

TECHNICAL REPORT

**Surficial Geology of the South ½ Decatur and South ½ Marcellus 7.5 Minute
Quadrangles, Cass and St. Joseph Counties, Michigan;**

Award No. #G 16AC00377



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Abstract

Surficial geologic mapping of the south halves of the Decatur and Marcellus 7.5 Minute Quadrangles, located in Cass and St. Joseph Counties, Michigan were completed by the Michigan Geological Survey. The map area is located in complex interlobate deposits of the Lake Michigan and Saginaw Lobes of the Laurentide Ice Sheet.

Major glacial geological features mapped in the quads include the outer Kalamazoo Moraine complex, the western end of the Sturgis Moraine of the Saginaw Lobe, large outwash fans, tunnel valleys, numerous ice-walled lake plains and eskers. The bedrock topography and drift thickness were also mapped due to the thick glacial drift and limited bedrock well control. A prominent bedrock valley was mapped, which is significant because even in a prolific drift aquifer system with significant high capacity irrigation, in most places only the upper half or less of the glacial deposits been characterized or are being used for aquifers. The large fans, ice-walled lake plains, eskers and bedrock valleys were not previously mapped.

Recommended Citations

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Acknowledgements

The following people greatly assisted in this project: Randy Cuthbert, DEQ-WRD and SW Michigan Farmers - Cass County Pilot Study (DEQ-WRD staff and Tritium, Inc. Consultants).

Technical Report

Figures

South ½ Decatur and South 1/2 Marcellus Quadrangles

- Figure 1: Topographic Quadrangles, South ½ Decatur and South 1/2 Marcellus
- Figure 2: LiDAR Elevation with shaded relief
- Figure 3: Generalized Geologic Map, South ½ Decatur and South ½ Marcellus, Cass and St. Joseph Counties, Michigan
- Figure 4: Diamicton, Ice Wall Lake Plains and Glacio-lacustrine deposits (Qdu, Qds, Qdlm, Qiw, Ql)
- Figure 5: Sand Dunes, Esker and Gravel Pits
- Figure 6: Peats, Muck-Wetlands and Watershed Boundaries
- Figure 7: Cross Section, Southwest to Northeast, Decatur and Marcellus
- Figure 8: Regional Water Table
- Figure 9: Wireline Core Log and Sieve Analysis (CAS-17-02)
- Figure 10: Drift Thickness, Decatur, Marcellus, Vandalia, Jones
- Figure 11: Bedrock Topography, Decatur, Marcellus, Vandalia, Jones
- Figure 12: Regional Surficial Geology (MGS Five Quadrangles mapped 2015-2017 and published 2017)
- Figure 13: Regional Quaternary Geology (Farrand, 1982)-Comparison with 2017-new mapping products

Introduction

In October 2011, the Michigan State Legislature transferred responsibility for applied geological research and geological mapping within the state to the Michigan Geological Survey (MGS), which was created by this act within the Geosciences Dept. at Western Michigan University. The Geological Survey Division of the Michigan Dept. of Environmental Quality (MDEQ), which previously conducted geologic mapping, was renamed the Office of Oil, Gas, and Minerals.

These quadrangles were chosen as part of a larger project initiated by MGS in Cass County under the USGS National Cooperative Geologic Mapping Program (NCGMP) having an additional mapping program, the USGS Great Lakes Geologic Mapping Coalition, composed of eight Great Lakes state geological surveys and USGS.

Location and Geologic Setting

The Decatur and Marcellus Quadrangles, which were mapped as part of the larger Cass County project area, are underlain by unconsolidated deposits of glacial and post-glacial origin from the Saginaw and Lake Michigan Lobes (Leverett and Taylor 1915) of the Laurentide Ice Sheet. Kehew et al. (2012) describe the regional sediment-landform associations of the Saginaw Lobe and Kehew et al. (2005) discuss the dynamics of the Lake Michigan Lobe. The sediments include diamicton (till), sand and gravel and interbedded silt and clay. Till is a characteristic type of glacial deposit that is unsorted and has a range of grain sizes from clay to boulders. The glacial deposits are late Wisconsinan (~30,000 to ~15,000 yrs. before present) in age, although some deeply buried deposits may be Illinoian or older (Winters and Rieck 1982). The glacial geology in the Decatur quad and the Marcellus quad to the east shows very complex interactions between the Saginaw Lobe and the Lake Michigan Lobe. A likely interlobate area occurs within these quads as well as evidence for the different lobes advancing and depositing sediment over buried ice from a different lobe.

Purpose and Justification

The mission of the Great Lakes Geologic Mapping Coalition (GLGMC) includes mapping the surficial geology in the high priority areas of the coalition states. This project is within one of the Michigan high priority areas. This task fulfills the mapping priorities of the GLGMC by providing these previously unavailable detailed surficial geologic map products to the public within these priority areas and it will deliver scientific information in formats readily usable by public policymakers. It also supports sustainable development of resources and understanding of environmental issues. Cass County includes portions of the Kalamazoo Moraine of the Lake Michigan Lobe in the western part of the county transitioning to the east into Saginaw Lobe terrain. Detailed mapping has never been done in this area. This project will also contribute to the effort to develop a Quaternary Stratigraphic framework for the Lake Michigan and Saginaw Lobes.

