The National Cooperative Geologic Mapping Program

In 1992, Congress signed into law the National Geologic Mapping Act and created the National Cooperative Geologic Mapping Program (NCGMP). A prime objective of the program is to determine the Nation's geologic framework through the systematic development of geologic maps, and establish a National Geologic Map Database.

The Central Great Lakes Geologic Mapping Coalition

Detailed surficial geologic maps are essential today to make sensible development decisions regarding water and mineral resources, environmental protection, and geologic hazard reduction. Yet only a very small part of the nation's regional surficial geology is mapped in sufficient detail to support truly informed decisions. Timely production of this geologic information requires resources and capabilities beyond those available to any one state, hence the geological surveys of Illinois, Indiana, Michigan and Ohio have joined with the U.S. Geological Survey to form the Central Great Lakes Geologic Mapping Coalition. These states share the common geological heritage of the Great Ice Age, and the complexity of materials deposited by glaciers presents these states with a shared set of unique and common challenges.

Detailed mapping of glacial deposits is critical to preserving a safe and healthy environment for ourselves and our children. As citizens, we face many important health and environmental issues: 1) keeping our surface and groundwater resources free of pollution, 2) protecting against floods, earthquakes, and soil and lakeshore erosion, 3) safe siting of landfills, agrichemical facilities, and hazardous waste disposal facilities, 4) reclaiming land polluted by previous generations, and 5) maintaining and restoring natural areas and wetlands for hunting, fishing, boating and recreation.

Who Uses Geological Maps?

County and city planners
Water and other utilities
Public health agencies
State and county transportation departments
Federal and state environmental protection agencies
Builders and developers
Agricultural agencies
Insurance companies
U.S. Army Corps of Engineers
Mining companies
Environmental consultants
Engineering firms
The EDMAP Geologic Mapping Program

The U.S. Geological Survey's EDMAP program is a component of the NCGMP with the primary goal of training the next generation of geologic mappers. The Department of Geology at Wayne State University has been part of the EDMAP program since 2000. The program has funded the training of graduate and undergraduate students under the guidance of Dr. Howard. Below is a summary of results from the 2005 mapping season.

Quaternary Geology of the Walled Lake and Pontiac South Quadrangles, Oakland County, Southeastern Michigan: Results from the 2005 field season

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Abstract

Mapping during the 2005 field season involved the PI, three undergraduate students (Mike Coram, Steve Chumney and Amelia Letvin), and one graduate student (Tamara DeFrain). We mapped most of the southern halves of the Walled Lake and Pontiac South quadrangles, parts of northern halves of these quadrangles, and part of the adjacent Birmingham quadrangle. The results show that morainal stratigraphic units defined previously in the Northville quadrangle are viable geologic units now defined more formally as the River Rouge Till, Farmington Hills Formation, Novi Till and Walled Lake Formation. Our mapping shows that morainal deposits extend east of the topographically defined boundary of the moraine at the Lake Maumee paleoshoreline, and lie directly beneath the surface as far east as the paleoshoreline of glacial Lake Whittlesey. This resolves the issue of how to delineate map units along the western margin of the Detroit Lowland. Our new mapping also shows that the Defiance paleochannel does extend through the map area, but Defiance channel sediments are eroded way east of Franklin. Defiance paleochannel sediments were well exposed at a construction site where a soil profile was described and sampled. The contact between the Novi Till and Walled Lake Formation was also well exposed during construction at the Cranbrook Institute of Science (Birmingham quadrangle). The Walled Lake Formation appears to cover all the northern Walled Lake and Pontiac South quadrangles, but further mapping is needed to establish its geographic extent. Future mapping is also recommended of the Salem quadrangle, which bounds the Northville quadrangle on the west, and in the Birmingham quadrangle farther east where there are several glacial landforms of uncertain origin and significance.

INTRODUCTION

Southeastern Michigan lies in the southern Great Lakes region, bordered on the northeast and southeast by Lakes Huron and Erie, respectively. The southern Great Lakes region is a relict Late Pleistocene glacial landscape that consists of the erosional remnants of an arcuate series of morainal uplands, and regionally extensive proglacial alluvial and lacustrine lowlands (Fig. 1). The glacial history of sediments and landforms in southeastern Michigan is relatively well understood. However, this knowledge is based almost entirely on small-scale geologic mapping and geomorphic analysis.
(Leverett and Taylor, 1915; Flint et al., 1959; Farrand and Bell, 1982; Fullerton et al., 1991). Little information is available regarding the detailed stratigraphic and sedimentological characteristics of the Pleistocene sediments composing this glacial landscape. Rapid urbanization and urban redevelopment have also created a pressing need for geologic data pertaining to the surficial geology of southeastern Michigan. Published mapping has established the general character of surficial deposits and landforms there, but the scales at which the maps were published are generally too small (e.g. 1:500,000) for site-specific applications.

The purpose of this project is to generate 1:24,000 scale geologic maps of the Walled Lake and Pontiac South 7.5 minute quadrangles in southeastern Michigan. These quadrangles (Fig. 2) cover an environmentally sensitive part of a massive and rapidly growing expanse of suburban sprawl in the metropolitan Detroit area characterized by numerous wetlands and inland lakes. The area contains elements of both morainal upland and alluvial-lacustrine lowland glacial landscapes. It borders the Northville, Redford and Royal Oak quadrangles, where geologic mapping of the by the PI and his students is complete, and it is adjacent to the Birmingham quadrangle, where mapping is underway by the PI, and Kent Murray and his students at the University of Michigan, Dearborn. The results of this study will provide a useful geologic framework for the interpretation of site-specific geotechnical and environmental problems. It is expected that the geologic maps of southeastern Michigan will help society make better decisions about resource use and protection.
GEOLOGIC SETTING AND STUDY AREA

