. May contain gas in the Defiance 30 x 60-minute quadrangle.
SGi	**Sand and gravel (predominantly Illinoian).** Properties similar to unit SG, except upper part of unit is deeply weathered and leached where near surface.
T	**Till (predominantly Wisconsinan).** Unsorted mix of silt, clay, sand, gravel, and boulders; variable carbonate content, generally grey to light brown when unweathered. 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 till. Surface may be wave-planed or modified by lacustrine erosion and deposition. May contain gas in the Defiance and Adrian 30 x 60-minute quadrangles.
Ti	**Loam till (predominantly Illinoian).** Properties similar to unit T. Generally, overlain by loess that becomes thicker along bluffs bordering major rivers.
Tk	**Clay-loam till (predominantly pre-Illinoian).** Properties similar to unit T, except overlain by well-weathered loess that has been entirely leached. Till highly weathered and leached; brown to reddish-brown color; thin to absent on slopes. Sand-size voids common.

Bedrock Units

LsSh	**Limestone and shale (predominantly Ordovician).** Interbedded limestones and shales of varying dominance. Shale-rich lithologies prone to landslides. Shale is gray; thin to thick bedded. Limestone is medium gray; thin to medium bedded; fossiliferous. Occasionally contains dolomite in the Maysville 30 x 60-minute quadrangle.
DLs	**Dolomite and limestone (predominantly Silurian and Devonian).** Carbonate bedrock dominated by dolomites with occasional limestones. Thin to massive bedded. Contains well-developed karst and solution features. Frequently fossiliferous; may be cherty.
Sh	**Shale (predominantly Devonian).** Clayey shale with limestone nodules and overlying organic-rich, hard, fissile shale.
Ss	**Sandstone (predominantly Mississippian).** Thin to massive bedded; fine to medium grained.
SsSh	**Sandstone and shale (predominantly Mississippian).** Interbedded shale, siltstone, and sandstone and associated colluvium, with common vertical and horizontal changes in rock type.
P	**Sandstone, siltstone, shale, clay, limestone, and coal (predominantly Pennsylvanian).** Sandstone nonbedded to massive, medium to coarse grained with abundant rounded quartz pebbles; quartz pebble conglomerate present. Interbeds of shale, sandstone, siltstone, clay, coal, and limestone common in upper portions of unit. Common horizontal and vertical changes in rock type.
Pd	**Sandstone, siltstone, shale, and clay (predominantly Permian).** Sandstone fine grained to conglomeratic; thin to massive, crossbedding present. Limestone and coal beds present in lower part of unit.

APPENDIX B

Published Map References

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APPENDIX C

Table C1 (below) describes the legacy units from published 30 X 60-minute quadrangles. Many of these legacy units were merged into other existing units for simplicity. Merged unit names (see Appendix A for descriptions) can be significantly different from legacy names. The quadrangle(s) in which legacy units appeared can be found in the far-right column.

TABLE C1. ***Legacy units and unit descriptions from published 30 X 60-minute quadrangles***