Cass County lies just south and east of I-94, the major interstate connecting Chicago and Detroit. This project fits well with Michigan's long-range plan of mapping around development corridors and to consolidate areas where mapping has already been done. Berrien County to the west has been mapped by the U.S.G.S. and St. Joseph and Van Buren Counties to the east and north, respectively, have been mapped by the Michigan Geological Survey.

One of the most pressing and significant scientific problems in Michigan is management of groundwater resources using the Michigan Water Withdrawal Assessment Tool (MI-WWAT). Every new high capacity well (>70 gal per min) must be permitted using this tool, which is based on modeling of stream flow response from water withdrawals from aquifers connected to streams and aquatic ecosystems. Wells that are predicted to produce an adverse response by the tool then must proceed to and pass the site specific review (SSR) process, in which owners must submit site specific drilling and hydrogeologic data. For areas utilizing aquifers in glacial deposits, the SSR currently uses the statewide 1982 Quaternary geology map, which is highly generalized and outdated. Detailed surficial geologic maps and more accurate subsurface data (relative to water well logs which are currently used) are urgently needed. These maps make a huge contribution to the accuracy of the MI-WWAT process in defining the geologic units where they are available. Cass County is located in the southwest part of the state, in which the demand for new irrigation wells is the highest in the state.

There are several objectives to this project in sequential order, namely:

- To produce surficial geological maps in a high priority area having complex geology with little available public domain surficial and subsurface geological data.
- Make these maps available to the geological community, groundwater management staff of MDEQ, engineering firms, aggregate industry, water supply industry, researchers, teachers, and to the public.
- To complete the detailed mapping in Cass County.
- To map the interlobate area between the Lake Michigan and Saginaw Lobes. New subsurface data will be used for correlation with deep boreholes in Saginaw Lobe deposits in Barry County to the northeast and in Van Buren, Kalamazoo and St. Joseph Counties to the north and east, respectively. The Lake Michigan Lobe portion of the county will be correlated with borings in Van Buren County to the north. The ultimate goal is to develop a regional stratigraphic framework for the Wisconsin deposits of both lobes, which can be tested against future borings.
- To delineate the occurrence and stratigraphy of aquifers and sand and gravel deposits, the abundance of which are not known in these quadrangles. This project will provide support for the proposed aquifer study and modeling project being implemented by a coalition composed of MDEQ and private entities (Southwest Michigan Farmers and agricultural industry), Cass County Pilot Study (CCPS).

Methods and Personnel

Surficial geologic maps are produced by field investigation of surficial materials observed in natural exposures, road and stream cuts, building and construction excavations, shallow hand-augered borings, and small pits dug by the investigators. Depth of investigation is generally around 6 feet except in areas of greater exposure like deep cuts and gravel pits. In addition, aerial photographs, topographic maps, digital elevation models (DEMs), county soil surveys, existing geologic maps, reports, and the geologic literature for the area are reviewed. Farmers often provided valuable insight into the soils in the area. LiDAR data, which include high-resolution elevations of the land surface, were available for Cass County and were used to create DEMs. The LiDAR data was a critical tool to allow interpreting the subtle features like the ice-walled lakes, eskers, sand dunes, terraces and structural or depositional features. Without the LiDAR data many of these features would not have been recognized using USGS DEM data at 10' accuracy. Subsurface information concerning the thickness, extent, and stratigraphic position of surficial geologic units was obtained to the extent possible by reviewing and validating digital well log data from the MDEQ Wellogic and historical scanned water-well log databases.

Test borings using the rotary wireline coring methods were drilled as part of this mapping project and are plotted on the maps. Cores and samples were sieved and the remnants are archived at the Michigan Geological Repository for Research and Education (MGRRE) facility at the Michigan Geological Survey. These borings are essential to an understanding of the subsurface geology of the glacial deposits. Gamma-ray logs are made of the borehole at the time of drilling. This method involves measurement of the natural gamma ray content of surficial materials detected as a probe is lowered down and up the borehole within the drill pipe. Clays and other fine-grained materials emit more gamma radiation than sands and gravels and the gamma ray log is compared to the cores for interpretation of the contacts between different types of strata. Geologic cross-sections are created from the validated digital water well data and a representative cross-section is shown on each map product. For mapping projects in areas of thick glacial drift, logs from oil and gas test wells are reviewed to confirm depth to bedrock. Due to the limited number of bedrock control points in the quad, a Tromino passive seismic instrument was used. This technique uses the horizontal -to-vertical spectral ratio (HVSR) method to record ambient seismic noise with 3-component geophones (Lane, et al., 2008). A total of 77 locations in this map area (34 Oil and Gas wells and 43 HVSR) and incorporated the southern two quadrangles (Vandalia and Jones) using a total of 198 locations to compile the depth to bedrock and the bedrock topography. This data compilation indicates a series of two bedrock valleys trending N-S in this area of the County, which may represent a pre-glacial valley.

Primary field mapping of the Decatur and Marcellus Quads was done by John Esch (contract mapper) and Alan Kehew with support from John Yellich.