Southeastern Michigan is underlain by a weakly deformed sequence of Paleozoic carbonate and clastic sedimentary rocks about 1000 m thick that forms the southeastern flank of the Michigan Basin (Cohee, 1965; King and Beikman, 1974). These rocks are truncated by an erosional unconformity, representing most of Mesozoic and Cenozoic time, and veneered with a cover of Quaternary sediments as much as 170 m thick (Mozola, 1969; Rieck, 1981). The Quaternary section includes glacial Late Pleistocene till and stratified drift, as well as Holocene fluvial, deltaic, lacustrine and eolian sediments. A cover of such Quaternary sediments extends more or less continuously northward across continental platform strata of the Michigan Basin, and then discontinuously into the southern part of the Canadian Shield in Ontario (Dyke and Prest, 1987). Late Wisconsinan glaciation of the Great Lakes region is characterized by three major advances of the Laurentide Ice Sheet that became progressively more lobate and less extensive geographically over time. All of Michigan lay buried beneath the ice sheet when it reached its maximum extent during early Woodfordian time, about 22 to 17 kA (Clayton and Moran, 1982; Dyke and Prest, 1987). During the second and third maxima at about 15 and 11 kA, southeastern Michigan was affected by three distinct glacial lobes (Saginaw, Huron and Erie) that generally correspond to respective lobe-shaped parts of the modern Great Lakes. As the ice sheet retreated northward over the course of the Late Wisconsinan, proglacial lakes became widespread along its southern margin (Teller, 1987). These glacial lakes were generally short-lived but as large, or larger, than the modern Great Lakes.

Figure 2. Geomorphic features in the study area (see Fig. 1). Cities: N, Northville; B, Birmingham; F, Farmington; O, Royal Oak; D, Detroit. Glacial paleolake shorelines (dotted where inferred): M, Lake Maumee; H, Lake Whittlesey; W, Lake Warren; Y, Lake Wayne; G, Lake Grassmere; E, Elkton; R, Rouge.
The Walled Lake and Pontiac South quadrangles are located in Oakland County about 35 km northwest of downtown Detroit, Michigan (Fig. 2). These quadrangles lie between N42°30' and N42°37'30" latitude, and between W83°15' and W83°30' longitude. They are bounded by the Milford, Clarkston, Northville, Pontiac North, Birmingham, and Redford quadrangles. The landscape in the map area consists primarily of the northeast-trending Ft. Wayne-Defiance Moraine at 267-326 m (800-980 ft) elevation, transected along strike by a northeast-trending glacial outwash channel (Defiance paleochannel), and flanked on the southeast by lacustrine terraces of the Detroit Lowland at 233-267 m (700-800 ft) elevation (Fig. 2). These terraces were formed as a series of proglacial lakes, and are associated with morainal uplands that form a recessional pattern related to regional Late Pleistocene deglaciation. Locally, two peat bog sites in the morainal upland of Oakland County near the study area have yielded radiocarbon ages between 9.5 and 12.8 kA BP; associated spruce pollen suggests a paleoclimate cooler and wetter than present (Dorr and Eschman, 1971; Shoshani and Smith, 1996). Radiocarbon dates elsewhere in southeast Michigan suggest that sediments associated with paleolake Whittlesey and the Port Huron moraine were formed 12.7-13.5 kA BP (Blewett et al., 1993). Regional relationships suggest that these landforms were formed during the Port Bruce Stade of Late Wisconsinan time when southeastern Michigan was at the juncture of three glacial lobes -- Saginaw and Huron lobes that extended south from the Lake Huron basin, and an Erie lobe that moved southwestward across the Lake Erie basin (Farrand and Eschman, 1974; Fullerton, 1980; Mickelsen et al., 1983; Eschman and Karrow, 1985; Larsen, 1999; Larson and Schaetzl, 2001). The study area encompasses the drainage divide between the Clinton and Rouge Rivers, and includes over thirty large freshwater lakes along with a multitude of wetlands. These rivers have eroded headward during the Late Holocene and partially captured a relict Late Pleistocene deranged drainage system associated with knob-and-kettle topography developed on the morainal upland surface.

METHODS AND TERMINOLOGY

Mapping was carried out with standard 2 meter-long hand (soil) augers with 9 cm-diameter buckets. Exposures along roads are relatively common in the map area but in general, at each location plotted on the map, holes were bored through soil horizons and into the underlying surficial sedimentary deposit, which was then identified and labeled according to the textural lithosome classification shown in Table 1. It is not possible to recognize sedimentary structures in such borings. Hence, exposures in sand and gravel pits (largely abandoned), and in excavations for buildings or sewers, were studied in order to define lithofacies on the basis of texture and sedimentary structures. The locations of key sites (e.g. soil pits, excavations, radiocarbon samples) were determined using a Garmin GPS III-plus navigator unit and National Geographic's Topo! software. Clast counts for provenance analysis were carried out using the area method for sampling (Howard, 1993), i.e. at each sampling location, the largest 100-150 clasts in a 4 x 4 m area of outcrop were collected and returned to the lab. Each clast was cleaned, broken open and identified using a binocular microscope.