Merged Unit	Legacy Units	Original Unit Descriptions	30 X 60-minute quadrangles
o	Om	Organic and marl deposits, Holocene age. Found only in the area north and west of Castalia, where groundwater rich in calcium carbonate discharges from springs at the base of the Columbus Limestone escarpment. Precipitation of carbonate [marl] around plants on poorly-drained Lake Plain sediments has constructed these "upland bogs."	Lorain
a	At	Alluvial terraces, Wisconsinan age. Old floodplain remnants along streams that flowed into intermorainal lakes. Highly variable textures; commonly positioned tens of feet above modern floodplains. Unit considered thinning to zero at contact with adjacent polygons.	Cleveland South, Findlay, Lorain and Put-In-Bay, Marion
	Ac	Alluvium and alluvial terraces, combined. Shown in areas where insufficient space is available to delineate separate units. Unit considered to thin to zero at contact with adjacent polygons.	Lorain and Put-In-Bay, Mansfield
Ci	CA	Clay and silt, pre-Wisconsinan-age, with Sangamon-age paleosol developed in upper few feet of the unit. Patchy distribution of paleosol. Upper part of unit leached with loess and abundant organics, lower part of unit may contain till. Up to 100 feet thick. Lacustrine unit, restricted to the subsurface, formerly exposed to surface soil processes.	Cincinnati and Falmouth
	CB	Clay and silt similar to unit CA, but with paleosol (Yarmouthian?-age) developed in Early Illinoian or Pre-Illinoian loess and lacustrine deposits. Unit coarsens downward but does not contain till as does unit CA. Unit 10 feet thick.	Cincinnati and Falmouth
Ck	CV	Clay in Teays-age valleys, early Pleistocene-age. May contain interbedded silt and fine sand deltaic deposits where main trunk valley joins tributary valleys. May fill main trunk valley to 800 feet msl, slightly higher in tributary valleys. Unit up to 300 feet thick. Stratigraphic name: Minford Clay. Unit is lacustrine deposits found only in the subsurface in the largest, deeply buried valleys of the classical Teays Valley System.	Bellefontaine, Springfield
CG	LA	Silt, clay, sand and gravel as distinct interbeds 10 or more feet thick, Wisconsinan-age. Sequence of lithologies variable; 30 to 40 feet thick. Deposited in buried valleys, which alternated between free-draining and ponded conditions. Mapped where individual units cannot be shown separately due to map scale and insufficient data. Unit limited to valleys upstream of numerous bedrock narrows along the Little Miami River.	Cincinnati and Falmouth, Dayton

Merged Unit	Legacy Units	Original Unit Descriptions	30 X 60-minute quadrangles
G	GA	Basal gravel. Highly variable, poorly sorted gravel and sand, with significant amounts silt and clay. Deposited at or near the front of the ice sheet directly on bedrock. Presumably of Wisconsinan age. Mapped only in the northeast corner of map.	Findlay, Lorain and Put-In-Bay, Marion, Newark
	Gg	Description is the same as G, but units may contain patchy gas.	Defiance,
IC	IM	Till and water laid deposits juxtaposed near valley walls and the ice margin, Wisconsinan-age. Till in low-relief swells and swales and stratigraphically underlying other units. Till-swales are partially infilled with debris-flow material, lacustrine silt, clay, fine sand, and fluvial or ice-contact sand and gravel; fluvial units may be stratigraphically over and/or under lacustrine units. Up to 70 feet thick; unit thickness reflects maximum thickness of till. Deposited in ablational swales or lowlands of till on which meltwater was initially ponded (lacustrine deposition), until free-flowing conditions were established (fluvial conditions).	Cincinnati and Falmouth, Lancaster
LC	LB	Backwater lake deposits, unspecified age. Mostly lacustrine silt and clay commonly interfingered with coarser sediments of alluvium, fan-deltas, and debris flows. Found in steep-walled tributary and main valleys in the eastern map area.	Canton East, Liverpool, Mansfield, Newark
	SC	Interlayered medium-fine to fine grained materials, unspecified age. Fine sand predominates and includes clay, silt, and thin gravel interbeds; variable thickness and sequence of lithologies. Similar to unit CS above but coarser; up to 150 feet thick. Deposited as lacustrine and proximal deltaic facies as well as overbank sediments within the area's largest valleys.	Cincinnati and Falmouth
	CS	Interlayered, very fine-grained materials, unspecified age. Clay and silt predominate with interbeds of fine sand, gravel is rare; may include till at depth. Variable thickness and sequence of lithologies. Unit identified from well logs; up to 150 feet thick. Deposited as fine overbank sediments or in lacustrine settings as lake bottom and distal deltaic facies. Found in area's largest valleys including Norwood Trough and Mill Creek Valley.	Cincinnati and Falmouth, Dayton
SL	LS	Silt and sand, Wisconsinan-age. Laminated to interbedded, may contain clay or gravel layers. Found as surface lacustrine deposits in the northeast corner of the map area.	Canton, East Liverpool

