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Quaternary Geology of the Indiana Portion of the Elkhart 30- x 60-Minute Quadrangle

By
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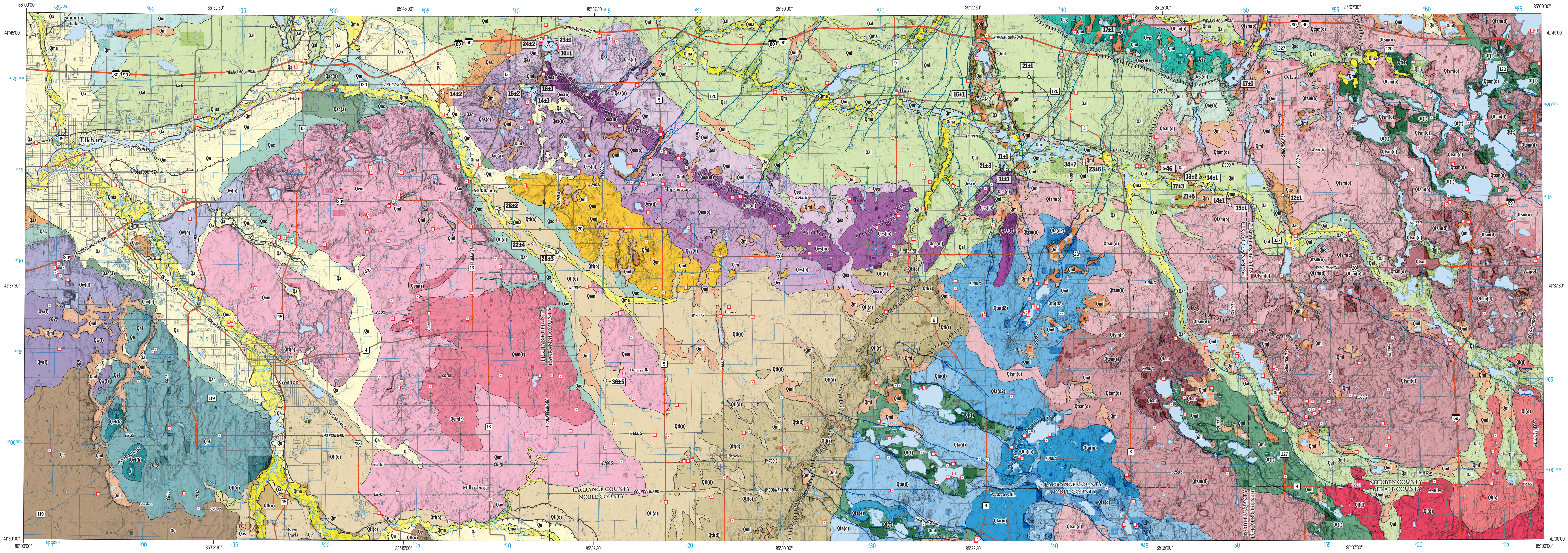
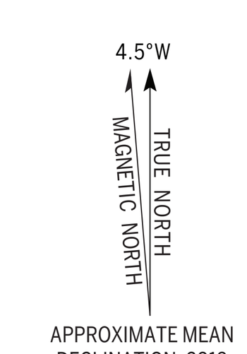
2019





SCALE 1:100,000

0 5 10 15 Miles

0 5 10 15 Kilometers

INTRODUCTION

Overview of the Geology, Stratigraphy, and Landform Assemblage

The map area is underlain by unconsolidated deposits of Pleistocene and Holocene age having thicknesses greater than 350 ft in the southwestern portion of the map, usually reaching 200 ft elsewhere. All surficial deposits are late Wisconsin Episode or younger (< 25,000 years ago, or <25 ka). A variable cover 20 to 150 ft thick of Wisconsin glacial and glaciofluvial sediments lies over pre-Wisconsin sediments, which compose most of the stratigraphic sequence. A minor discontinuous cover of postglacial alluvial, lacustrine, paludal, and aeolian deposits not exceeding 25 ft caps the glacial sequence. Toward the central part of the map area, morphology is strongly marked by the presence of a pre-Wisconsin upland at a shallow depth (30–50 ft).