MAP PREPARATION PROCEDURES

Surficial geologic maps are produced by the field investigation of surficial materials observed in natural exposures, road and stream cuts, building and construction excavations, shallow hand-augered borings, and small pits dug by the investigators and the other field and data compilations as described above. A test boring using the rotary, wireline coring method was drilled as part of this mapping project and is plotted on the map. Cores and samples were sieved and the remnants are archived at the Michigan Geological Repository for Research and Education (MGRRE) facility at the Michigan Geological Survey. These borings are essential to an understanding of the subsurface glacial deposits. Gamma Ray logs are made of the borehole at the time of drilling. Geologic cross-sections are created from the digital water well data and a representative cross-section is shown on the map. A drilled bore hole was gamma-ray logged and was for the DEQ Cass County Pilot Study (CCPS). This bore hole was used in the analysis (CCPS-DMEF) and inserted into the cross-section. For mapping projects in areas of thick glacial drift, logs from oil and gas test well are reviewed. Due to the limited number of oil and gas test well bedrock control points (34) in the map area, a Tromino passive seismic instrument was used at 43 locations to fill in the gaps in determining the depth to bedrock and the bedrock topography and drift thickness. Tromino Passive Seismic data points were collected in the Marcellus and Decatur quads and the data is contoured for four quadrangles, which include Vandalia and Jones using a total of 198 data points. This data compilation indicates a series of two bedrock valleys trending N-S in this northeast area of Cass County, which may represent a pre-glacial valley.

Results: Decatur (South ½) and Marcellus (South ½) 7.5 Minute Quadrangles

The portion of the Decatur and Marcellus Quadrangles that lies within Cass County, which was mapped as part of the larger Cass County project area, is underlain by unconsolidated deposits of glacial and post-glacial origin from the Saginaw and Lake Michigan Lobes (Leverett and Taylor 1915) of the Laurentide Ice Sheet. Kehew et al. (2012) describe the regional sediment-landform associations of the Saginaw Lobe and Kehew et al. (2005) discuss the dynamics of the Lake Michigan Lobe. The sediments include diamicton (till), sand and gravel, and interbedded silt and clay. Till is a characteristic type of glacial deposit that is unsorted and has a range of grain sizes from clay to boulders. Cass County lies in an interlobate area and the diamicton could be of either the Lake Michigan Lobe or Saginaw Lobe origin. The relief of the area is high and it is likely that stagnant, debris-covered ice persisted in the quad after the active margin of the glaciers retreated. The diamicton is not uniform in thickness and does not cover the entire area. The lithology of CAS-17-02 (TD 298' 92 m) drill/core hole, in the southwest part of the Decatur Quadrangle, consists of a thick surficial sand and gravel unit to 95 feet. It is underlain by a diamicton, and then another sand and gravel unit below. A borehole that was drilled for the DEQ Cass County Pilot Study (CCPS) was used in the analysis (DDPS-DEF). The glacial deposits are late Wisconsinan (~30,000 to ~15,000 yr before present) in age, although some deeply buried deposits may be middle Wisconsinan or older (Winters and Rieck, 1982). The

total thickness of glacial deposits typically ranges between 50 and 500 ft (15-150 m) in the area of Cass County.

The most prominent glacial landform in the Marcellus Quadrangle is the large sand and gravel outwash fan (Qf) in the center of the quad. This fan was deposited by meltwater streams emanating from the Lake Michigan Lobe flowing southward from a gap in the Kalamazoo Moraine west of Schoolcraft in Kalamazoo County. Another much smaller fan occurs in the Decatur Quad. The areas of outwash mapped as Qsg2 are irregular sand and gravel deposits that lack a distinct fan shape. They are also very hummocky (non-oriented hills and depressions), which suggests that they were deposited on discontinuous masses of stagnant ice which melted out and collapsed to form the high relief depressions that are adjacent to hummocks that were underlain by less buried ice. Surficial diamicton (Qdu) occurs in several parts of the quad. The "u" modifier refers to undifferentiated, because the specific lobe that deposited the diamicton is not known. These deposits occur on the east side and middle of the mapped area that are topographically higher than the fan sediments. Qds in the SE part of the map is diamicton interpreted to be from the Saginaw Lobe. Qdlm in the NE part of the map is diamicton and abundant bedded sand and gravel from the Lake Michigan Lobe.

Several ice-walled lake plains (Qiw) are mapped in the quad. Generally flat topped, these landforms represent the formation of a short-lived lake that existed while stagnant and partially buried glacial ice was still in the area. Stagnant ice masses formed the boundary of the lake and left the flat-topped lake deposits of sand to clay size material in a relatively high position on the landscape. A large southwest trending and broadly sloping outwash surface occurs within the Decatur quad. Sand dunes (Qsd) occur in the southwest corner of the side of the map.

The exact ages of the glacial deposits have not been determined in this map area but are correlated to dated features elsewhere. Some recent optically stimulated luminescence (OSL) dates obtained from the Vandalia Quad to the south suggest that the Kalamazoo Moraine of the Lake Michigan Lobe was probably formed by re-advance of the Lake Michigan Lobe about 19,000 years ago (Kehew and Esch, unpublished). Mapping in other parts of southwestern Michigan (Kehew et al. 1999, 2005, 2013) and most recent mapping data indicate that the Saginaw and Lake Michigan Lobes were not synchronous in the timing of their advances and retreats, which explains why deposits of both lobes are present and intertwined in these quads.

Other map units include a small kame (Qk), which is an isolated hill of sand and gravel deposited in a hole in the stagnant glacier, some flat lying lacustrine (lake, Ql) sediment likely deposited very soon after ice retreat and peat and muck of postglacial age (Qp) found in depressions on the landscape associated with a high water table.