RESULTS FROM 2005 FIELD SEASON

Mapping during the 2005 field season involved the PI, three undergraduate students (Mike Coram, Steve Chumney and Amelia Letvin), and one graduate student
(Tamara DeFrain) who was to use the geologic map of the Pontiac South quadrangle as part of her M.S. thesis. Tamara is now attending another university, but she has been replaced by Mike Coram whose thesis will consist of a geologic map of the Walled Lake quadrangle, and a detailed study of the soils and groundwater geology of a natural wetland near Woodpecker Lake in West Bloomfield. Field work during 2005 was carried out with three main objectives: 1) Determine the geographic extent of previously defined morainal units in the Northville quadrangle, 2) Clarify stratigraphic relationships along the western margin of the Detroit quadrangle, i.e., resolve the issue of how to distinguish lacustrine terrace deposits of the Detroit Lowland from morainal units of the Defiance Moraine, and 3) Determine the nature and extent of the Defiance paleochannel. During the 2005 field season, we traced previously defined geologic units in the Northville and Redford quadrangles, into the Walled Lake and Pontiac South quadrangles. The attached maps show that morainal units delineated previously in the Northville quadrangle are mappable entities that extend continuously across the Walled Lake and Pontiac South quadrangles, and into the Birmingham Quadrangle. Hence, they are designated herein as informal stratigraphic units (Fig. 3). Their full geographic extent remains to be determined. It is also clearly established that morainal deposits extend east of the paleoshoreline of glacial Lake Maumee, where they lie directly beneath the surface at many places as far east as the Lake Whittlesey paleoshoreline. The depositional geomorphic surface of the Defiance paleochannel was found to extend into the Pontiac South quadrangle, but is largely eroded away in the eastern Pontiac South and Birmingham quadrangles.

**Table 1. Lithosome classification used in this study.**

<table>
<thead>
<tr>
<th>Map Symbol</th>
<th>Lithosome</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dg</td>
<td>gravelly diamicton</td>
<td>mass flow</td>
</tr>
<tr>
<td>Ds</td>
<td>sandy diamicton</td>
<td>mass flow</td>
</tr>
<tr>
<td>Dsi</td>
<td>silty diamicton</td>
<td>mass flow</td>
</tr>
<tr>
<td>Dc</td>
<td>clayey diamicton</td>
<td>mass flow or till</td>
</tr>
<tr>
<td>G</td>
<td>gravel</td>
<td>fluvial or lacustrine (beach ridge)</td>
</tr>
<tr>
<td>Sg</td>
<td>gravelly sand</td>
<td>fluvial or lacustrine (beach ridge)</td>
</tr>
<tr>
<td>S</td>
<td>sand</td>
<td>fluvial, lacustrine, eolian</td>
</tr>
<tr>
<td>Si</td>
<td>silt</td>
<td>fluvial or eolian</td>
</tr>
<tr>
<td>Csi</td>
<td>silty clay</td>
<td>fluvial or lacustrine</td>
</tr>
<tr>
<td>C</td>
<td>clay</td>
<td>fluvial or lacustrine</td>
</tr>
<tr>
<td>P</td>
<td>peat</td>
<td>lacustrine swamp or bog</td>
</tr>
<tr>
<td>M</td>
<td>marl</td>
<td>lacustrine swamp or bog</td>
</tr>
<tr>
<td>S/Dc, etc.</td>
<td>sand overlying clayey diamicton</td>
<td>stratified sequence</td>
</tr>
<tr>
<td>E</td>
<td>-----</td>
<td>glacial erratic</td>
</tr>
</tbody>
</table>

**STRATIGRAPHY**

Paleozoic Bedrock (Undifferentiated)
The southern part of the map area is underlain by the Upper Devonian Antrim Shale, which is a finely laminated, dark gray or black, bituminous shale containing some interbeds of argillaceous dolomite and limestone, nodules of pyrite and marcasite, and calcareous concretions up to 2 m in size (Sanford, 1967; Mozola, 1969). The western part of the map area is probably underlain by the Upper Devonian-Lower Mississippian Bedford and Berea Formations. The former is characteristically a light gray or sandy shale containing occasional beds of micaceous sandstone, shaley dolomite and limestone. The later is an alternating sequence of light gray or brown, fine grained micaceous sandstone, and gray or blue-gray shale containing some calcareous interlayers (Sanford, 1967). Most of the map area is underlain by the Lower Mississippian Sunbury and Coldwater Formations, which are composed of dark gray to black shale similar in lithology to the Antrim Shale, with some dolomite, sandstone and siltstone interbeds (Mozola, 1969).

Quaternary System
Pleistocene Series
Undifferentiated Subsurface Drift

The Subsurface Drift unit is an undifferentiated deposit of sand and gravel lying unconformably on Paleozoic bedrock that is not known to crop out at the surface. The logs of closely spaced deep test borings along I-96 in the southern part of the Northville quadrangle suggest that the unit extends more or less continuously beneath the western margin of the Detroit Lowland there. However, the unit is typically a series of discontinuous lenticular bodies generally less than 10 ft thick, but ranging up to 25-50 ft in thickness. These deposits extend westward beneath the eastern Defiance Moraine, but their westernmost extent is not known. The Subsurface Drift unit probably correlates