Landforms and near-surface deposits mostly reflect the complex interplay between the Huron-Erie, Saginaw, and Michigan Lobes of the Laurentide Ice Sheet. Between 25 and 17 ka, retreating ice fronts from the Saginaw and Huron-Erie Lobes left a succession of ice-contact sediment ramps and associated pitted and collapsed fan-moraine complexes throughout most of the map area. These ice-contact features define the position of the ice margin as the Saginaw Lobe retreated from southwest to northeast, aligned in approximately parallel broad NW-SE ridges. These ridges are interspersed with lowlands occupied by Huron-Erie Lobe outwash deposits, with outwash flow toward the northwest, derived from an ice margin retreating from west to east. All outwash fans from the Saginaw Lobe are truncated or covered by the slightly younger outwash deposits of the Huron-Erie Lobe. Late-glacial aeolian activity 14 to 12 ka is evident in dune fields north of Middlebury and in the Pigeon River valley. The occurrence of collapse features attributed to stagnant ice is common across the landscape; they partly guided proglacial meltwater pathways in the uplands. Most of this discharge was short-lived, and an integrated drainage network did not develop. Low spatial connectivity of fluvial systems is reflected in poorly drained areas underlain by lacustrine and paludal deposits.

For units derived from the Saginaw Lobe, informal names are introduced to develop the stratigraphic framework. These include the Elkhart formation and associated members. In addition, informal names are used for specific units of the Atherton and Trafalgar Formations (Wayne, 1963).

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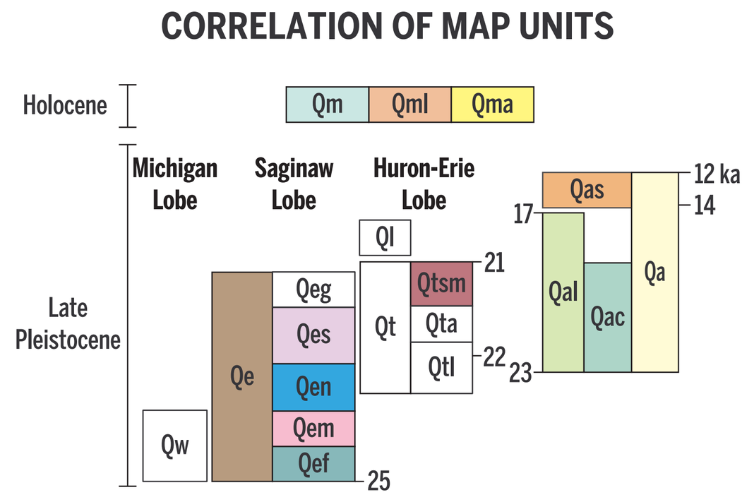
CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

Martinsville Formation (Holocene)

Qm — ***Undifferentiated deposits***
Silt, sand, and gravel in postglacial valleys that follow former channelized outwash deposits and distal outwash fans. Incorporates remnants of alluvial deposits in a surface higher than the widespread alluvial terraces in unit Qma.

Qml — ***Paludal and lacustrine deposits***
Gyttja, marl, sedge peat, and sphagnum peat, interbedded with silt and sand. Organic-rich sediments occur in saturated depressions, reflecting the poorly drained morphology developed in collapsed outwash or diamicton substrate; also developed at the edges of low-gradient channels entrenched by outwash fans. Thickness ranges from <3 ft in abandoned swales to >10 ft in deeply entrenched channels, for example, the depression containing Emma Lake, and former subglacial (tunnel) channels. The unit includes sandy alluvial facies too small to be mapped independently.

Qma — ***Alluvial deposits***
Silt, sand, and gravel in the bed and alluvial plain of modern river valleys. Alluvial channels are incised into the surface of outwash plains and outwash fans, units Qal, Qtsm(o) and Qtl(o), with a thin veneer of fine-grained alluvium and organic silt present in low-lying stretches of channels and oxbow lakes. In the Pigeon and Fawn Rivers, gravel bars and gravel bluffs indicate faster flow compared to the rest of the area. Gravel-rich deposits are up to 15 to 30 ft thick, although usually less in smaller feeding streams. The deposits represent lateral accretion during the Holocene of streams in a low-energy regime. The unit includes paludal and lacustrine deposits too small to be mapped independently.

Atherton Formation (Late Pleistocene)

Qa — ***Undifferentiated deposits***
Bedded sand, gravel, and silt primarily associated with outwash, but also including aeolian sand or slackwater deposits, the latter genetically and spatially related to distal outwash fan and glaciofluvial deposits. Well-stratified; thicknesses of 15 to 60 ft.