Merged Unit	Legacy Units	Original Unit Descriptions	30 X 60-minute quadrangles
SG	SGA	Sand and gravel, pre-Wisconsinan-age, similar to unit SG above but with Sangamon-age paleosol developed in upper portions. Patchy distribution of paleosol. Paleosol red brown to green gray, clay to clayey gravel, 15 feet or thicker, found between elevations 530 and 550 feet. Below paleosol, unweathered sand and gravel of Illinoian-age, generally coarser than any overlying SG unit. Unit may also include sand and gravel overlying paleosol. Up to 190 feet thick. A fluvial unit generally limited to the New Haven Trough in the southwestern map area.	Cincinnati and Falmouth
	SGB (1)	Sand and gravel, undifferentiated, unspecified age. A deeply buried unit of predominantly sand and gravel; depositional origin or age cannot be differentiated further with the available data. Unit associated with large, buried stream valleys in the eastern and western map area.	Bellefontaine, Dayton, Lancaster, Springfield
	SGB (2)	Sand and gravel, generally Wisconsinan-age, similar to unit SG above, but including discontinuous, thick interbedded till or clay. Up to 100 feet thick. Differs from unit Tif in having a higher proportion of sand and gravel to till or clay. In deep buried valleys, may be older than Wisconsinan-age. Found in lowlands near valley sides where it was deposited as outwash receiving periodic flow-till deposition from the uplands. Unit associated with Great Miami River Valley, Mill Creek Valley and Turtle Creek Valley.	Cincinnati and Falmouth: unique description
	SGC	Sand and gravel, Wisconsinan-age, similar to unit SG above, but includes clay and silt interbeds limited to the upper part of the unit and concentrated just upstream of junctions with major tributaries. From 60 to 100 feet thick. Unit resulted as coarse-textured fans and deltas formed at the mouths of tributaries that were fed by a melting ice margin. Clay and silt accumulated in localized slack water upstream of the tributaries. Unit found in the Little Miami River gorge between South Lebanon and Loveland.	Cincinnati and Falmouth
	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.	Canton East, Liverpool, Mansfield
	SGg	Description is the same as SG, but units may contain patchy gas.	Defiance
T	TA	Loam till, high carbonate content, Wisconsinan age. May contain silt, sand, and gravel lenses. Joints/fractures common. Averages 20-30 feet thick; at depth includes unspecified till units of various lithologies and may include clay and silt beds. Stratigraphic names: Darby and Caesar Tills. Common surface till.	Cincinnati and Falmouth, Bellefontaine, Dayton, Lancaster, Springfield