<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Map Symbol</th>
<th>Geologic Unit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quaternary</td>
<td></td>
<td>Qha</td>
<td>Recent Alluvium</td>
<td>Stratified gravel, sand and mud of active stream channels and floodplains. Possibly contains appreciable organic matter. Maximum thickness about 3 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qhw</td>
<td>Recent Lake and Wetland Deposits</td>
<td>Peat, muck and marl in lakes, bogs and river floodplains: n, natural wetlands; a, artificial wetlands. Possibly contains appreciable clastic sediment. Maximum thickness about 20 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpl</td>
<td>Lacustrine Terrace Deposits (Undifferentiated)</td>
<td>Intercalated clayey diamicton with wavy partings, sand and gravel, and rhythmites. Maximum thickness about 10 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpt</td>
<td>Fluvial Terrace Deposits</td>
<td>Stratified gravel and sand underlying older river terraces. Maximum thickness about 2 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpc</td>
<td>Fluvial Paleochannel Deposits</td>
<td>Gravel and sand in outwash channel of morainal upland. May show significant weathering of clasts. Maximum thickness about 10 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpw</td>
<td>Walled Lake Formation</td>
<td>Intercalated clayey diamicton (locally bouldery), sand and gravel, and rhythmites. Maximum thickness about 16 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpu</td>
<td>Novi Till</td>
<td>Unstratified, calcareous, clayey diamicton containing glacially striated and faceted clasts; locally bouldery. Maximum thickness about 12 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpf</td>
<td>Farmington Hills Formation</td>
<td>Intercalated texturally variable diamicton, sand and gravel, and rhythmites; geosol (?) locally at top. Maximum thickness about 37 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpr</td>
<td>River Rouge Till</td>
<td>Unstratified, calcareous, clayey diamicton containing glacially striated and faceted clasts; locally bouldery. Found mainly in subsurface. Maximum thickness about 15-60 m.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Qpu</td>
<td>Subsurface Drift (Undifferentiated)</td>
<td>Stratified sand and gravel overlying irregular bedrock surface. May contain appreciable organic matter. Found only in subsurface. Maximum thickness about 30 m.</td>
</tr>
<tr>
<td>Paleozoic</td>
<td></td>
<td>PZ</td>
<td>Paleozoic Bedrock (Undifferentiated)</td>
<td>Carbonaceous shale and mudrock; quartzose and micaceous sandstone.</td>
</tr>
</tbody>
</table>
Figure 3. Geologic units mapped previously in the Northville Quadrangle and in the map area.

with deposits referred to previously as "pre-Wisconsin drift" (Russell and Leverett, 1915; Leverett and Taylor, 1915; Scherzer, 1916; Stanley, 1936). Such deposits are reportedly found sporadically beneath the Detroit Lowland throughout the metropolitan Detroit area, where they are typically 2-3 m thick, and at least 16 m thick beneath the western part of Livonia (Rogers, 1996). Relatively thick, stratified deposits of subsurface sand and gravel are also reported beneath Plymouth and Farmington (Mozola, 1954; Rogers, 1996). In some places, the deposits contain cobble- and boulder-sized material, and may be cemented by carbonate or iron oxide. Fragments of wood or other plant remains, layers of peat or carbonaceous materials, and oxidized soil-like horizons are reported locally in the uppermost part of this unit (Leverett and Taylor, 1915; Scherzer, 1916; Stanley, 1936; Mozola, 1954).

**Morainal Deposits**

The Defiance Moraine is underlain by a stratified succession of mainly unconsolidated clayey diamicton, sand and gravel, and rhythmite which is grouped here into four newly defined formations of Late Pleistocene age (Fig. 3). The River Rouge Till and Farmington Hills Formation crop out primarily along the eastern flank of the Defiance Moraine. The Novi Till and Walled Lake Formation underlie a relict morainal upland glacial landscape composed of ground moraine and knob-and-kettle topography found over a wide area in southeastern Oakland County. Map units interpreted as till appear to be geographically extensive deposits of unstratified diamicton (> 6 m thick) containing abundant glacially striated and faceted clasts of distant provenance. The Farmington Hills and Walled Lake Formations are strata of ice-contact affinity; i.e. texturally variable sequences composed of relatively thin (< 2 m thick) and laterally discontinuous layers of diamicton, deposited as debris flows, interstratified with lacustrine rhythmite, and alluvial sand and gravel. Clayey diamicton is common throughout the morainal section, hence lower and upper contacts of ice-contact units are delineated arbitrarily at the stratigraphically lowest and highest sand intervals (> 2m in thickness), respectively.

**River Rouge Till.** The name River Rouge Till is introduced here for a relatively thick (15-60 m), unstratified deposit of clay-rich diamicton found primarily in the subsurface lying either on the Subsurface Drift unit, or directly on Paleozoic bedrock. Water well data and geotechnical boring logs suggest that the River Rouge Till is ubiquitous in the subsurface beneath the Detroit Lowland, where it is usually encountered within 10 m depth, and disappears westward beneath the Farmington Hills Formation along the eastern flank of the Defiance Moraine. I have studied several deep excavations in the unit at various locations in the Detroit Lowland. The deposit is uniform in lithology to a depth of 20 m or more, although the lower part locally contains immense blocks of carbonate rock. The upper part of the unit is often exposed along the River Rouge in the northern Redford and southern Pontiac South quadrangles. The best known exposures are the bluffs along the Upper River Rouge at Shiawassee Park in Farmington, although neither the lower nor upper contact is exposed there.

The River Rouge Till consists primarily of unstratified, highly compacted and calcareous, clayey diamicton (Fig. 4) containing gravel-sized clasts of variable size,
shape and lithology that are commonly striated, polished and faceted. It is characterized by a heavy clay matrix that is generally firm to very firm when moist, and hard to extremely hard when dry. This matrix material is light to medium gray, or medium bluish-gray, but it appears yellowish-brown where oxidation has occurred in the vadose zone. The clast suite of the River Rouge Till is a mixed bag of carbonate and clastic sedimentary rocks, together with a wide variety of igneous and metamorphic rocks. Clasts range from well rounded to subangular, and are generally pebble- and cobble-sized, but boulders up to about 1 m in size are relatively common. Glacial striations and facets are found on all types of clasts, but most often on limestone clasts. The upper 3 to 5 m of the unit is often characterized by a steeply dipping, rectilinear set of joints or fractures, along which pedogenic clay and/or carbonate may have accumulated by illuviation. Irregularly shaped bodies of unstratified fine gravel and gravelly sand, and occasionally stratified sand, are sometimes present within the River Rouge Till. These bodies appear to be grossly lenticular, and less than a few meters in thickness. Minor lithologic discontinuities, defined by very slightly oxidized accumulations of granule- and fine pebble-sized clasts, are also present locally.