Qac, Qac(a) — ***Colluvium and alluvial fan deposits***
Sand, gravel, and minor silt deposited in coalesced wedges and fans at erosional edges developed in relatively narrow sluiceways and drainage outlets. These deposits guide surface drainage and the location of postglacial units of the Martinsville Formation west of Honeyville and in the Little Elkhart River valley, southeast of Middlebury. Most landform development and sediment deposition likely occurred during and immediately after deglaciation ca. 21 ka. Thickness not exceeding 15 to 25 ft. Qac(a): sandy facies having an alluvial fan morphology.

Qal — ***Lima-Howe outwash plain member (informal name)***
Well-sorted, medium- to coarse-grained sand and gravel. In places includes silt, sand, and gyttja in depressions linked to the collapse of outwash above ice contained in subglacial (tunnel) channels. The unit is composed of glacial outwash, 20 to 60 ft thick, locally interbedded with alluvial and colluvial sediments, deposited over the internal (ice-contact) ramps of the Shipshewana moraine and over the distal areas of the meltwater channels for the Sturgis fan and South Milford members of the Elkhart formation. Along the northern portion of the map, 30 ft of sand and gravel of the main Lima-Howe outwash body sits directly on top of the pre-Wisconsin surface.

The main body of outwash has a northern-source lithology signature derived from glacial erosion of the central Michigan Basin. This main body of outwash was scoured and the surface streamlined in an east-west direction by younger flows containing shales, Silurian dolomites, and other eastern-source lithology derived from meltwater from Huron-Erie Lobe ice margins to the east of the plain. The uppermost reworked outwash is 20 to 30 ft thick in the east and thins to the west. Near Bristol and Brighton, the smooth outwash plain surface is interrupted by pitted sections related to collapsed dead ice in former subglacial channels roughly oriented N-S. Toward the northwest and west, the unit is interbedded with outwash from the Three Rivers area to the north, in Michigan. These deposits derive from outwash fans dated to ca. 18 ka in Michigan (Kehew and others, 2017). Toward the south, this unit grades to a surface of outwash deposits that can be traced to the Ligonier and Leesburg distal fans, also dated ca. 18 ka. Toward the east, the unit grades to deposits dated from 23 to 17 ka, in meltwater channels linked to ice margins for the Huron-Erie Lobe (Valachovics, 2019; and this study).

Qas — ***Sand sheets and parabolic dunes***
Well-sorted medium to coarse sand forming linear and parabolic dunes up to 20 ft thick (15-ft-high landforms), mostly developed along the southern edge of the Lima outwash plain between Elkhart and Middlebury, and in the Pigeon River valley. The sand sheets and dunes are deposited on top of units Qa and Qal, and have a barely discernible pedogenic horizon at the contact, as seen in borings. These aeolian deposits indicate a wind direction from the west and are dated between 14.5 and 12 ka (Horton, 2015; Valachovics, 2019; and this study).

Wedron Group (Late Pleistocene)

Qw, Qw(o), Qw(d), Qw(l) — ***Undifferentiated deposits***
Silt-clay diamicton, sand and gravel outwash from the Lake Michigan Lobe; glaciolacustrine sand, silt, and clay also occur as irregular upland deposits centered around Elkhart. Thicknesses range between 25 and 50 ft. Equivalent to the Wedron Group as defined in Illinois (Frey et al., 1968; Hansel and Johnson, 1996). Silty-clay gray diamicton are present southwest of Elkhart, sitting atop variably textured tan diamicton that appear to have eastern-source lithology. To the south, silt, clay, and sand of glacio-lacustrine origin appear in thicknesses up to 60 ft; this unit is well developed in an upland between Elkhart and Foraker. The glacio-lacustrine facies are bound in all directions by diamicton of the Wedron Group or occur on top of the Elkhart formation to the south and east. Sand and gravel in 30- to 50-ft outwash packages occur as irregular upland deposits near Elkhart. Qw(o): sand and gravel outwash facies; Qw(d): diamicton facies; Qw(l): glacio-lacustrine facies.

