Institute of Natural Resource Sustainability
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ILLINOIS STATE GEOLOGICAL SURVEY
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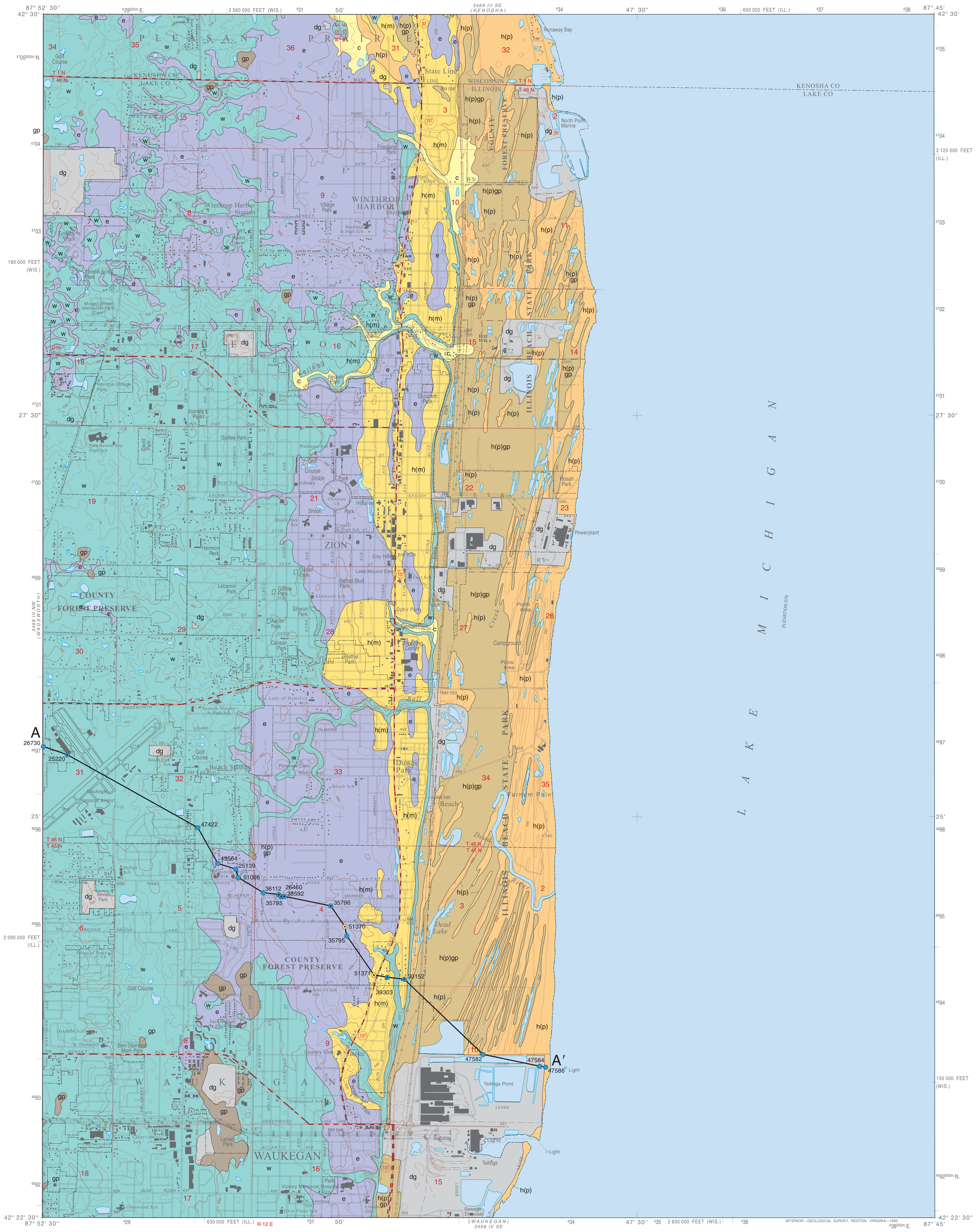
Surficial Geology of Zion Quadrangle
Lake County, Illinois and Kenosha County, Wisconsin

