Quaternary Geology of the Indiana Portion of the Western Extent of the South Bend 30- x 60-Minute Quadrangle

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OVERVIEW OF THE GEOLOGY, STRATIGRAPHY, AND MORPHOLOGY

The map area is underlain by unconsolidated deposits of Pleistocene and Holocene age that reach thicknesses generally between 100-250 ft, except for a northwest-southeast trending bedrock valley which is estimated to hold 400 ft of unconsolidated sediment near La Porte (Naylor and others, 2016). All surficial deposits are late Wisconsin Episode or Holocene in age (less than 24,000 years ago, or less than 24 ka), directly above Devonian shale bedrock (Brown and others, 1996). A discontinuous cover of postglacial (mostly Holocene) alluvial, lacustrine (including shore facies), paludal, and aeolian deposits not exceeding 50 ft caps the glacial sequence, except for thick dune sequences bounding the present-day Lake Michigan shoreline.

Glacial landforms and near-surface deposits reflect a northwestward-retreating ice front of the Lake Michigan Lobe (LML). Ice sheet retreat in the map area occurred between roughly 21 and 17 ka, after the LML reached its Last Glacial Maximum (LGM) extent around 24 ka in central Illinois and west-central Indiana (Curry and others, 2018). Retreating ice left a succession of ice-contact sediment ramps and associated pitted and collapsed fan-moraine complexes throughout the area. Between 21 and 17 ka, diamicton and sand and gravel sediments were stacked in fan heads in a strip between Westville and north of New Carlisle. Diamicton-capped fans and pitted outwash fans descend toward the Kankakee lowlands to the south, where the distal ends of units are eroded by alluvial and glaciofluvial deposition, mostly during the Kankakee Torrent event (Curry and others, 2020). Lowlands southwest of the Valparaiso Moraine fan system in the map area are mostly occupied by post-18 ka valley-train outwash deposits. Collapse features attributed to stagnant ice are common on the pitted landscape around the Kankakee valley. The outwash discharge over this area was short-lived, and low spatial connectivity of fluvial systems is reflected in poorly drained areas underlain by lacustrine and paludal deposits. Inboard of the Valparaiso Moraine system, late-glacial lacustrine and aeolian landforms and sediment are found near Michigan City (Brown and Thompson, 1995; Brown and others, 1996). As the LML retreated northward and out of the basin, variable water levels of ancestral Lake Michigan resulted in coastal landforms and sediments at several levels. These levels controlled post-glacial fluvial drainage patterns and locations of alluvial, paludal, and lagoonal deposits throughout the Holocene (Brown and Thompson, 1995). The present-day shoreline of Lake Michigan is flanked by a late Holocene dune sequence that in most of the map area is being eroded (Argyilan and others, 2014, 2018).

Formal and informal names are introduced to develop the stratigraphic framework. Informal names include specific units and facies of the Atherton and Martinsville Formations (Wayne, 1963), and members of the Wedron Group (Hansel and Johnson, 1996). The latter is defined in Illinois with tentative equivalent units in the map area.

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DESCRIPTION OF MAP UNITS

Martinsville Formation (Holocene)

Qma *Alluvial deposits*
Silt, sand, and minor gravel in the bed and alluvial plain of modern river valleys. Alluvial channels are incised into pre-Chippewa phase sediments. Typical thickness of about 15 ft. A maximum thickness of up to 50 ft is composed of fine-grained alluvium and organic silt accumulated in channels, mostly backfilled during the Nipissing phase (Brown and Thompson, 1995). Sediments mapped Qma may comprise interspersed units Qml and Qma, including paludal and lacustrine deposits too small to be mapped independently.

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 backbarrier lagoon swamps. Unit is found lakeward of the Valparaiso Moraine, in collapsed outwash fan surfaces and channels or diamicton substrate on the Valparaiso Moraine, or immediately to the south, between the moraine and the Kankakee lowlands. Thickness ranges from less than 3 ft in abandoned swales to ~50 ft in backfilled Nipissing and post-Nipissing phase lagoons, which were entrenched during low phases of Lake Michigan during the Holocene (Brown and Thompson, 1995), or in former subglacial (tunnel) channels near the Valparaiso Moraine (Brown and others, 1996). Where thickness is greater than 5 ft, sediments in places contain late glacial deposits that grade upwards into Holocene deposition. The unit can include sandy alluvial facies toward the base, too small to be mapped independently. For lagoon sediment stacks associated with successively younger deposits behind beach and dune complex deposits along the Lake Michigan shoreline, numbers denote order of successive stacks that can be differentiated in the unit: 1: Calumet lagoon deposits; 2: Tolleston lagoon deposits (cf. Bretz, 1951; Brown and Thompson, 1995).