Elkhart formation (informal name, Late Pleistocene)

Qe — ***Undifferentiated deposits***
Loamy- and silty-clay diamicton interbedded with clast-rich sandy diamicton and outwash fan deposits, incorporating distinctive lithology derived from the central Michigan Basin. Morphology generally defined by ridges and hummocks is interspersed with a collapse fan morphology left by stagnant ice after the ice sheet margin retreated. Deposits were formerly assigned to an unnamed member of the Lagro Formation (Wayne, 1963), chronostratigraphically equivalent to the New Holland Till member and to parts of the Cartersburg Till Member of the Trafalgar Formation (Wayne, 1963). These sediments represent deposition by glaciers of the Saginaw Lobe of the Laurentide Ice Sheet 25 to 21 ka. In the southeastern portion of the map, sections stratigraphically equivalent to the Wakarusa megasequence (Fleming and Karaffa, 2012) of diamicton and interbedded minor sand and gravel occur.

Qeg, Qeg(m), Qeg(o) — ***Sturgis outwash fan and moraine member (informal name) (Qeg)***
Medium to coarse sand and coarse gravel, interbedded with sandy to sandy-loam diamicton, in a WNW-ESE ridge morphology, flanked to the north by a sand and gravel ramp and to the south by an outwash fan graded to the Lima-Howe outwash plain member toward Ontario. Thickness is estimated up to 100 ft or more at the axis of the ridge. Gravel hummocks appear in the north ramp flanking former subglacial (tunnel) channels, mostly collapsed and filled with younger deposits of the Martinsville and Atherton Formations. Gravelly facies of the outwash fan in the east coalesced with outwash derived from ice that deposited the South Milford member of Huron-Erie source. The Sturgis moraine is also covered on its north ramp by outwash derived from Huron-Erie source. Qeg(o): outwash fan; Qeg(m): hummocky gravel and coarse diamicton facies.

Qes, Qes(o), Qes(d), Qes(e), Qes(m), Qes(r) — ***Shipshewana outwash fan and moraine member (informal name)***
Medium to coarse sand and coarse gravel, interbedded with sandy to sandy-loam diamicton, in a main northwest-southeast ridge moraine morphology, genetically related to a northwest-southeast ice margin. The ridge is flanked to the east by a sand and gravel ramp and to the west by push ridges and a collapsed proximal outwash fan, whose distal surface can be followed continuously over the landscape east of Middlebury. Thickness ranges from 20 to 50 ft when draped over older units in the north or to the southwest, and up to 150 ft or more at the axis of the ridge. Near Stone Lake in the northern portion of the map, a series of closely spaced sand and gravel ridges suggest that an advance of the ice front pushed a frozen sand and gravel fan bed into the Shipshewana ridges, unit Qes(r). Eskers and thick gravel hummocks appear in the eastern ramp flanking the course of former subglacial (tunnel) channels, mostly collapsed and filled with younger deposits of the Martinsville and Atherton Formations. To the east, sandy diamicton commonly appears interbedded within the sand and gravel ramps. At the contact with the Newbury unit, Qen, the sand and gravel facies of the outwash fans entered shallow lakes, resulting in sands deposited in deltaic and lacustrine environment, unit Qes(d), on top and surrounding hummocky sediment of the Newbury member. At the easternmost tip of outcropping sediments, the gravel ridge morphology that marks the highest point in the landscape might represent contact between ice of the Saginaw Lobe and Huron-Erie Lobe. There, the Shipshewana moraine appears partially covered and interbedded with diamicton and fan deposits from the Ligonier member of the Trafalgar Formation. Qes(o): outwash fan; Qes(m): hummocky gravel and coarse diamicton facies; Qes(e): esker; Qes(r): sand and gravel ridges; Qes(d): deltaic and lacustrine facies.

Qen — ***Newbury diamicton member (informal name)***
Mostly silty diamicton with interbedded (20–50 ft) sand and gravel, especially to the west and north. A thin (~10-ft) mantle of sand and loam overlies a thick (50–100+ ft) of silty olive-tinted diamicton that forms the main body of the unit. The entire diamicton sequence overlies a basal Wisconsin proglacial sand and gravel outwash that is directly on top of the pre-Wisconsin sediments. Most of the eastern and southeastern (inboard) portion of this unit was washed and modified extensively by water action at the time of deposition of the Shipshewana outwash fan and moraine member unit, Qes, and later by deposition of the northernmost edge of the Ligonier outwash fan unit, Qtl(o). A thin (<5 ft) layer of postglacial sand, gravel, and silt alluvium and paludal deposits occurs in places. To the east, an eroded hummocky surface containing sand and gravel deposits forms the base for the deltaic facies of the distal Shipshewana outwash fan unit, Qes(d). Between the town of Shipshewana and the lowlands west of Emma, a moderately thick sand and gravel channel is eroded into the Newbury diamicton along a north-south direction, with prominent gravel mounds at the edges of the channel and 5 to 15 ft of silty to clay diamicton capping the channel.