![Fig. 4. River Rouge till exposed in Shiawasee Park.](image)

**Farmington Hills Formation.** The Farmington Hills Formation is named here for the city of Farmington Hills, which it underlies, in the northern Northville quadrangle. It is a highly variable succession composed of interstratified diamicton, sand and gravel, and rhythmite (Fig. 5). The diamicton lithosome consists of very poorly sorted, massive, laterally discontinuous deposits, 10 cm to 3 m in thickness, composed of gravel, sand, silt and clay in highly variable proportions. Four distinct end members (Dg, Ds, Dsi, Dc) are easily distinguished in the field (see Table 1), although clayey diamicton deposits (in some cases containing little gravel) are most common. The sand and gravel lithosome is occasionally massive or crudely stratified, but it is usually characterized by well-defined horizontal- or cross-stratification. Rhythmite in the Farmington Hills Formation ranges from repetitious sets of ungraded, parallel laminated silty clay, to repetitious cycles of very thin-bedded marl overlain by clay grading inversely upward into silt, sand and fine gravel. Facies changes within the Farmington Hills Formation are abrupt and not mappable. The lower and upper contacts are drawn at the stratigraphically lowest and highest occurrences of sand in contact with the River Rouge and Novi Tills, respectively. The Farmington Hills Formation so defined is about 45 m (135 ft) thick, and underlies the eastern Defiance Moraine at 237-282 m (710-845 ft) elevation. In the Walled Lake quad,
it crops out only along Seeley Drain at 287-297 m (860-890 ft) elevation, but forms an extensive belt about 3 km wide that underlies Franklin and much of the southeastern Pontiac South quadrangle. The unit extends into the Birmingham quadrangle where it crops out in the Bloomfield Hills area. The unit disappears into the subsurface northwestward beneath the Novi Till.

A. Crudely stratified, channelized sand and gravel lithosome.

B. Crudely stratified sand and gravel resembles braided stream sediments

C. Overview of pit at I-275 and 7 Mile Rd: Rhythmite overlying sand and gravel.

D. Trough cross-bedded sand of braided fluvial origin.

E. Foreset bedding in sand unit, resembling Gilbert-type delta, indicates paleoflow toward the southeast.

F. Penecontemporaneous soft-sediment slump structure in lacustrine rhythmite indicates paleoslope dipping toward southeast.

Figure 5. Lithofacies of the Farmington Hills Formation in the Northville quad.
**Novi Till.** The name Novi Till is introduced here for a deposit of unstratified clayey diamicton that underlies much of the Novi area in the northern Northville quadrangle. The Novi Till is lithologically similar to the River Rouge Till and is typically highly compacted with a firm to very hard, heavy clay matrix. The lower part of the Novi Till tends to be very gravelly, with abundant pebble- and cobble-sized clasts. Locally, where boulders are abundant, they are found on the ground surface, or they are unearthed during construction and used extensively in landscaping. The clasts are often striated or faceted, and are mainly various types of carbonate, granitoid, granitoid-gneiss, quartzite, mafic and ultramafic rocks. The largest seen is a boulder of migmatitic granitoid gneiss about 2 m in size. Elsewhere, the diamicton is exceptionally clay-rich, containing only a few scattered fine pebbles or granules and occasionally, irregularly shaped bodies of sand and fine gravel.

The Novi Till underlies much of the gently rolling upland surface that forms the crest of the Defiance Moraine in the Northville quadrangle. It extends northward into the Walled Lake quadrangle where crops out along Seeley Drain and Minnow Pond. In the Pontiac South quadrangle, the unit extends from Farmington Hills to Bloomfield Hills where the contact with the Farmington Hills Formation was exposed in an excavation for a new parking structure at the Cranbrook Institute of Science. The Novi Till extends into the Birmingham quad where it is generally found only east of the Defiance paleochannel. The lower contact of the Novi Till is generally found at about 297 m (845 ft) elevation, although the upper contact appears to be irregular. The Novi Till disappears into the subsurface northwestward beneath the Walled Lake Formation. The unit appears to be about 8 m (25 ft) thick beneath the eastern Defiance Moraine, and may thicken to as much as 13 m (40 ft) farther west. The Novi Till was previously mapped as ground moraine or till plain (Bay, 1938; Bergquist and MacLachlan, 1951; Mozola, 1969).

**Walled Lake Formation.** The Walled Lake Formation is named here for a variable sequence of interstratified diamicton, sand and gravel, and rhythmite that underlies most of the Walled Lake quadrangle. The diamicton lithosome consists of debris flow deposits that are generally clay-rich and yellowish-brown, in massive or wavy bedded layers 30-120 cm in thickness. Intervals of clayey diamicton 2-3 m thick are also present, although these probably represent stacking and amalgamation of many thin debris flow layers. The diamicton deposits are often gravelly, and locally contain boulders up to 1 m in size. The clasts are commonly striated or faceted, and generally similar in lithology to those in the Novi Till. Locally in the upper part of the Walled Lake Formation, debris flow sediments are interstratified with sheet-like deposits of poorly sorted, horizontally stratified or normally graded sandy gravel resembling braided fluvial sediments characteristic of a proximal alluvial fan depositional setting (Bull, 1972; Nilsen, 1984). A conspicuous bed, or series of beds, of reddish-brown, boulder-bearing clayey diamicton is also present in the upper part of the unit. The sand and gravel lithosome is primarily trough cross-bedded sand locally containing poorly sorted, sandy gravel. The rhythmite lithosome includes repetitious sequences of normally graded sand and silt, associated with deposits of massive sand, and repeated inversely graded cycles of very thin bedded marl overlain by clay grading upward into silt, sand and fine gravel.
The Walled Lake Formation is found primarily west of the Defiance paleochannel at about 307-367 m (920-1100 ft) elevation. A knob-like outlier is found east of the paleochannel at 290-297 m (870-890 ft) elevation in the southeastern Walled Lake quad-