The Mississippian Coldwater Shale is the bedrock subcrop formation underlying the Decatur and Marcellus quads. The bedrock surface ranges from 400 feet to 660 feet above mean sea level (amsl) within these ½ quads. A pronounced buried bedrock valleys runs S to N through the southern ½ of the Decatur Quad and another buried bedrock valley run runs SSE to NNW

through the southern ½ of the Marcellus quad. These bedrock valleys are extensions of deep bedrock valleys that run SE-NW across Van Buren County to the north. The glacial deposits in the southern half of the Decatur and Marcellus Quads range from 230 to 490 feet thick with the thicker drift overlying the bedrock valleys. The orientation of these bedrock features might suggest a different formational age, possibly a pre-glacial drainage.

Scattered sand and gravel mining operations occur within the quads. Most of the gravel pits are associated with outwash, Qdu, or Qdlm, especially along the northern high relief side. Significant additional sand and gravel deposits may potentially occur in these deposits and in the newly mapped esker (Qe) along the south boundary.

The northwest corner of the mapped area is within the Dowagiac River watershed. The Dowagiac Creek watershed occurs to the northwest and the Rocky River watershed occurs in the southeast part of these two quads.

All the water wells in the quad are screened in glacial drift aquifers. The average depth of water wells in the quad is 82 feet and average water table depth is 28 feet. Most of the land use within the quad is for agriculture having associated irrigation prevalent across the quad having high capacity irrigations wells.

USES OF SURFICIAL GEOLOGY MAPS

A surficial geology map shows the geological materials such as diamicton or till (sometimes called hardpan), sand and gravel, or clay found within 5-6 feet of the ground surface. In many cases these surface units extend to much greater depths but in others the materials change with depth. The map shows the areal distribution of the different types of glacial deposits and landforms as described in the map explanation. Features such as moraines can be used to reconstruct the movement and position of the glacier and its margin, especially as the ice sheet melted. Other ancient features include shorelines and deposits of glacial lakes, now long gone from the state. This glacial geologic history of the quadrangle is useful to the larger understanding of past earth climates, and how our region of the world underwent recent geologically significant climatic and environmental changes. We may then be able to use this knowledge in anticipation of similar changes for long-term planning efforts in the future, such as land use planning or waste disposal.

Surficial geology maps can assist anyone wanting to know what lies at and just beneath the land surface. For example, these maps may aid in the search for water supplies, or economically important deposits such as sand and gravel for aggregate or clay for bricks or clay tile.

Test borehole CAS-17-02 (See Figure 8 below) located on the westside of the Decatur quad, showed the presence at the surface of nearly 95 feet of sand and gravel to a confined aquifer below, which is used locally for irrigation, divided by a diamicton in this area. Additional borings would be needed to delineate the extent and distribution of this aquifer. The maps, along with water-well logs can provide an indication as to whether an aquifer at depth is

connected to a surface stream. This information is critically important in assessing whether or not a water well near a stream could cause an excessive depletion or adverse impact to surface water. Foundation conditions determined by the surficial geological materials are critical inputs to any type of development. Environmental issues such as the location of a suitable landfill site or the possible spread of near surface contaminants are directly related to surficial geology. Construction projects such as locating new roads, excavating foundations, or siting new homes may be better planned with a good knowledge of the surficial geology of the site. Once a surficial geologic map is constructed, it can be used for a variety of derivative maps, such as aquifer thickness and extent, range of transmissivity values, sensitivity to surface and near surface derived contaminants and reserves of sand and gravel.

Conclusions

Mapping of the south halves of the Decatur and Marcellus 7.5 and minute quadrangles has provided new, detailed information on surficial landforms and deposits within the Lake Michigan and Saginaw Lobes in southern Michigan. This mapping project is part of a larger project to map Cass County. The maps produced in this project will be of use to aggregates producers exploring for new deposits, planners, and hydrogeologists in MDEQ who must evaluate permits for high-capacity water wells that now require a permit and must be shown to not deplete streams in the area beyond an amount that will not affect fish populations.