STATEMAP Zion-SG

Michael L. Barnhardt
2009



QUATERNARY DEPOSITS

Description	Unit	Interpretation
HUDSON EPISODE (~12,000 years before present [B.P.] to today)		
Fill, compacted land, or other disturbed material; highly variable in grain size (may range from clay to gravel), and may contain construction and mining debris; typical thickness: variable	Disturbed ground dg	**Human-disturbed deposits** modified during construction of buildings, roads, and landfills; includes excavations in gravel pits and quarries
Silt and clay; occasional sand lenses; trace gravel; stratified; brown to yellowish brown; loose to compact; may be mottled and gleyed; some bedding; organic-rich in places; typical thickness: 1 to 20 feet	Cahokia Formation (floodplain deposits) c(fp)	**Postglacial (modern) stream sediments** deposited on active floodplains; derived mainly from eroded loess and diamicton; overlies outwash sand and gravel along lake bluff; may overlie or interfinger with lacustrine silt and clay; includes silty slopewash deposits along footslope and minor drainage-ways on moraines
Sand; fine and medium; well sorted; loose; may be mixed with organics, including layers of peat; some thin lenses of clay; typical thickness: 1 to 12 feet	Henry Formation (Parkland facies) h(p)	**Windblown sand in dunes** and sheet-like deposits between active shoreline of Lake Michigan and wave-eroded bluff; local relief generally less than 12 feet; interdune swales often contain peat, muck, and organic-rich sand; eolian facies of Henry Formation
Peat, muck, marl, and organic-rich sediment; may contain interbeds of silt, clay, and very fine to fine sand; black to dark brown; sediment may be gleyed and mottled; soft to firm; snail shells common; typical thickness: 1 to 10 feet	Grayslake Peat gp	**Organic-rich sediments** accumulated in low-lying depressions, drainageways, and on floodplains; may include small areas of open water; locally intertongued with modern alluvium, or lake sediment; commonly found around lakes and marshes and channels connecting bodies of water; intermixed with sand dunes along Lake Michigan beach-ridge plain
Sand and peat, muck, marl, and organic-rich sediment; intermixed dune sand and peat in back dune area; fine and medium sand with trace silt and clay; peat and silt and clay content increases in lower-lying areas; stratified; typical thickness 1 to 12 feet	Henry Formation (Parkland facies) and Grayslake Peat, intermixed h(p)gp	**Former active dunes now heavily vegetated;** intervening swales are often saturated; may contain silt and clay and fine sand deposited in splays by wave overwash into shallow ponds and lagoons; complex intermixture of Henry Formation, Parkland facies, and Grayslake Formation peat; found only in beach-ridge plain
WISCONSIN EPISODE (Late) (~25,000 years–12,000 B.P.)		
Sand, fine to coarse with variable amounts of gravel; stratified; typical thickness: 10 to 35 feet	Henry Formation (Ravina facies) (cross section only) h(r)	**Nearshore lacustrine facies of Henry Formation;** occurs along Lake Michigan in active wave zone; underlies beach-ridge complex; thickness decreases toward the lake bluff and eastward under Lake Michigan to a water depth of about 30 to 50 feet.
Silt and clay; massive to bedded; dark gray to light gray; calcareous; soft to hard; compact; may be sticky and plastic; very fine and fine sand common along bedding planes; occasional inclusions and lenses of light gray to white silt; some wood fragments; very few clasts; generally abrupt upper and lower contacts; typical thickness: 5 to 25 feet	Equality Formation e	**Postglacial and glacial proglacial lake deposits** that infill low-lying areas, or depressions in drainage channels and where water was impounded behind moraines, such as the Highland Park Moraine; at the surface, these sediments may interfinger with or be overlain by alluvium and organic-rich deposits.
Sand and gravel; stratified; occasionally massive; yellowish to grayish brown; calcareous; loose; sand is very fine to very coarse, very well to poorly sorted; gravel is very fine to coarse, very well to very poorly sorted; trace to little amounts of silt and clay, frequently as thin beds; typical thickness: 5 to 120 feet	Henry Formation (Mackinaw facies) h(m)	**Proglacial fluvial (outwash) sediments** exposed along the Lake Michigan bluff as terraces above present lake level; deposited by meltwater originating along the glacier terminus located to the northeast
Diamicton; silty clay loam to silty clay; dark gray to yellowish brown; massive; calcareous; compact; firm to very hard; pebbly with occasional cobbles and boulders; commonly contains silt and sand inclusions and sand and/or gravel lenses; may contain pebble-free, silty and clayey zones with strongly expressed laminations that may be interbedded with the diamicton; lenses of saturated silt and very fine sand are loose and runny; typical thickness: 50 to 200 feet	Wadsworth Formation w	**Subglacial and ice-marginal sediments (till)** deposited from Wadsworth glacial ice; sediment that melted out on top of the glacier or along the ice margin was reworked by slope processes and water; laminated sequences may be more than 40 feet thick, but their areal extent is irregular and difficult to delineate; extensive areas and thicknesses of bedded sand, silt, and clay may be intermixed with diamictons of mudflow and meltout origin along the ice margin.

PRE-QUATERNARY DEPOSITS

Description	Unit	Interpretation
SILURIAN PERIOD (~443 to 416 million years B.P.)		
Rock; predominantly dolomite overlain locally by shale; upper surface is commonly fractured with crevices and solution cavities; some oil staining	Bedrock (cross section only)	**Bedrock** buried by ~100 to 250 feet of Quaternary sediments

Data Type

- Stratigraphic boring
- Water well boring
- 26211 Boring labels indicate the county number. Dot indicates boring is to bedrock.
- Contact
- A — A′ Line of cross section

Note: The county number is a portion of the 12-digit API number on file at the ISGS Geological Records Unit. Most well and boring records are available online from the ISGS Web site.

Base map compiled by Illinois State Geological Survey from digital data (Digital Line Graphs) provided by the United States Geological Survey. Topography by photogrammetric methods from aerial photographs taken 1958. Field checked 1960. Revised from aerial photographs taken 1988. Field checked 1992. Map edited 1993.

North American Datum of 1983 (NAD 83)
Projection: Transverse Mercator
10,000-foot ticks: Illinois State Plane Coordinate system, east zone (Transverse Mercator)
1,000-meter ticks: Universal Transverse Mercator grid system, zone 16

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SCALE 1:24,000
1 1/2 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER

BASE MAP CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

Geology based on field work by Michael L. Barnhardt, 2008–2009.

Digital cartography by Jennifer E. Carrell and Jane E.J. Domier, Illinois State Geological Survey.