Qms2b *Sand sheets, littoral sands and parabolic dune deposits*
Moderately to well-sorted medium to fine-grained sand forming beach ridges, and high relief-domal, linear and parabolic dunes with relief as much as 130 ft toward Lake Michigan (unit Qms2), decreasing inland (5–40 ft in unit Qms1), developed along former Holocene shorelines of Lake Michigan. The sand sheets and dunes are interpreted as aeolian deposits on top of Pleistocene sediments, indicating wind direction from the west. The oldest Holocene dune deposits in the area, the Calumet dunes (Qms1), started to form near 11.8 ka, when the Calumet shoreline was established. The youngest set of dunes, associated with the Tolleston beach unit, started to form near 4.5 ka (Thompson, 1992; Argyilan and others, 2014) and the main phase of deposition was around 3.5–3.4 ka (Unit Qms2; Argyilan and others, 2014). Some of the sand sheets of Qms1 cover and blend into sand dunes of unit Qas (late Glenwood phase dunes, cf. Brown and others, 1996). Numbers denote order of successive sediment stacks that can be differentiated in this unit: 1: Calumet dunes; 2: Tolleston dunes; 1b: Calumet shoreline nearshore facies; 2b: Littoral facies, last 150 years of sedimentation around Michigan City.

MAP INFORMATION

Digital cartography and GeMS database compilation by Matthew R. Johnson.

Topographic shading and contours based on 2016–2020 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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Atherton Formation (Late Pleistocene)

Qal *Ice-marginal lacustrine, nearshore, and fan-delta deposits*
Fine to medium sand, silt, and clay. Minor sand and gravel in fan delta facies. Proglacial lacustrine sediment that accumulated roughly between the Valparaiso Moraine and the Lake Border Moraine. Includes nearshore, colluvial, and fan-delta facies toward the north, between strictly lacustrine facies and the Valparaiso Moraine to the south. In unit Qal3, the complete sequence starts with a silt layer that gradually coarsens into sand, being capped by clay. In unit Qal1, 2, mostly fine sand and sand with subordinated silt and clay. Variable thickness depends on accommodation space in former topography. In regions near the Michigan-Indiana border, thickness of units Qal1 and 2 exceeds 100 ft (cf. the Michigan area descriptions of Stone and others, 2017, with thicknesses of up to 180 ft), while areas covered by this unit near Michigan City are composed only of a thin (5 ft or less) fine sand cover on top of diamicton of the Lake Border moraine complex (Qwb). Numbers denote order of deposition in successive glacial lakes: 1: glacial Lake Madron (Stone and others, 2003, 2017); 2: glacial Lake Dowagiac (Stone and others, 2003, 2017); 3: glacial Lake Border (Leverett and Taylor, 1915). Where fan delta facies have been identified, they are marked as fd.

Qao *Valley train outwash deposits*
Well- to moderately sorted, medium- to coarse-grained sand and gravel. Beds fill the Kankakee River valley. Includes thin sandy diamicton, silt, sand, and gyttja in depressions, linked to the collapse of outwash deposited above stagnant ice in the Valparaiso fan complex, along the northwest side of the Kankakee valley. The sediments comprise glacial outwash, 20 to greater than 120 ft thick, locally interbedded with alluvial fan and colluvial sediments, mostly deposited in distal areas of the meltwater channels associated with the Valparaiso and Clay-Edwardsburg fan members of the Wedron Group, and therefore in a stratigraphically similar position. Units Qao2-3 are a probable remnant of Kankakee Torrent age sediments as described by Curry and others (2014, 2020). Unit Qao4 represents waning meltwater flowing to the southwest before meltwater flow turned northward near South Bend. Scouring of the Qao4 surface is linked to LML meltwater as the ice left the Valparaiso Moraine toward the north. Bottom of channels carved in the latest event of Valparaiso fans and subsequent alluvial fans (Qac unit) grade toward the plain formed by unit Qao4. Ordering of units (2-3-4) correspond with those defined in the South Bend area by Antinao and Rupp (2021).