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Technical Report

Figures

Decatur and Marcellus mapping project

Topographic Maps

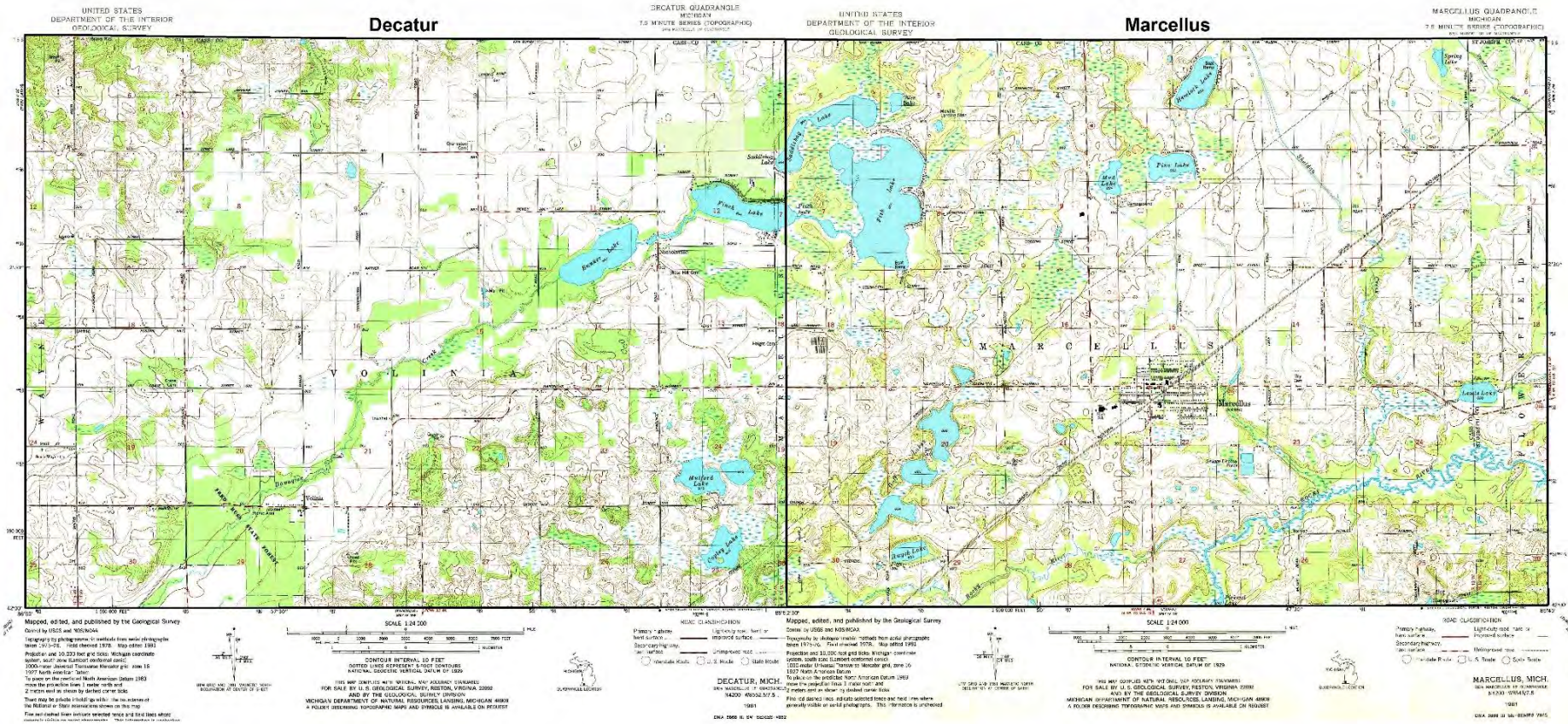


Figure 1: Topographic Quadrangles, South 1/2 Decatur and South 1/2 Marcellus