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The Illinois State Geological Survey and the University of Illinois make no guarantee, expressed or implied, regarding the correctness of the interpretations presented in this document and accept no liability for the consequences of decisions made by others on the basis of the information presented here. The geologic interpretations are based on data that may vary with respect to accuracy of geographic location, the type and quantity of data available at each location, and the scientific and technical qualifications of the data sources. Maps or cross sections in this document are not meant to be enlarged.

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ADJOINING QUADRANGLES
1 Pleasant Prairie, WI
2 Kenosha, WI
3 Lake Michigan
4 Wadsworth, IL
5 Lake Michigan
6 Libertyville, IL
7 Waukegan, IL
8 Lake Michigan

APPROXIMATE MEAN DECLINATION, 2009

ROAD CLASSIFICATION
- Primary highway, hard surface
- Secondary highway, hard surface
- Light-duty road, hard or improved surface
- Unimproved road
- State Route

Introduction

Most of the counties in northeastern Illinois are among the most rapidly growing areas of population in the state and some communities are among the most rapidly growing in the country. Although some of this region draws the majority of its drinking water from Lake Michigan, a significant portion, including most of the rapidly-growing areas, relies upon groundwater from Quaternary sand and gravel deposits or from shallow bedrock.

The Illinois State Geological Survey (ISGS) has implemented a mapping program to develop three-dimensional maps of the glacial geology from land surface to the top of bedrock. Funding for mapping the surficial geology of the Zion Quadrangle was provided in part by a grant from the USGS National Cooperative Geologic Mapping Program (STATEMAP). These funds were used to develop the detailed map of the surficial geology, the cross section, and the extensive database that is required to accomplish the planned three-dimensional mapping, which is funded by a separate cooperative agreement with the USGS Central Great Lakes Geologic Mapping Coalition (CGLGMC) and additional funding from the General Revenue Fund of the State of Illinois. Map and digital products that will be developed include three-dimensional models of the material (sediment) and aquifer-bearing units, and maps of the surficial geology, aquifer conductivity, aquifer sensitivity, recharge, aquifer geometry, and susceptibility to contamination. These maps and products can be used by county and municipal agencies and the public for a variety of projects including water utilization, land use and transportation network planning, and open space and environmental issues.

Regional Setting and Geomorphology

The surficial geology of the Zion Quadrangle developed predominantly as a result of continental glaciers and their meltwater during the last glaciation (Wisconsin Episode). While the thickness of glacial sediments in Lake County ranges from about 120 to 350 feet, the Quaternary deposits in the Zion Quadrangle are generally less than 220 feet. These sediments were deposited throughout Lake County during at least three major glacial advances that occurred between about 25,000 and 14,000 years ago (Wisconsin Episode) and a fourth (and possibly more) that occurred between about 200,000 and 130,000 years ago (Illinois Episode) (fig. 1). In the Zion Quadrangle area, however, the majority of the sediments were deposited during the last 15,000 years the oldest of which directly overlie bedrock and comprise the bulk of the sediments found in the Highland Park Moraine (see cross section).

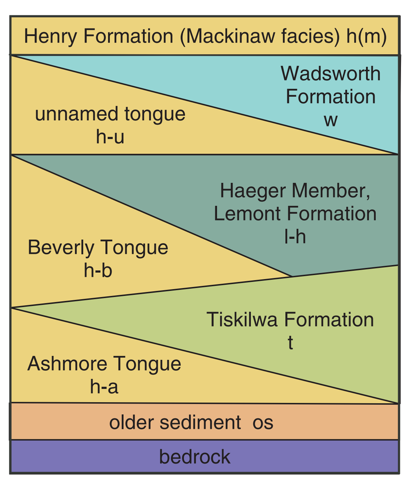

Figure 1 Intertonguing between Henry Formation outwash (gold) and Wisconsin episode till units (green). Older sediment may be early Wisconsin or older. After Hansel and Johnson 1996.

Multiple ice advances that originated in the Lake Michigan basin most likely scoured bedrock and removed previously deposited sediments in the Zion area. Only during the waning stages of the last glaciation did the ice and its meltwater begin to deposit sediments in the study area. There is little evidence in the sediment records from boreholes drilled in the study area that suggests the presence of significant amounts of sediment much older than 15,000 to 16,000 years. As the glaciers of different ice advances moved westward across Lake County, greater amounts of sediment were deposited resulting in a complex stratigraphy with a considerable range in age (Barnhardt 2005, 2008; Barnhardt et al. 2001; Hansel 2005; Stumpf and Barnhardt 2005; Thomason and Barnhardt 2007, 2008; Stumpf 2004, 2006).

The Zion Quadrangle is dominated by three major landscapes—the Zion beach-ridge plain, which roughly parallels modern Lake Michigan on the east, the Highland Park Moraine, which covers the western-most part of the quadrangle, and an intervening plain composed of sediment deposited in bodies of water impounded or dammed behind the Highland Park Moraine. A high stand of the ancestral Lake Michigan may have contributed additional sediments to this plain.

As the last glacier receded from the Zion area to the northeast, a huge volume of water was released from the melting ice. Outwash sand and gravel was transported southward toward modern day Chicago and a vast body of water was impounded between the Highland Park moraine and the remaining glacial ice. A number of wave-cut terraces document several high stands of water derived from the melting ice (Chrzastowski and Frankie 2000).