Merged Unit	Legacy Units	Original Unit Descriptions	30 X 60-minute quadrangles
T	TB	Clay loam till, high carbonate content, Wisconsinan age. May contain silt, sand, and gravel lenses. Sand/silt/clay percentages center around 16/42/42 (Wentworth classification); sparsely pebbly. Joints/fractures common. Averages 20-30 feet thick; at depth includes unspecified till units of various lithologies and may include clay and silt beds. In low relief ablation terrain, areas of surficial clay also included in unit. Stratigraphic names: Hiram and Hayesville Tills. Common surface till in the northern map area.	Bellefontaine, Newark
	TC	Silty clay till, high carbonate content, Wisconsinan age. Sand/silt/clay percentages center around 6/38/56 (Wentworth classification); very sparsely pebbly. Joints/fractures common. Averages 20-30 feet thick; at depth includes unspecified till units of various lithologies and may include clay and silt beds. In low relief ablation terrain, areas of surficial clay also included in unit. A very clayey facies of TB. High clay content of TC probably from ice overriding pre-existing local lake deposits. Stratigraphic names: Marysville Till, Hiram and Hayesville Tills. Surface till of limited extent northwest of Marysville in north-central map area.	Bellefontaine,
	TD	Loam till, medium carbonate content, Wisconsinan-age. Till contains silt, sand, and gravel lenses. Joints/fractures common. At depth includes unspecified pre-Wisconsinan till units of various lithologies and may include clay and silt beds. Stratigraphic name: Mt. Liberty till (informal name); Mt. Liberty till is a time equivalent and medium carbonate facies of the Darby Till (map unit TA). Limited extent in the northeastern map area.	Bellefontaine, Newark, Lancaster, Springfield
	TE	Loam till, low carbonate content, Wisconsinan-age. Till contains silt, sand, and gravel lenses. At depth includes unspecified pre-Wisconsinan till units of various lithologies and may include clay and silt beds. Stratigraphic names: Navarre Till, Jelloway Till (name now abandoned) and Knox Lake till (informal); older than TB and TD; may be time equivalent of the Caesar Till of south-central Ohio. Deposited by glacial ice. Limited surficial unit in the north-central map area.	Ashtabula, Cleveland North, Newark, Youngstown
	TF	Silty clay till, high carbonate content, Wisconsinan age. May contain silt, sand, and gravel lenses; very sparsely pebbly. Joints/fractures common. At depth includes unspecified till units of various lithologies and may include clay and silt beds. High clay content from ice overriding lacustrine clay of proglacial predecessors of Lake Erie.	Toledo
	TG	Clayey to silty till, low carbonate content, Wisconsinan age. May contain silt, sand, and gravel lenses. Joints/fractures common. At depth includes a pebbly basal unit as well as unspecified till units of various lithologies. Common surface till on lake plain in northern map area; bounded to south by Lake Escarpment Moraine.	Ashtabula, Cleveland North

Merged Unit	Legacy Units	Original Unit Descriptions	30 X 60-minute quadrangles
T	Tg	Description is the same as T, but units may contain patchy gas.	Defiance
Ti	Tif	Flow-till with fine to coarse clastic interbeds, Illinoian-age. Flow-till, with characteristics of Ti above, in thin to moderately thick beds, interbedded with lesser amounts of horizontal to high angle layers of sand, gravel, fine sand, silt, and clay, inches to many feet thick. Unit averages 30 feet thick. Differs from unit SGB, which contains more sand and gravel, and unit IC, which contains less till. Stratigraphic name: Rainsboro Till. Found in high-level terraces near the Illinoian-ice margin, along the southern Mill Creek Valley. May have been deposited as till-derived debris-flows from a stagnant or drowned ice tongue in lowland trough, with some drift contribution from uplands.	Cincinnati and Falmouth
LsSh	L-S	Limestone and shale bedrock, Ordovician-age. Interbedded limestone and shale; limestone ranges from 50% to 85% of the unit; shale-rich beds present. Stratigraphic names: Ordovician Undifferentiated. Found in deeply buried Teays Valleys in the western map area.	Cincinnati and Falmouth, Bellefontaine, Dayton, Springfield
	S-L	Shale-dominant bedrock and clay-rich, bedrock-derived colluvium, prone to landsliding, Ordovician-age. Interbedded shale, gray, thin to thick bedded, and limestone, medium gray, thin to medium bedded, fossiliferous. Shale ranges from 50% to 85% of the unit, although minor limestone-dominant intervals are present. Unit associated with the shale-rich Kope Formation on steep slopes in the southern part of the map area, and with the Waynesville Formation in stream valleys in the northern part of the map area. On side-slopes and toe-slopes, unit is clay-rich colluvium with downslope-oriented limestone slabs and organic matter. Colluvium has relatively low shear strength and is the source of numerous landslides, especially on steep slopes. Landslides commonly form at the colluvium-bedrock interface.	Cincinnati and Falmouth, Dayton, Findley, Lorain and Put-In-Bay, Mansfield, Marion
DLs	D	Dolomite bedrock, Silurian- and/or Devonian-age. Dolomite, thin to massive bedded and rare dolomitic shale, thin to thick bedded. Contains solution features; buried upper surface may be rubbly and include thick red clay (terra rosa-type paleosol). Source of aggregate. Stratigraphic names: Lockport Dolomite and the overlying Salina Group. Cliff-forming in stream exposures and in buried valleys throughout the map area.	Bellefontaine, Dayton, Findlay, Lorain and Put-In-Bay, Marion, Springfield, Toledo
	Ls	Limestone and dolomite bedrock, Devonian-age. Limestone and dolomite, thin to massive bedded, fossiliferous, may be cherty. Contains areas of well-developed karst topography; buried upper surface may be rubbly and include thick red clay (terra rosa-type paleosol). Source of aggregate. Stratigraphic names: Columbus and overlying Delaware Limestones.	Bellefontaine, Cincinnati and Falmouth, Dayton, Findlay, Lancaster, Lorain and Put-In-Bay, Mansfield, Marion, Springfield