![Figure 6. Lithofacies of the Walled Lake Formation: A, Stratified sand and gravel of probable braided fluvial origin; B, Closeup of A; C, Wavy bedforms in gravelly sand; D, Irregularly interstratified massive sand and normally graded rhythmite similar to turbidite deposits; E, Closeup of D; F, Closeup of turbidite (?) deposits.](image)

rangle. Numerous such outliers are present northeast of Bloomfield Hills in the Birmingham quadrangle. The Walled Lake Formation lies directly beneath a striking and extensive landscape of knob-and-kettle topography. It appears to encompass all of the northern Walled Lake and Pontiac South quadrangles, where it is probably related to the
Commerce Outwash plain of Lanney (1977). The unit is estimated to be 30-50 ft in thickness. However, exposures at a construction site showed that the contact between the Novi Till and Walled Lake Formation is undulating or highly irregular because of collapse and tilting associated with knob-and-kettle formation. The lower contact is mapped somewhat arbitrarily at about 307 m (920 ft) elevation throughout the Walled Lake and western Pontiac South quadrangles, but lies at 290-297 m (870-890 ft) elevation over the remainder of the Pontiac South quad, and in the Birmingham quadrangle. The Walled Lake Formation was previously mapped as kame deposits or undifferentiated moraine (Bay, 1938; Bergquist and MacLachlan, 1951; Mozola, 1969).

**Fluvial Paleochannel Deposits**

Deposits of moderately to well-sorted, crudely stratified, normally graded or cross-stratified sand and gravel, underlying depositional geomorphic surfaces of the Defiance paleochannel, make up the Fluvial Paleochannel map unit. The sediments, which resemble those of braided fluvial origin described elsewhere (Miall, 1974), were well exposed in an excavation near 15 Mile and Franklin Roads during the 2005 field season. The gravelly lithosome contains moderately to well-rounded, pebble- and cobble-sized clasts generally similar in lithology to those found in the morainal deposits. Fluvial Paleochannel deposits is found directly beneath the floor of the Defiance paleochannel where it is up to 8 m in thickness. The Defiance paleochannel is a long, narrow topographic depression in the Defiance Moraine that trends N30-40°E in the Northville quadrangle, but the channel bends eastward across the southwestern Pontiac South quadrangle before resuming a more northeasterly trend near Bloomfield Hills. The margins of the channel are remarkably straight and usually defined by a well-defined break in slope in the Northville quad, but the channel margins are poorly defined in the Walled Lake and Pontiac South quadrangles. The depositional surface of the Paleochannel unit appears to be relatively intact in the southwestern Pontiac South quadrangle, but it is deeply dissected by Franklin Branch and eroded away in the eastern Pontiac South and Birmingham quadrangles. The channel varies from 0.5 to 1.0 km in width, being narrowest in the northeastern part of the map area.

Where it is well preserved and well drained, the Fluvial Paleochannel unit is characterized by a conspicuous soil profile with a reddish B-horizon mapped as the Boyer Series (Fig. 7). The typical soil profile is approximately 1 m thick with a reddish-brown (5YR4/4), strong brown (7.5YR4/6), or dark brown (7.5YR4/4) B2-horizon with little if any structural development. The lower boundary of the B-horizon is irregular with accumulations of illuvial clay extending into the C-horizon. The soil is formed from gravelly sand containing a mixed suite of igneous, metamorphic and sedimentary clasts similar to those in the morainal sequence. Clasts of argillite and limestone show significant weathering in the C-horizon.

**Fluvial Terrace Deposits**

The Fluvial Terrace unit previously mapped along the Middle River Rouge in the Northville quadrangle is not found in Walled Lake or Pontiac South quadrangles.
Lacustrine Terrace Deposits (Undifferentiated)

This unit is a variable assemblage of sand and gravel, clayey diamicton, and minor argillaceous rhythmitite that underlies various depositional geomorphic surfaces composing lacustrine terraces of the Detroit Lowland. These landforms are often underlain directly by the sand and gravel lithosome which is typically less than 2-3 m, and locally no more than 10 m, in thickness. The sand and gravel lithosome is usually characterized by well-defined horizontal- or cross-stratification, and locally underlain by very thin (< 0.5 m thick) deposits of rhythmically laminated silt and clay. These deposits generally overlie the diamicton lithosome which forms a blanket as much as 6 m thick on the underlying River Rouge Till. The diamicton lithosome is clay-rich and lithologically similar to the underlying River Rouge Till, but it contains fewer and smaller gravel-sized clasts of variable types of carbonate, plutonic and metasedimentary rocks. It is considered to be part of the lacustrine plain assemblage because it interfingers with lacustrine sand and gravel, and is locally separated from the underlying till by discontinuous bodies of highly deformed, massive or wavy bedded sand. Clayey diamicton in the lacustrine assemblage is usually characterized by wavy partings and thin wavy stringers of light colored silt, and locally by well-defined lamination, or a breccia-like fabric composed of augen-shaped argillaceous clasts in thin wavy bands.
| A. Pit at Schoolcraft and Haggerty provides cross section through crest of paleolake Whittlesey beach ridge. |
| B. Wavy and lenticular bedding indicating deposition by traction, i.e. by lacustrine wave activity. |
| C. Load casts; resembles "involution structure" possibly indicative of periglacial conditions. |
| D. Ball-and-pillow structure. |
| E. Involution structure (?). |
| F. Close-up showing clay layer that foundered into underlying presumably water-saturated sand. |