Qem, Qem(r) — ***Middlebury diamicton and outwash fan member (informal name)***
Mixture of silty-clay loam to clay loam diamicton and sand and gravel units, in places boulder- to cobble-sized gravels. To the north and west the unit is mostly composed of sand and gravel hummocks, stratified sandy diamicton, and ice-contact sand and gravel deposits. Patches of sandy diamicton in the northern area appear interbedded with sand and gravel units (60–100 ft thick). West of Middlebury the remains of a partially collapsed sand and gravel outwash fan appear interbedded with diamicton in a complex fashion (10-50 ft thick). Toward Millersburg, the surface displays ridges oriented WNW-ESE; the ridges in this area are composed mostly of sand and gravel in a thin (5–30 ft) discontinuous layer draping mostly diamicton and silt-clay glaciolacustrine facies. The pre-Wisconsin surface is at depths of less than 50 ft in the southernmost tip of this unit. In the Honeyville area, a loam to silty-clay diamicton overlies a truncated outwash fan composed of a sequence of sand and gravel interbedded with clay diamicton up to 60 ft thick. There, a N-S-oriented moraine stands above the surface of the medial Ligonier outwash fan, which drapes around it. This unit represents ice-contact deposition, with ice filling the Little Elkhart River valley and eastern areas. The area near Millersburg could have developed as a complex interlobate region similar to the one developed in LaGrange County to the east (Karaffa and Sowder, 2010). Qem(r): gravel ridges.

Qef, Qef(k) — ***Foraker member (informal name)***
Clay- to silt-loam diamicton of distinct Saginaw Lobe source. Toward the north interbedded with gravel-rich, stratified diamicton, and sand and gravel in lenses and ice-contact landforms. The ridge west of Goshen is cored with interbedded sand and gravel and sandy diamicton and forms the head of an outwash fan toward the north and west. Collapsed areas contain chaotic assemblages of diamicton and gravel facies, with diamicton facies composing most of the ridges. Qef(k): ice-contact stratified diamicton and kame terraces.

Lagro Formation (Late Pleistocene)

Ql, Ql(o), Ql(d) — ***Undifferentiated deposits***
Clay diamicton; glaciolacustrine sand, silt, and clay; and sand and gravel outwash in meltwater channels. The diamicton assigned in the map area to the Lagro Formation were formerly assigned to the New Holland Till member of the Lagro Formation (Wayne, 1963). The outwash fan facies grade to valley train and outwash plain deposits of the Lima-Howe outwash plain unit towards the west. Ql(d): diamicton; Ql(o): outwash fan facies.

Trafalgar Formation (Late Pleistocene)

Qt, Qt(t) — ***Undifferentiated deposits***
Silty-clay to clay diamicton, and glaciolacustrine sand, silt, and clay, with sand and gravel located along former subglacial channel positions. Deposits occur as irregular lowland deposits east of the ice position marked by the Ligonier fan member and stratigraphically below (west) of the Lagro Formation (Wayne, 1963). Thicknesses range between 25 and 50 ft in the area. Qt(t): stratified sand and gravel subglacial channel facies.

Qtsm, Qtsm(o), Qtsm(d), Qtsm(r) — ***South Milford member (informal name)***
Silty-clay to clay diamicton, and sand and gravel outwash. The diamicton is transitional between the loam- and silt-loam diamicton of the Trafalgar Formation and the clay-loam diamicton of Lagro Formation. South Milford outwash deposits grade into the Lima-Howe outwash plain deposits to the northwest, dissecting hummocky topography of the interlobate area and Saginaw Lobe deposits older than the Sturgis outwash fan and moraine complex. Qtsm(d): diamicton facies; Qtsm(o): sand and gravel outwash; Qtsm(r): sand and gravel ridges.