The Glenwood phase (14,500 to 12,200 years B.P.) was a high stand of the lake that reached about 630 to 640 feet a.s.l., which is about 40 to 50 feet above modern Lake Michigan (587 feet a.s.l.). The Calumet phase (11,800 to 11,200 years B.P.) reached an elevation of about 620 feet or about 30 feet above modern Lake Michigan. The Chippewa phase lasted from about 10,000 to 5500 years B.P. and represented an exceptionally low stand of the lake at 319 feet a.s.l., which is about 260 feet below modern Lake Michigan. This low stand initiated significant downcutting by streams and rivers flowing eastward into the lake as evidenced by the deep ravines that truncate the bluffs that parallel the shoreline. South of the Zion Quadrangle, where the Highland Park Moraine forms the lake bluff, these ravines provide an important cross sectional view of the sediments that form the moraine. On the Zion Quadrangle, several ravines can be seen at the eastern edge of the cross section. They reveal that the sand and gravel deposits and the lake sediments that overlie the glacial diamicton (till) are generally thin. The till is increasingly exposed toward the west and occurs at land surface along the Highland Park Moraine (see cross section and surficial geology map). The Nipissing phase (5500 to 3800 years B.P.) represents a time when the lake had again risen to about 20 feet above historical lake levels. This phase represents the early formation of the beach-ridge plain (Chrzastowski and Frankie 2000). During the Algoma and Modern phases (3800 years B.P. to present) the lake was near current levels and represents the early migration of the beach-ridge plain. Erosion and transport of sand from the northern portions of the beach-ridge plain continues today and the gradual southward migration of the plain underscores the ephemeral and transitory nature of the Lake Michigan shoreline.

Interpreting the shape (geomorphology) of the landscape is important to understanding the late Quaternary glacial history of the study area. On numerous occasions, glaciers fluctuated into and out of the Lake Michigan basin. Their former margins are preserved on the landscape commonly as arcuate ridges (moraines) (fig.2). These boundaries help delimit the interpretations of the stratigraphy and depositional environments associated with them (Thomason and Barnhardt 2007).

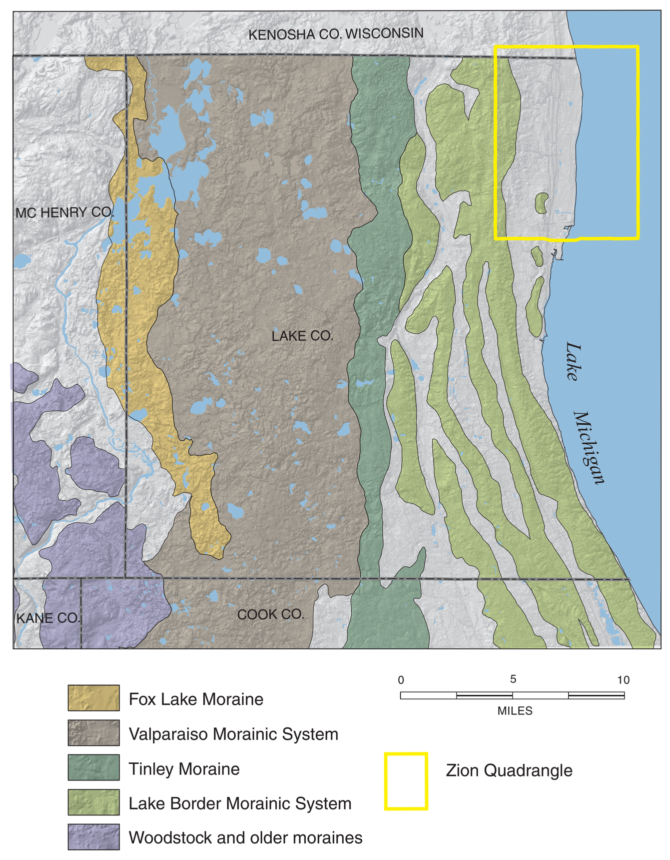

Figure 2 Surface topography and moraines of northeastern Illinois. After Willman and Frye 1970; Willman and Lineback 1970.

Unit Characterization and Stratigraphy

Several lithologically distinct diamictons, silt and clay beds, and sand and gravel units were deposited by the Lake Michigan lobe as it repeatedly advanced and retreated across northeast Illinois from about 25,000 to 12,000 years ago (fig. 1). All of the diamicton found in the Zion Quadrangle is interpreted as Wadsworth Formation; however, it still may comprise only a small volume of each of the moraines of the Lake Border Morainic System (see cross section; figs. 2 and 3). Locally, glacial meltwater deposits (predominantly sand and/or gravel) and lake deposits (silt and very fine sand with interbedded clay and sand) are present within the tills and are classified as part of the Wadsworth Formation, and not as separate tongues of sand and gravel or lake deposits of the Henry or Equality Formations separating tills, as described by Hansel and Johnson (1996). The diamictons of the Tiskilwa and Lemont Formations (Haeger Member) and the intervening sand and gravel units of the Henry Formation and silt and clay units of the Equality Formation are abundant in the rest of Lake County but are missing or very sparse in the Zion Quadrangle where outwash, lacustrine, and ice-contact sediments all are classified as Wadsworth Formation.

The Quaternary deposits in the mapping area overlie directly dolomitic bedrock of Silurian age. The uppermost part of this bedrock may be shaly, highly fractured, vugy, and, locally, oil-stained. It exhibits an eastward regional slope but over small areas tends to be rather flat.