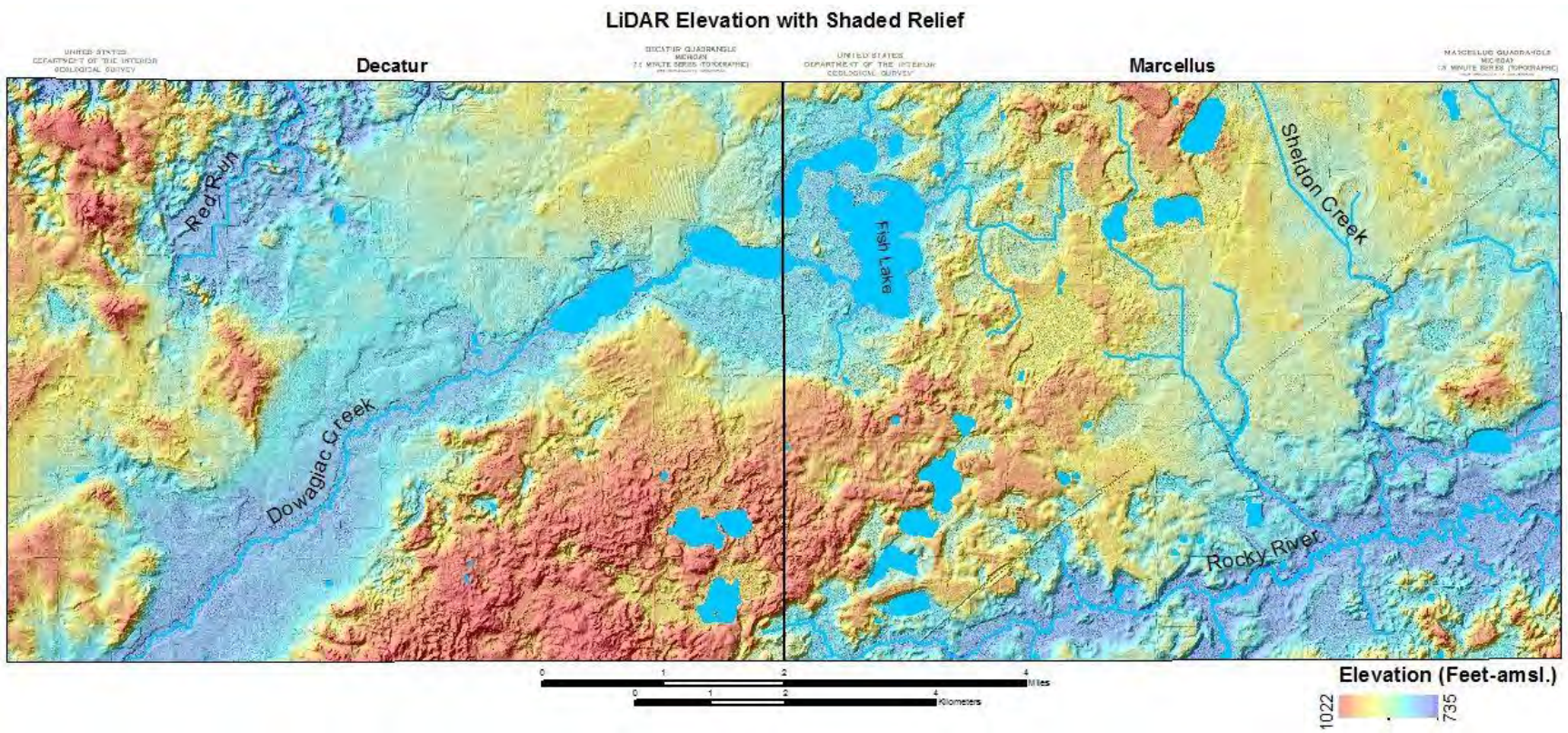


Figure 2: LiDAR Elevation with Shaded Relief

Surficial Geology

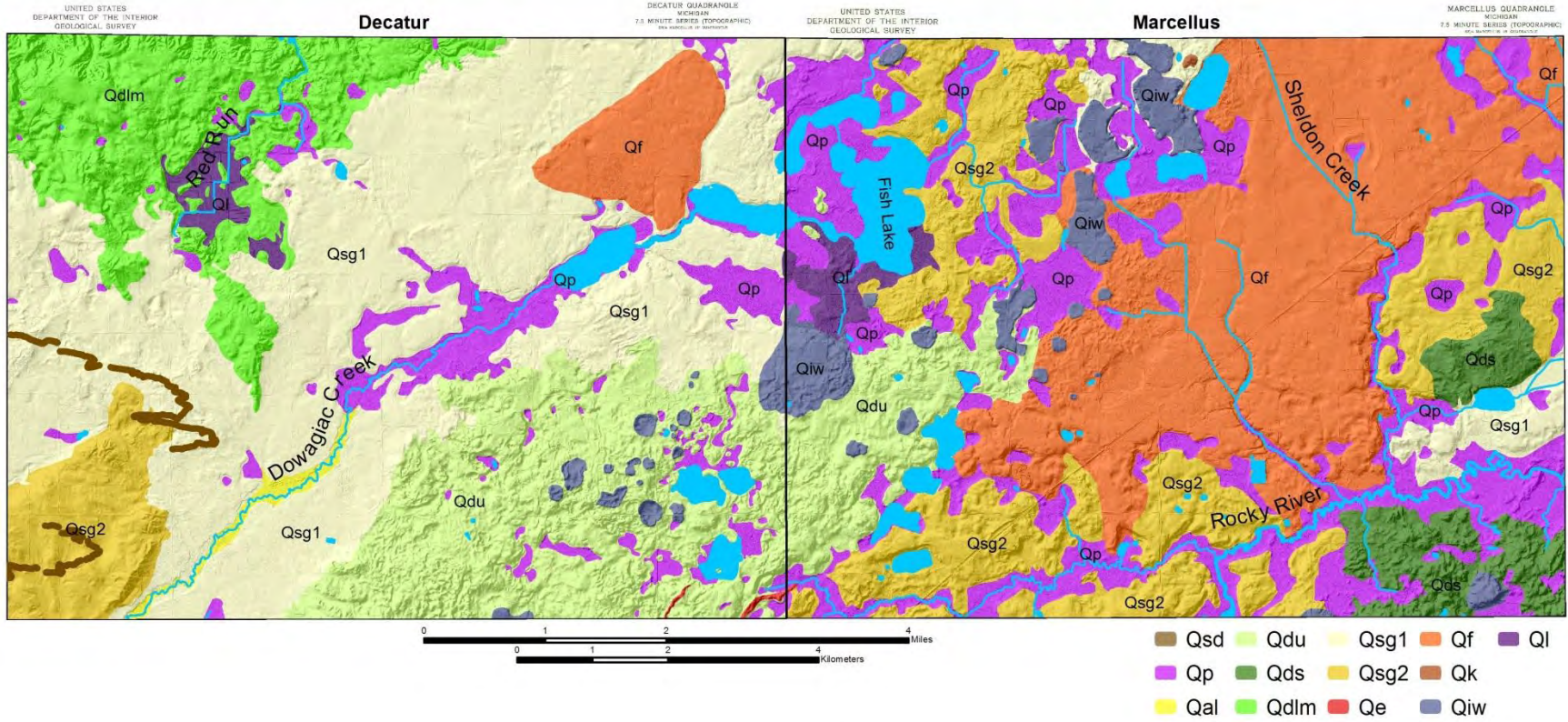


Figure 3: Generalized Geologic Map, South 1/2 Decatur and South 1/2 Marcellus, Cass and St. Joseph Counties, Michigan