Qta, Qta(o), Qta(d), Qta(d2), Qta(e), Qta(m) — ***Oliver-Adams Lake basin glaciolacustrine deposits***
Glaciolacustrine sand, silt, and clay, along with fan-head hummocky sand and gravel interbedded with diamicton, and sand-silt deltaic deposits. These sediments were deposited as the Huron-Erie Lobe ice margin was standing at the Adams Lake moraine, unit Qta(m). This landform was the head for fan and deltaic deposits to the west, filling the Oliver Lake basin with deltaic sands partially interbedded with and covering glaciolacustrine silt and clay. The upper glaciolacustrine units grade laterally to the west to the Ligonier fan upper diamicton. The lower glaciolacustrine deposits are directly on top of the pre-Wisconsin units, here at more than 150 ft. Qta(m): sand and gravel moraine ridge; Qta(d): deltaic sediments; Qta(d2): diamicton partially interbedded with Saginaw Lobe diamicton and sand and gravel sediments in an interlobate region; Qta(o): sand and gravel outwash; Qta(e): esker.

Qtl, Qtl(o), Qtl(d), Qtl(r) — ***Ligonier fan member (informal name)***
Cobble gravel lenses and hummocks in a pitted outwash fan grade toward the northwest into sand and gravel outwash, partly covered in the east with a pervasive silt loam to gravelly loam diamicton. In exposed sections, crudely stratified sand and gravel. The silt-loam diamicton capping the sequence is usually less than 20 ft, although near the town of Topeka it reaches 30 ft thick, completely lacking gravel and deposited directly on top of older diamicton. In the south, the outwash gravel facies reach 50 ft thick over undifferentiated diamicton of the Trafalgar Formation. To the southeast, gravels >125 ft thick rest on top of eroded pre-Wisconsin units in a paleovalley. To the west the outwash is typically 10 to 40 ft thick over the Newbury member of the Elkhart formation. The medial outwash fan near Emma has developed an irregular surface compared to its surroundings, marked by the presence of a depression filled with up to 40 ft of muck, peat, marl, and sand centered around Emma Lake. The fan surface extends to the northwest, filling the valley of the Little Elkhart River with progressively finer gravels and sand, with a thickness of only 20 ft thick near Middlebury. Coalescing areas of this unit with alluvial fans west of Honeyville are underlain by poorly drained organic-rich sediments, suggesting slightly longer activity of the fan on the northeastern edge. The distal fan is abutted (and probably covered) by alluvial fans derived from the Shipshewana area. Equivalent sand and gravel units form the main substrate underlying the Elkhart River valley in the western portion of the map area. All distal unit deposits interdigitate with distal Lima-Howe outwash plain member deposits of the Elkhart formation near Elkhart and Middlebury. Interbedded with the Atherton Formation near the junction of Turkey Creek and Elkhart River, south of Goshen. The Ligonier outwash fan represents mostly deposition by glaciofluvial activity derived from the Huron-Erie Lobe of the Laurentide Ice Sheet between >24 and 21 ka (this study), and is chronostratigraphically equivalent to the Cartersburg Till Member of the Trafalgar Formation in central Indiana. Qtl(o): outwash fan; Qtl(d) diamicton facies; Qtl(r): sand and gravel ridges.

Geologic contact

Subglacial channel

Ice front positions. Serrated edge points in an up-ice direction

Fluvial and glacifluvial erosional scarp

Optically stimulated luminescence age (ka, 1 sigma uncertainty) (Horton, 2015; Dziekan, 2017; Valachovics, 2019; and this study)
- ○ *Sediment age*
- ▽ *Underlying unit minimum age*

Calibrated accelerator mass spectrometry C-14 age (ka, 2 sigma uncertainty) (Horton, 2015; Dziekan, 2017; Valachovics, 2019; and this study)
- ▲ *Sediment maximum age*
- ▼ *Underlying unit minimum age*

Gamma-ray log

Water-well log with standardized stratigraphy in digital database

Horizontal to vertical spectral ratio seismic data

ACKNOWLEDGMENTS AND DISCLAIMER

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BASE MAP INFORMATION

Digital cartography by Matthew R. Johnson.

Topographic shading based on 2011–2013 Indiana Lidar data.

Transportation network from OpenStreetMap.org (© OpenStreetMap contributors).

Hydrography from U.S. Geological Survey National Hydrography Dataset (local resolution).

Projection: Universal Transverse Mercator (UTM), Zone 16N.

Horizontal Datum: North American Datum of 1983 (NAD83).

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