The Wadsworth diamicton (w on cross section) is the only till exposed at land surface in the Zion Quadrangle (fig. 4). It is predominantly a dark grayish brown, silty clay to silty clay loam diamicton (a massive to poorly sorted mixture of clay, silt, sand, and gravel), but it also contains lenses and thick beds of sorted sediment, especially silty clay, silt, and fine sand (symbolized on cross section with stippled patterns). Near a moraine front, the Wadsworth diamicton may exhibit a coarser texture and an increase in the number and thickness of lenses and beds of sand and/or gravel. The more uniform diamicton likely was deposited subglacially, whereas the more variable (bedded and coarser) diamicton may represent material that melted out near the ice margin or on top of the glacier and was reworked by slope processes and water. The Highland Park Moraine is the youngest of the moraines comprising the Lake Border Morainic System. It is the only moraine found on this map and generally occurs along the western edge. The Wadsworth Formation ranges from about 100 to 220 feet in thickness, with the thicker accumulations occurring near the moraine.

Outwash sand and gravel of the Henry Formation, Mackinaw facies, h(m), is found along the lake bluffs and was deposited when the ice front was located to the northeast of the study area. These sediments overlie Wadsworth diamicton. Proglacial silt and clay deposits of the Equality Formation (e) are located between the Highland Park Moraine and the lakeshore. These were deposited in water impounded between the Highland Park Moraine and the ice front. These deposits are generally thin and may include some sediment deposited during the Glenwood phase high lake stand. The Henry Formation, Ravina facies, h(r), is composed of stratified sand of variable size with gravel and is found in the active wave zone of Lake Michigan.

Grayslake Peat (gp) and Henry Formation, Parkland facies, h(p), are abundant and intermixed along the beach-ridge plain where peat, muck, and organic-rich sand occur within and between the arcuate ridges of sand dunes. In this area the sediments are very young (<2500 years B.P.) and represent the most dynamic landscape on the map (Chrzastowski and Frankie 2000). The Cahokia Formation, c(fp), are sediments deposited along larger active floodplains mostly on upland positions. Deposits along smaller channels and drainageways located on uplands are generally not of sufficient thickness to map. Uplands may also contain small isolated depressions in which peat has accumulated.

Mapping Techniques

The map of surficial geology is based largely on digitized soils maps (scale 1:15,840) from the Soil Survey of Lake County, Illinois (Paschke and Alexander 1970; U.S. Department of Agriculture 2004). Initially, individual soil series were grouped by their parent material following (1) the classification key in Soils of Illinois (Fehrenbacher et al. 1984), (2) profile descriptions in the survey report, (3) NRCS field notes, (4) discussions with NRCS soil mappers, and (5) updated individual Soil Series Description sheets acquired either directly from the USDA-NRCS or downloaded from their web site. These parent material classes then were grouped into more general geologic material classes comprising the mapping units used for this map, following Hansel and Johnson (1996) and Willman and Frye (1970).