Figure 8. Lacustrine terrace deposits composing the Lake Whittlesey beach ridge.
The Lacustrine Terrace unit is found throughout the Detroit Lowland in the metropolitan Detroit area. It has been observed in numerous excavations extending from the Northville quadrangle eastward to the Warren quadrangle, and from the Birmingham quadrangle southward to the Belleville quadrangle. The typical section consists of a subsurface deposit of wavy-bedded clayey diamicton (resting disconformably on the River Rouge Till), grading upward into about 1 m of massive sand, overlain by a surficial deposit of stratified sand and gravel. However, closely spaced shallow test borings show that either clayey diamicton or sand and gravel lithosomes may be found directly beneath the land surface, apparently in a random and unpredictable pattern. Field observations show that even with minimal winnowing, clayey diamicton yields a significant volume of sand (and/or gravel) as a result of selective sorting. Hence, the sand and gravel lithosome was probably formed partly or largely through reworking of the underlying clayey diamicton lithosome by lacustrine wave activity, in which case the irregular distribution of lacustrine sand is attributable to geographic variations in the intensity of this sedimentary process. Locally, the complex map pattern is probably the result of interstratification of sand and gravel with clayey diamicton, and lateral gradation from one facies to the other. Elsewhere, erosion by lacustrine wave activity, stream dissection, mass wasting or eolian action has removed the surficial sand and gravel deposit, thereby exposing the underlying clayey diamicton facies. These relationships account for the complex pattern of surficial sand and clay shown on previous geologic maps (Scherzer, 1916; Mozola, 1969; Farrand and Bell, 1982), although much, if not all, of what was previously delineated simply as "clay" in the map area is determined to be clayey diamicton of probable lacustrine origin.

Theoretically, the Lacustrine Terrace unit could be mapped as four distinct subunits in the study area, corresponding to sediments deposited in various glacial lakes (e.g. Maumee, Whittlesey, etc.). However, the Lacustrine Terrace unit is undifferentiated in the erosional terrain of the Detroit Lowland west of the paleoshoreline of Lake Warren because it is not always possible to distinguish between sediments deposited in post-morainal glacial lakes, and lithologically similar ice-contact deposits of the morainal sequence. East of the paleoshoreline of Lake Warren, surficial sediments deposited in glacial Lakes Warren, Wayne and Grassmere lie beneath depositional surfaces that can be distinguished somewhat on the basis of elevation, or by cross-cutting relationships where they are exposed by erosion along wave-cut paleoshorelines. However, Lacustrine Terrace deposits are undifferentiated in the subsurface beneath lakebed plains where older lake sediments may be disconformably overlapped by younger ones without any visible evidence of erosion. Lacustrine Terrace deposits are also undifferentiated along constructional shorelines, where beach ridge deposits of a younger lake sequence overlap onto older lake deposits, and have been reworked by eolian activity to an unknown extent. The Lacustrine Terrace unit was previously mapped as lacustrine or deltaic clay and sand (Leverett and Taylor, 1915; Scherzer, 1916; Bay, 1938; Bergquist and MacLachlan, 1951; Mozola, 1969; Farrand and Bell, 1982). The clayey diamicton lithosome correlates with the upper clay unit of Roger (1996), and apparently corresponds to areas mapped as water-laid moraine by early investigators (e.g. Leverett and Taylor, 1915)

**Holocene Series**

**Recent Lake and Wetland Deposits**
The Recent Lake and Wetlands unit consists of elatic, chemical and organic sediments associated with natural and artificial lakes and wetlands. This unit is often characterized by a surficial deposit of peat or muck, underlain by marl, resting on gravel, sand or mud. The peat deposits appear to be composed mainly of fragmental woody or charcoal-like organic material derived from partially decomposed trees, shrubs and various hydrophytic plants. The marl facies is composed of lime mud or calcareous clastic sediments containing abundant shells of freshwater gastropods and pelecypods, generally less than 1 or 2 mm, but ranging up to 1.5 cm, in size. The Recent Lake and Wetlands unit ranges in thickness from less than 10 m, to 20 m or more.

Natural lakes and wetlands in the map area are typically found on impermeable deposits of clayey diamicton. They are common on the Novi Till, but are best developed on the Walled Lake Formation in association with a relict deranged drainage pattern of

Figure 9. Suburban development encroaching on a typical bog-type wetland in the Walled Lake quadrangle. Note telephone pole for scale.
Figure 10. Typical wetland-fringed kettle lake in the Pontiac South quadrangle.

glacial origin. The Rouge and Clinton Rivers have eroded headward such that they are capturing this relict drainage. Hence, their headwaters are often associated with chains of lakes and wetlands. Natural wetlands are stream- or spring-fed, and include perennial and ephemeral elements. Perennial wetlands are characterized by permanent, swampy lakes and ponds (or bogs with a continuously high water table); a diverse fauna and flora including various hydrophytic plants; and organic hydric soils such as the Houghton and Edwards Series composed of muck (sapric material) derived from mixed woody and fibrous organic matter. Perennial wetlands are found in both fluvial and lacustrine settings. Fluvial wetlands are located along floodplains and in spring-fed headwaters. Lacustrine wetlands are either bogs (Fig. 9), or swamp-fringed lakes and ponds (Fig. 10). Ephemeral wetlands are characterized by intermittent periods of standing water or a seasonally high water table; predominantly non-hydrophytic vegetation; and hydric mineral soils with an aquic moisture regime (Haplaqualf and Haplaquoll). Ephemeral wetlands are typically found in the headwaters of smaller tributaries of the River Rouge, in drainageways marginal to perennial wetlands, and anywhere in the map area that rainwater is temporarily ponded on impermeable earth materials.