Diamictons, Ice-walled Lake Plains and Glaciolacustrine Deposits

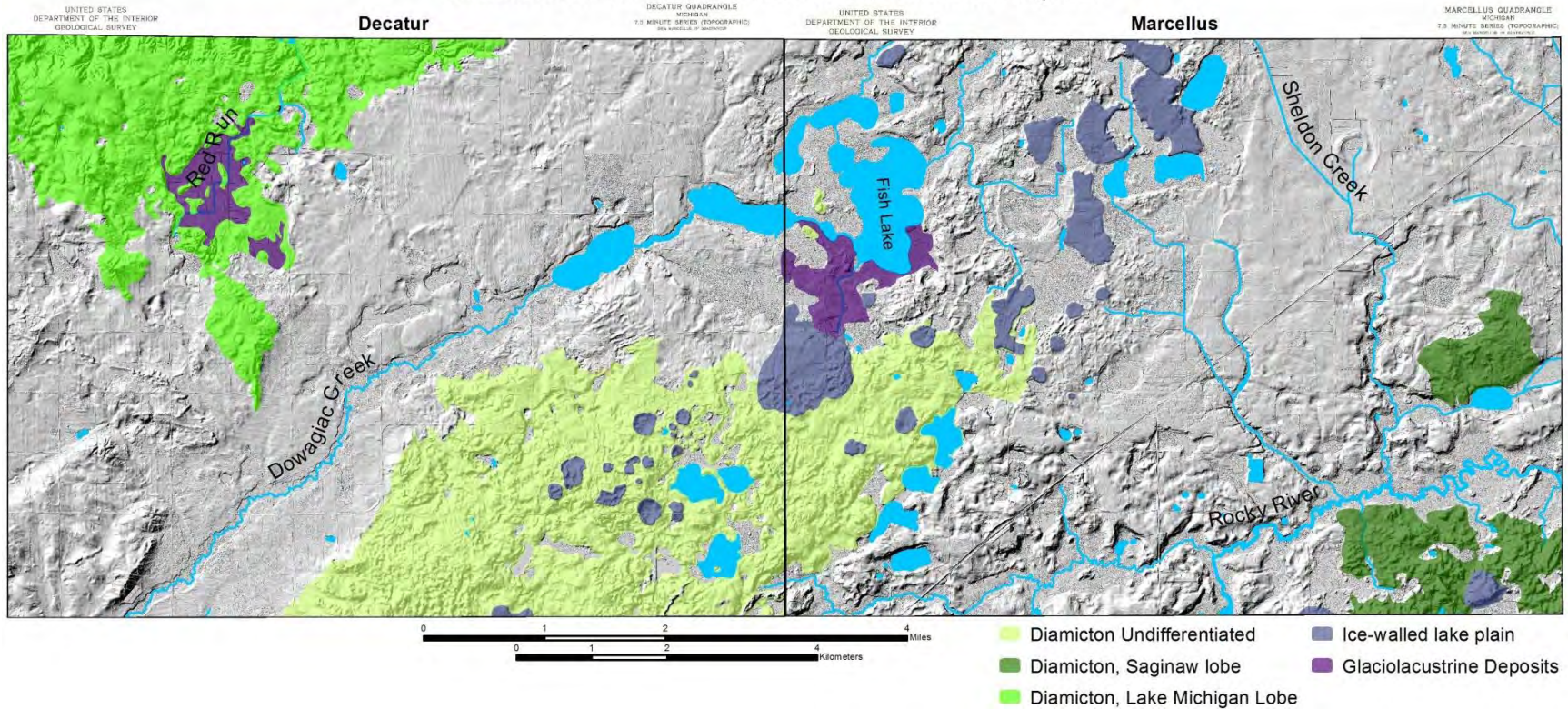


Figure 4: Diamicton, Ice Wall Lake Plains and Glacio-lacustrine deposits (Qdu, Qds, Qdlm, Qiw, Ql)