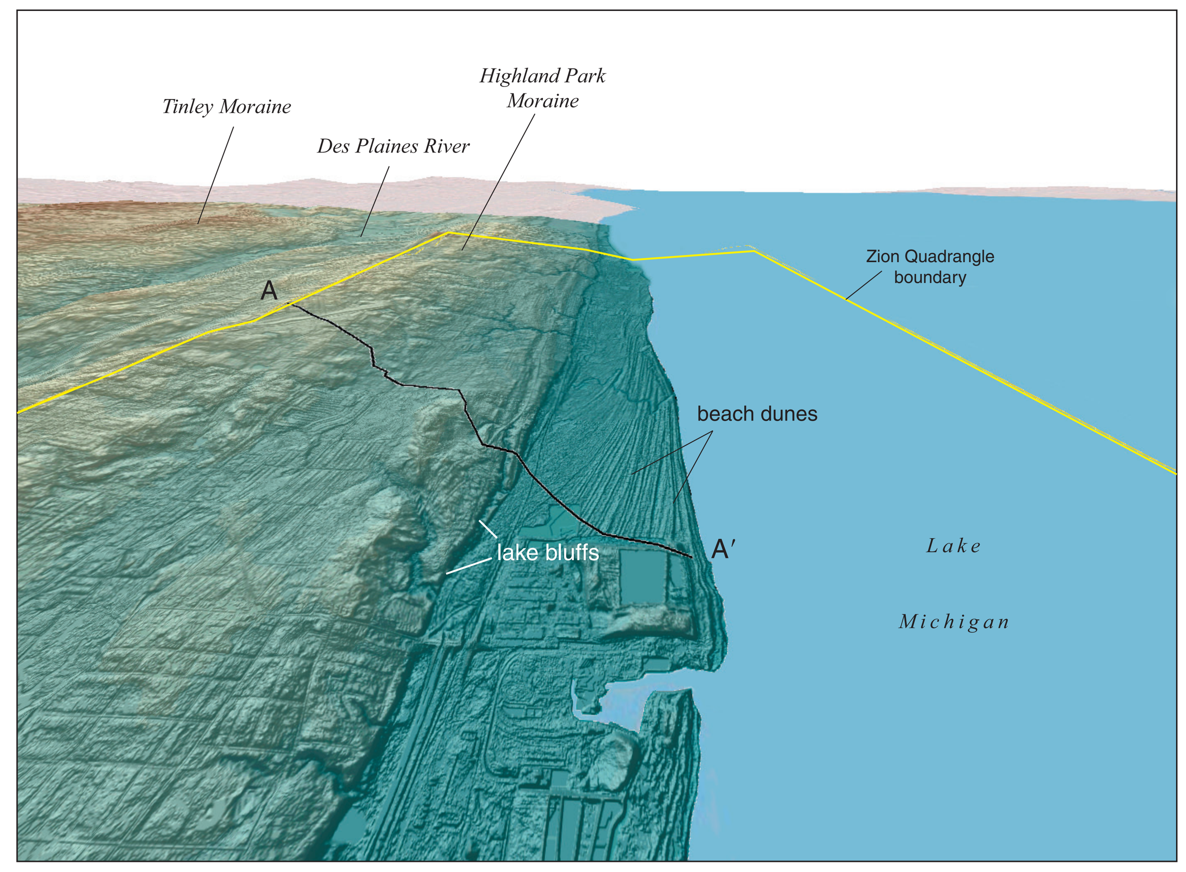

Figure 3 Surface topography of Zion Quadrangle with cross section A–A′. Digital elevation model generated from 2002 LiDAR data provided by Lake County GIS. The scene has been vertically exaggerated.

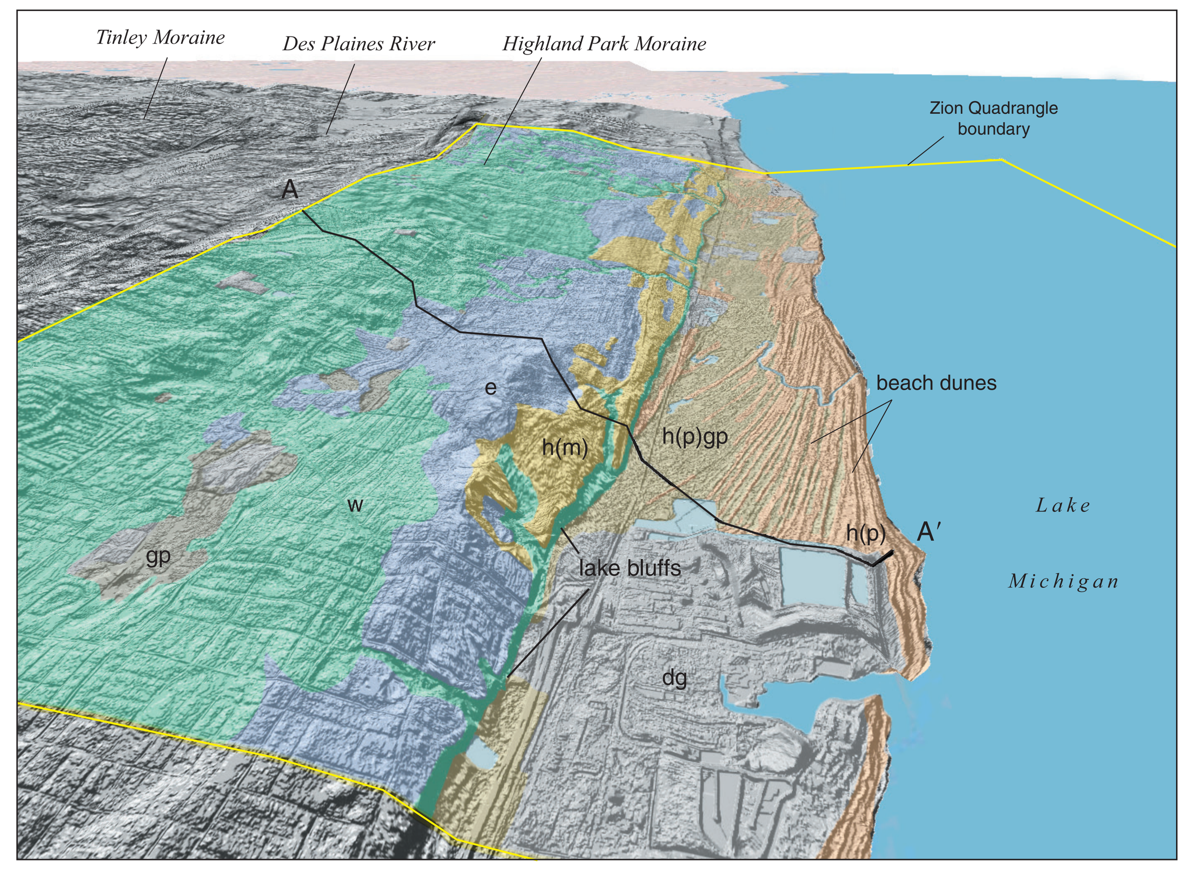

Figure 4 Surficial geology over topography of Zion Quadrangle.

The parent material (geologic material) classes were generalized for the surficial geology map because the soil-based data layer created a very complex map with polygons that were too small for incorporation into cross sections. It is assumed the thickness of each soil unit is at least 6 to 10 feet or more based upon the depth to which the soil scientists sample during their mapping. The thickness of specific units was adjusted where our drilling, field observations, or records suggested otherwise. Selected soil series, or in some cases individual polygons in various soil series, were regrouped into different geologic material classes following extensive fieldwork and data analysis for the Zion and other quadrangles in Lake County (Barnhardt 2005, 2008; Barnhardt et al. 2001; Stumpf 2004, 2006; Stumpf and Barnhardt 2005; Hansel 2005; Thomason and Barnhardt 2007, 2008). With the publication of the Zion surficial geology map, ten of the twelve quadrangles comprising the Lake County study area have been completed.