Artificial wetlands are scattered throughout the map area, but are most common in urbanized areas around Novi, Farmington Hills, Southfield, Bloomfield Hills and Birmingham. They are usually orthogonal in plan, small (less than 100-200 ft in length and width), constructed from fill derived from clayey diamicton, and occupied by cattails and a few other hydrophytic plant species. Small, artificial lakes are also scattered throughout the map area.

The map area is part of a vast terrain of wetlands in Michigan developed primarily on Late Pleistocene morainal uplands. Wetlands occur in depressions usually containing lakes and ponds that undergo progressive infilling by clastic, chemical and organic sediment (Veatch, 1953). Marl is primarily biogenic and deposited beneath bodies of
standing water. It is partly of algal origin, but calcareous skeletal materials derived from freshwater gastropods, pelecypods and ostracods are common components (Pollock, 1918; Wetzel, 1960; Jones and Wilkinson, 1978). Peat is formed in bogs and lake-margin swamps, and varies in composition from fibrous to fragmental and woody depending on the nature of associated vegetation (Veatch, 1953). A stratigraphic sequence grading upward from outwash to marl and then peat, is commonly developed in Michigan wetlands as they fill with sediment over time (Murphy and Wilkinson, 1980).

**Recent Alluvial Deposits**

This map unit consists of stratified deposits of gravel, sand and mud underlying active floodplains of the River Rouge and its tributaries. This unit is characterized by upward-fining sequences composed of horizontally- and cross-stratified gravely sand and sand, overlain by parallel-laminated silt and clay. These sediments often contain scattered shells of freshwater gastropods and pelecypods, usually only a few millimeters in size, and may contain significant organic matter in swampy areas. Pleistocene deposits of clayey diamicton are occasionally exposed along streambanks in the study area, locally even along the cut-banks of some of the wider floodplains, suggesting that the Recent Alluvium unit is generally less than 1 to 2 m thick. Lag gravel, in some places with boulders up to 1 m in diameter, often litters the streambed where it is cut into clayey diamicton of the morainal sequence.

The present floodplains of the River Rouge are generally occupied by a youthful cover of hydrophytic tree species such as willow, cottonwood and elm, along with dense underbrush. Severe historic flooding is indicated locally by barren, or sparsely vegetated, sand and gravel bars on floodplains littered with trash and other human artifacts of recent origin. Enormous masses of cement building materials, perhaps derived from bridges destroyed by catastrophic flooding, were observed in a few areas. Historic records suggest that flooding is generally confined between the sharply defined valley walls bounding floodplains of the River Rouge. The largest recorded flood occurred April 4-5, 1947 when as much as 3.7 in of rain fell on frozen ground (Knutilla, 1970). Severe flooding was reported on Tarabusi Creek, Bell Branch and the Middle and Upper River Rouge; the flood peaked at 23 ft along the Middle Rouge River at Plymouth Road. Other severe floods occurred March 24-25, 1954, and in June 25-27, 1968 when the flood peaked at 21.7 ft (USACOE, 1972; Great Lakes Basin Commission, 1987).

**DISCUSSION**

The results of our mapping suggest that the Ft. Wayne-Defiance Moraine, and perhaps other glacial landforms, in southeastern Michigan are composed of geologic units that can be mapped at 1:24,000 scale. This is significant because previous mapping has been based almost entirely on geomorphic expression, and the general perception is that the morainal deposits are too variable to map. The Walled Lake Formation, lying directly beneath a relict glacial landscape of knob-and-kettle topography, clearly represents the last glacial depositional event marking the final retreat of the ice sheet in Late Pleistocene time. It thus appears that two depositional cycles of glacial advance and retreat are represented by the morainal section. The presence of two till units in the morainal section, seems to support previous interpretations (e.g. Flint, 1971) that the Defiance is a composite or overridden moraine. However, there is no age control on any of the morainal units studied. The results of our mapping suggest that Stanley (1936) misinterpreted the Novi Till exposed along the Grand Trunk Western Railroad near
Birmingham as “Illinoian till.” Further mapping is needed to test Stanley’s hypothesis that the landscapes east of Cass Lake, and in the Union Lake area, are former lakebeds.

Several intriguing landforms are present in the Birmingham quadrangle. For example, Leverett and Taylor (1915) recognized the anomalous eastward swerve in the trends of paleoshorelines (particularly that of Lake Whittlesey at ~ 725 ft. elevation) shown on the attached map of the Birmingham quadrangle. All but the Lake Maumee shoreline are bent, thus forming a nested series of southeast verging bulges which trend along the axis of a broad, low-lying swell they referred to as the Detroit Interlobate Moraine. Our mapping shows that the trend of the Defiance paleochannel is also curiously deflected eastward, but the origin and significance of these landforms are uncertain. A better understanding of the Birmingham quadrangle is identified as critical for understanding the geologic history of this region. In particular, it is important to delineate the geographic extent of the Farmington Hills Formation and determine its stratigraphic relationship to various landforms.

BIBLIOGRAPHY


Bay, J. W., 1938, Glacial history of the streams of southeastern Michigan: Cranbrook Institute of Science Bulletin 12, 68 p. (map scale: ~1:200,000)


Fullerton, D. S., 1980, Preliminary correlation of post-Erie interstadial events (16,000-10,000 radiocarbon years before present), central and eastern Great Lakes region, and Hudson, Champlain, and St. Lawrence lowlands, United States and Canada: U. S. Geological Survey Prof. Paper 1089, 52 p.


King, P. B., and Beikman, H. M., 1974, Explanatory text to accompany the geologic map of the United States. U. S. Geological Survey Professional Paper 901, 40 pp. (scale: 2,500,000)


Rogers, D. T., 1996, Environmental geology of metropolitan Detroit: Clayton Environmental Consultants, Detroit, Michigan, 122 p. (map scale, 1:76,000)