Qac *Colluvium and alluvial fan deposits*
Sand, gravel, and minor silt deposited in coalesced wedges and fans within drainage outlets and along erosional edges developed in sluiceways. These deposits guide surface drainage and the location of postglacial units of the Martinsville Formation south of Westville and La Porte, along the Little Kankakee valley and other similar regions of the landscape. Most landform development and sediment deposition likely occurred in pulses immediately following deglaciation. Thickness not exceeding 15 to 25 ft.

- Geologic contact
- Meltwater flow direction
- Ridge, beach
- Ridge, dune
- Ridge, moraine
- Scarp
- Scarp, meltwater scouring
- Subglacial channel
- Boreholes with verified lithological logs
- Horizontal to vertical spectral ratio seismic data

Qas *Littoral sand sheets and dunes (ancestral Lake Michigan)*
Fine-grained sand and sandy gravel that accumulated in dune, nearshore and littoral settings along a wave-washed scarp during the earliest ice-free Lake Michigan (late Glenwood phase of Brown and others, 1996). An irregular dune topography tops the landscape. Thickness of 10-20 ft. Where littoral and nearshore facies are not covered by the more expansive aeolian facies, they have been identified: l: littoral, n: nearshore.

Wadsworth Formation of the Wedron Group (Late Pleistocene)

Qwb *Lake Border Moraine diamicton and glaciolacustrine complex beds*
Stratified and massive clay loam, silt-clay loam, and silty clay diamicton, dark gray to brown in color, with some stratified clay, silt, and sand and gravel deposits. Interpreted as mostly ice-marginal debris fans, including some glaciolacustrine pockets, along with subglacial till deposits associated with an advance of the LML, overlying the north slope of the Valparaiso Moraine. Glaciolacustrine facies in the proglacial environment that grade into this unit, toward the top of the stratigraphic package, are included in unit Qal. Diamicton units are 30-50 ft thick. 1: Tintley ridge (Bretz, 1951); 2: Lake Border Moraine (Leverett and Taylor, 1915).

Qww *Valparaiso Moraine diamicton and outwash fan complex member*
Boulder-bearing silt-clay loam diamicton, gray to grayish brown in color, and related sand and gravel outwash fans sourced at the Valparaiso Moraine. Proximal facies display boulders at the surface and a thicker (>10 ft) cover of diamicton, with a total thickness of up to 200 ft. Distal facies display sandy gravel and sand in fans graded toward valley train units Qao3 and Qao4 in the Kankakee valley. All units ca. or post-19 ka in age. Equivalent with the Wadsworth Formation of the Wedron Group in Illinois (Hansel and Johnson, 1996). Numbers denote progressively younger units, with 1 being oldest. Progressively finer sand and gravel in younger units. Diamicton cap prominent in unit 1, and north portion of unit 2, closest to moraine ridge, and thins toward the south. Unit 3 lacks diamicton cap.

Lemont Formation of the Wedron Group (Late Pleistocene)

Qwpp1 *Portage Prairie diamicton and outwash fan complex member*
Boulder-bearing gray to grayish brown silt-clay loam diamicton and sand and gravel fans at an intermediate position between the Valparaiso margin and the Inner Kalamazoo margin to the east, near South Bend (Russell and Leverett, 1908; Stone and others, 2017; Curry and others, 2020). In the map area, isolated remnants of the unit appear surrounded by younger fan lobes of the Valparaiso Moraine diamicton and outwash fan complex member of the Wadsworth Formation. The latest flows during the Kankakee Torrent event (Curry and others, 2014, 2020), ca. 19 ka in age, eroded the eastern margin of the unit south of New Carlisle and deposited units Qao2 and now-eroded Qao3. Youngest sediments of the Atherton Formation are incised into and abut this unit toward the Kankakee valley. Estimated thickness between 40 and 75 feet. Diamicton facies are tentatively equivalent with the Haeger Member of the Lemont Formation of the Wedron Group in Illinois (Hansel and Johnson, 1996) and the Ganges Till unit in Michigan (Monaghan, 1988).

CORRELATION OF MAP UNITS