The sediment at land surface (parent material for the soils) was examined and correlated with its geomorphic (landscape) position to develop a sediment-landscape model. This was accomplished within ArcGIS by draping the sediment (parent material) layer over a digital elevation model (DEM) with a 2-foot resolution (figs. 3 and 4). In addition, the original, high-complexity soil series layer was added to increase the degree of detail available for analysis. Variations of this model were combined with records of water well and stratigraphic and engineering borings and analyzed in ArcScene to better understand the subtle sediment-landscape relationships and the changes in subsurface stratigraphy as depicted in the cross section. This model was used to interpret the sediment description for every water well, stratigraphic, or engineering boring used in the mapping.

Two boreholes were drilled to bedrock and continuously sampled using the ISGS CME-75 drill rig, which is equipped with a wireline sampler. Downhole natural gamma logs were also collected for each. The high-quality cores from these two boreholes were described in detail in conjunction with their gamma logs to better understand and interpret the descriptive records from adjacent water wells. Subsamples were taken for particle-size analysis. Geologic information for subsurface units depicted on the cross section was obtained from core descriptions for the two ISGS boreholes and sample sets and drilling logs obtained from water wells and engineering boreholes, which are available in databases at the ISGS. A total of 2042 location-verified water well and engineering boreholes are located on the quadrangle most of which are verified to tax parcel size and repositioned as needed (fig. 5). The quality of the geologic information for each borehole was evaluated as they were selected for developing and validating the surficial geology map and cross section. The legend of map units provides additional discussion on the variability of sediments and their occurrence on the landscape.

Acknowledgments

Funding for this project was provided in part through a contract grant from the U.S. Geological Survey, National Cooperative Geologic Mapping Program (USGS contract number 08HQAG0084 (STATEMAP)), a cooperative agreement with the U.S. Geological Survey (USGS contract number 04ERAG0052 (Central Great Lakes Geologic Mapping Program)), and the General Revenue Fund from the State of Illinois. The views and conclusions in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government, the State of Illinois, or the University of Illinois. This map is based on the most reliable information available at the time mapping was completed. However, because of project objectives and the scale of the map, interpretations from it should not preclude more detailed site investigations specific to any other project.

Many individuals assisted in this project by providing information and services including field assistance and drilling support, database management and development, data entry, cartographic and graphic production, technical review, and discussions on geology. ISGS staff J. Thomason and S. Brown (geology), V. Amacher and B. Stiff (data entry/database/GIS), T. Griest, (drilling), J. Carrell and J. Domier (cartography/graphics), D. Luman (imagery and LiDAR shaded relief maps), and D. Stevenson (GIS, database development) provided invaluable assistance to the author. Several Lake County departments provided assistance and information: the Department of Information and Technology, GIS and Mapping Division provided updates for various GIS layers and the Forest Preserve District provided access to their property and permission for drilling and monitoring well installation.

References

Barnhardt, M.L., 2005, Surficial geology of the Libertyville Quadrangle, Lake County, Illinois. Illinois State Geological Survey, USGS-STATEMAP contract report, 1:24,000.

Barnhardt, M.L., 2008, Surficial geology of the Wheeling Quadrangle, Lake County, Illinois. Illinois State Geological Survey, USGS-STATEMAP contract report, 1:24,000.

Barnhardt, M.L., A.J. Stumpf, A.K. Hansel, and R.C. Berg, 2001, Quaternary geology of Wadsworth Quadrangle, Lake County Illinois, and Kenosha County, Wisconsin: Illinois State Geological Survey, USGS-STATEMAP contract report, 1:24,000.

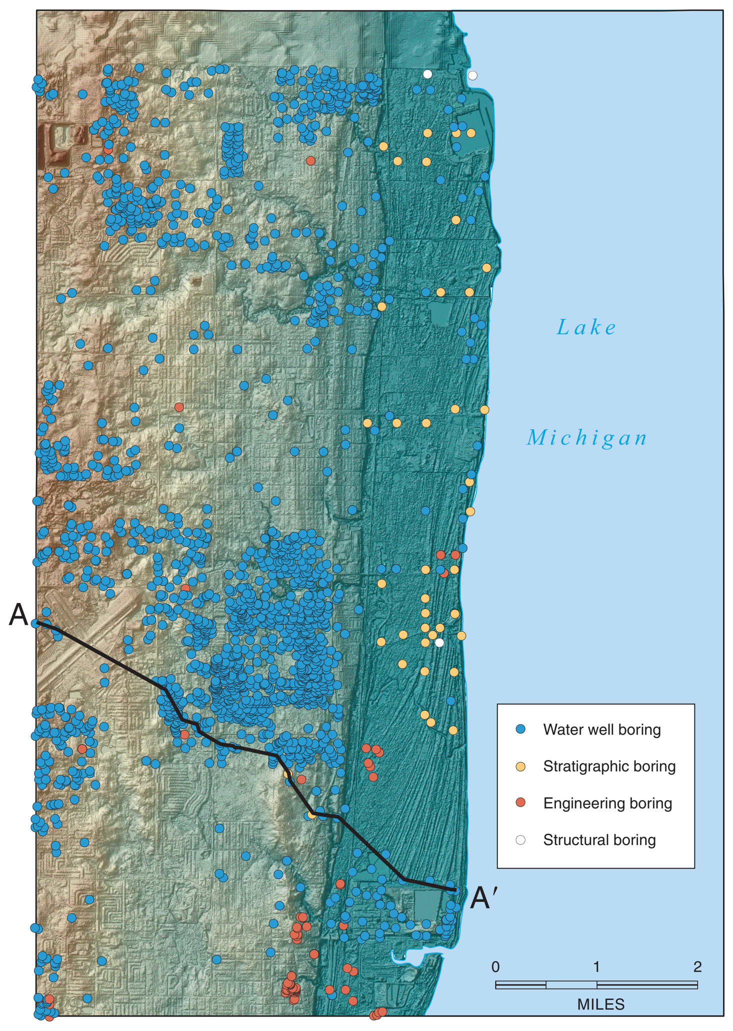

Figure 5 Locations of boreholes and cross section.