Merged Unit	Legacy Units	Original Unit Descriptions	30 X 60-minute quadrangles
SsSh	SSh	This description has not changed but the unit was renamed for consistency.	Ashtabula, Canton, Cleveland North, Cleveland South, Lancaster, Lorain and Put-In-Bay, Mansfield Newark, Toledo, Youngstown

APPENDIX D

Figure D1 below shows all 7.5-minute quadrangles in the state of Ohio, color coded based on which geologist reviewed and updated mapping (if necessary) for each specific quadrangle. Tracking the assignment of each quadrangle for the final statewide seamless review helped staff check progress throughout the project and recorded individual responsibilities and mapping styles.

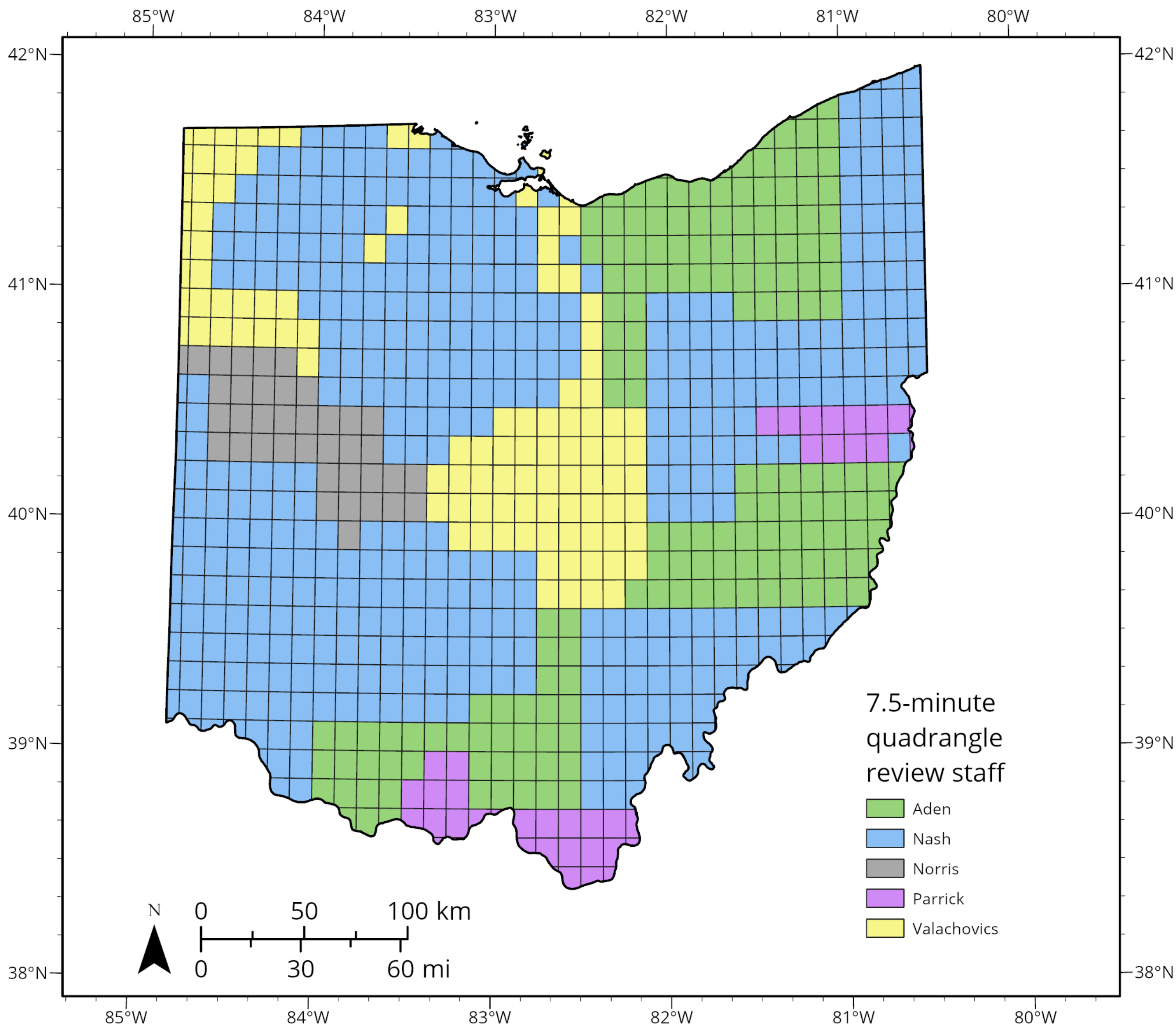

Figure D1. Mapping responsibility for the final review of all Ohio 7.5-minute quadrangles in 2022. Mappers listed in the legend are (in order alphabetically, from top to bottom): Douglas J. Aden, T. Andrew Nash, Tyler A. Norris, Brittany D. Parrick, and Thomas R. Valachovics.

APPENDIX E

Table E1 (below) contains an explanation of the data contained in the fields within the four feature classes (Polygons, Points, Labels, and Lines) that make up the surficial geology database. Fields in **bold** are used to display or label the data. Some fields, such as OBJECTIDs, are generated automatically within the GIS and are excluded from this table. These fields are useful as unique identifiers for querying data within a GIS environment. More specific information about the structure of each field can be found in the metadata documentation.

TABLE E1. ***Explanation of Ohio surficial geology map database fields***

Feature Class	Field	Description
Polygons	**Label**	Stack label describing the polygon's geology, pulled from the Labels feature class.
	Lith	Top, non-patchy stack unit. Used to symbolize the polygons.
	L1–L7	Layer 1 up to layer 7 (where present) for each respective part of the label with geology, thickness, and modifier appended to each other.
	L1G–L7G	Layer 1 up to layer 7 (where present) for each respective part of the label with only the geology unit (lithology).
	L1T–L7T	Layer 1 up to layer 7 (where present) for each respective part of the label with only the thickness unit.
	L1S–L7S	Layer 1 up to layer 7 (where present) for each respective part of the label with only the modifiers. Symbols include '()' and '-'.
	TotalThickness	Total stack thickness representing sediment thickness for the polygon.
	BedrockLith	Bedrock lithology of the bottom stack unit. Thickness is not provided.
Points	**Type**	Pit, Quarry, or Organic points that are too small to draw polygons.
Labels	**Label**	Stack label describing the vertical sequence of geologic units. Added to the Polygons feature class.
Lines	**LineType**	Solid or Dashed. Indicates lateral changes in geology based on first non-parenthetical (non-patchy) stack lithology.

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