Berg, R.C. and C. Collinson, 1976, Bluff erosion, recession rates, and volumetric losses on the Lake Michigan shore in Illinois: Illinois State Geological Survey, Environmental Geology Notes 76, 33 p.

Chrzastowski, M.J. and W.T. Frankie, 2000, Guide to the geology of Illinois Beach State Park and the Zion Beach-Ridge Plain, Lake County, Illinois: Illinois State Geological Survey, Guidebook GB 2000C and 2000D, 69 p.

Fehrenbacher, J.B., J.D. Alexander, I.J. Jansen, R.G. Darmody, R.A. Pope, M.A. Flock, E.E. Voss, J.W. Scott, W.F. Andrews, and L.J. Bushue, 1984, Soils of Illinois: University of Illinois at Urbana-Champaign, College of Agriculture, Agricultural Experiment Station and U.S. Department of Agriculture, Soil Conservation Service, Bulletin 778, 85 p.

Fraser, G.S. and N.C. Hester, 1974, Sediment distribution in a beach ridge complex and its application to artificial beach replenishment: Illinois State Geological Survey, Environmental Geology Notes, 67, 26 p.

Hansel, A.K., 2005, Three-dimensional model: surficial geology of Antioch Quadrangle, Lake County, Illinois and Kenosha County, Wisconsin: Illinois State Geological Survey, Illinois Preliminary Geologic Map, IPGM Antioch-3D, 1:24,000.

Hansel, A.K. and W.H. Johnson, 1996, Wedron and Mason Groups: lithostratigraphic reclassification of deposits of the Wisconsin Episode, Lake Michigan Lobe Area: Illinois State Geological Survey, Bulletin 104, 116 p.

Hester, N.C. and G.S. Fraser, 1973, Sedimentology of a beach ridge complex and its significance in land-use planning: Illinois State Geological Survey, Environmental Geology Notes 63, 24 p.

Lake County, Illinois GIS, 1993, Lake County wetlands inventory: Waukegan, IL, Department of Information and Technology, GIS and Mapping Division.

Lake County, Illinois GIS, 2004, LIDAR, DEM (2-foot): Waukegan, IL, Department of Information and Technology, GIS and Mapping Division.

Larsen, J.I., 1973, Geology for planning in Lake County, Illinois: Illinois State Geological Survey, Circular 481, 43 p.

Lineback, J.A. and D.L. Gross, 1974, Glacial tills under Lake Michigan: Illinois State Geological Survey, Environmental Geology Notes 69, 48 p.

Luman, D.E., L.R. Smith, and C.C. Goldsmith, 2003, Illinois surface topography: Illinois State Geological Survey, Illinois Map 11, 1:500,000.

Paschke, J.E. and J.D. Alexander, 1970, Soil survey of Lake County, Illinois: U.S. Department of Agriculture, Soil Conservation Service and Illinois Agricultural Experiment Station, University of Illinois, 82 p.

Stumpf, A.J., 2004, Surficial geology of Grayslake Quadrangle, Lake County, Illinois: Illinois State Geological Survey, Illinois Preliminary Geologic Map, IPGM Grayslake-SG, 1:24,000.

Stumpf, A.J., 2006, Surficial geology of Lake Zurich Quadrangle, Cook and Lake Counties, Illinois: Illinois State Geological Survey, Illinois Preliminary Geologic Map, IPGM Lake Zurich-SG, 1:24,000.

Stumpf, A.J. and M.L. Barnhardt, 2005, Surficial geology of Antioch Quadrangle, Lake County, Illinois and Kenosha County, Wisconsin: Illinois State Geological Survey, Illinois Preliminary Geologic Map, IPGM Antioch-SG, 1:24,000.

Thomason, J.T. and M.L. Barnhardt, 2007, Surficial geology of the Barrington Quadrangle, Lake, McHenry, Cook, and Kane Counties, Illinois: Illinois State Geological Survey, STATEMAP Barrington-SG, 1:24,000.

Thomason, J.T. and M.L. Barnhardt, 2008, Surficial geology of the Fox Lake Quadrangle, Lake County, Illinois and Kenosha County, Wisconsin: Illinois State Geological Survey, contract deliverable map, 1:24,000.

United States Department of Agriculture, 2004, Soil survey of Lake County, Illinois: Natural Resources Conservation Service (NRCS), digital update of Paschke and Alexander, 1970.

Willman, H.B., 1971, Summary of the geology of the Chicago Area: Illinois State Geological Survey, Circular 460, 77 p.

Willman, H.B. and J.A. Lineback, 1970, Surficial geology of the Chicago Region: Illinois State Geological Survey, 1:250,000.

Willman, H.B. and J.C. Frye, 1970, Pleistocene stratigraphy of Illinois: Illinois State Geological Survey, Bulletin 94, 204 p.