Sand Dunes, Esker and Gravel Pits

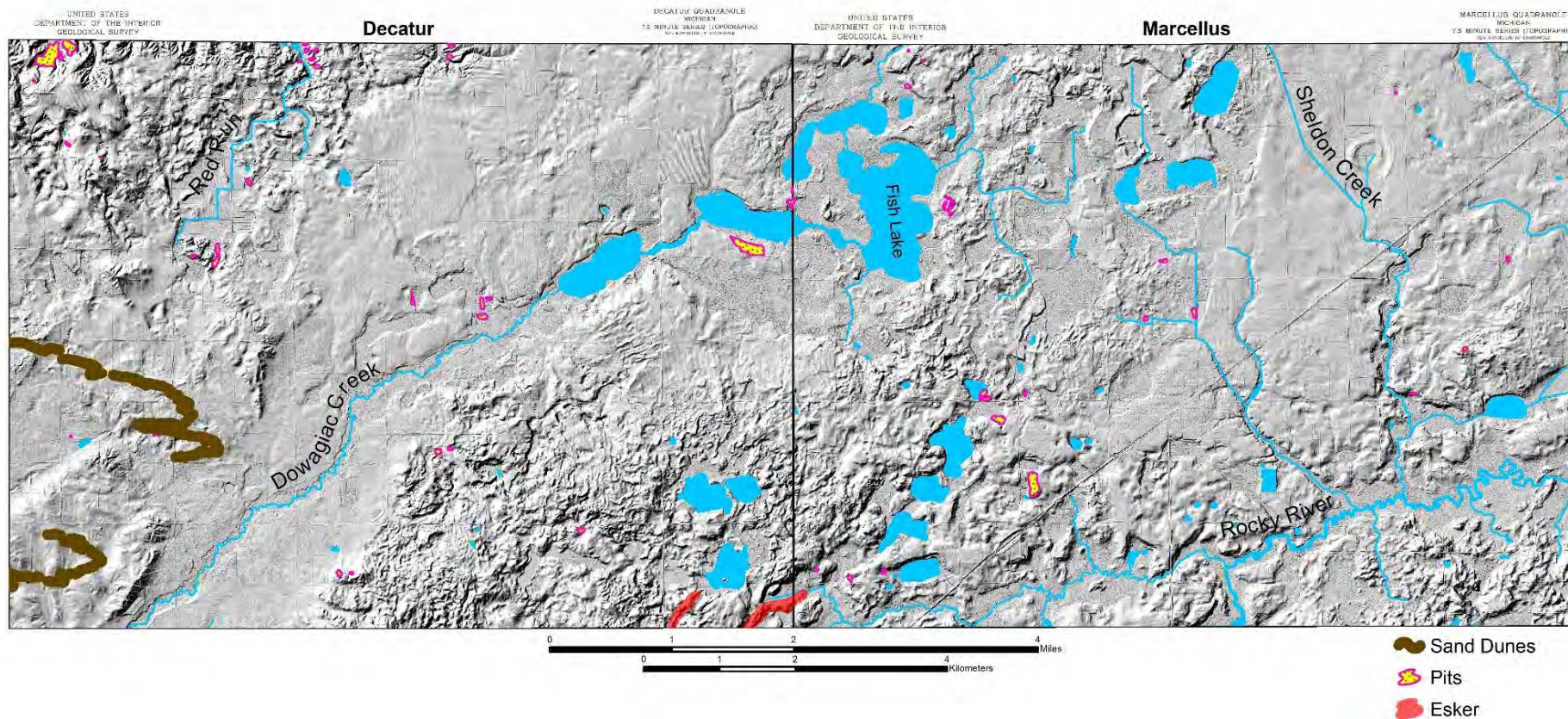


Figure 5: Sand Dunes, Esker and Gravel Pits

Peats and Watershed Boundaries

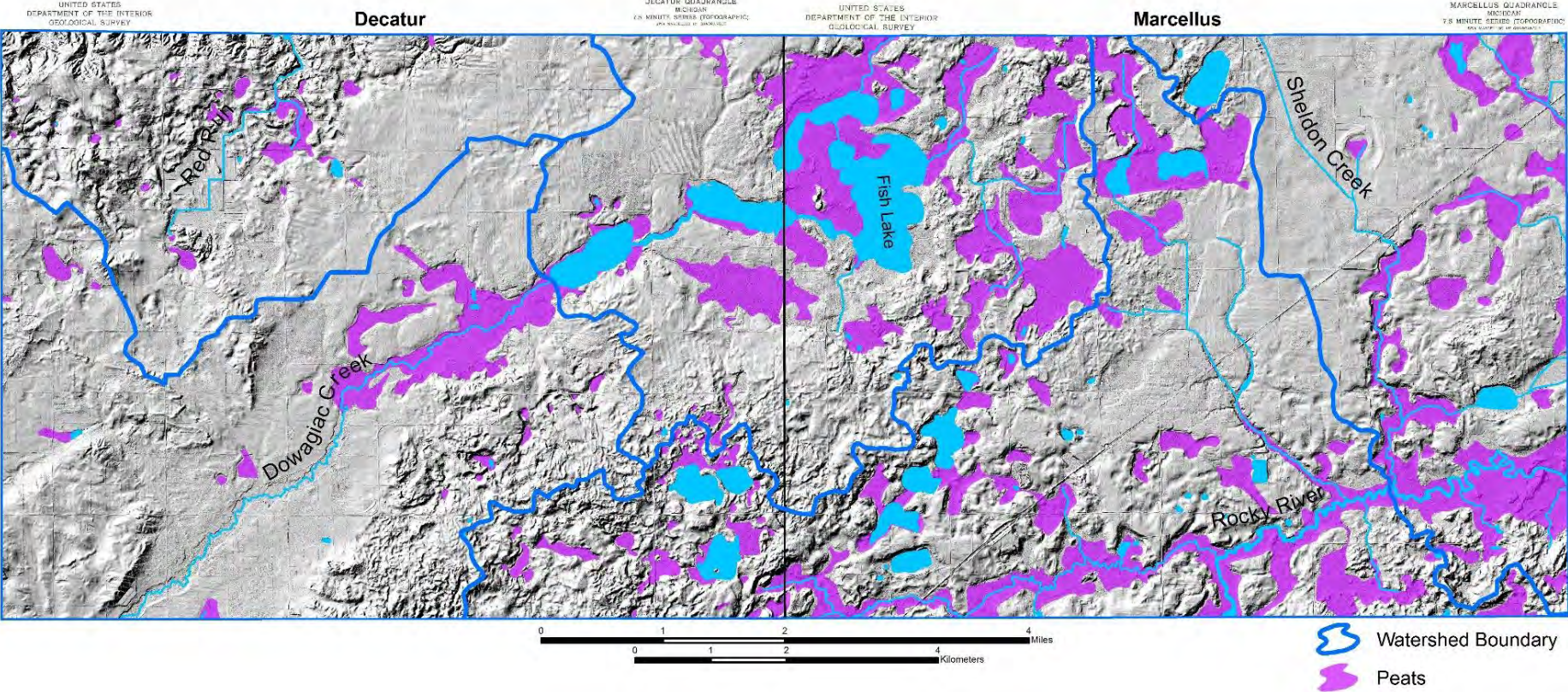


Figure 6: Peats, Muck-Wetlands and Watershed Boundaries

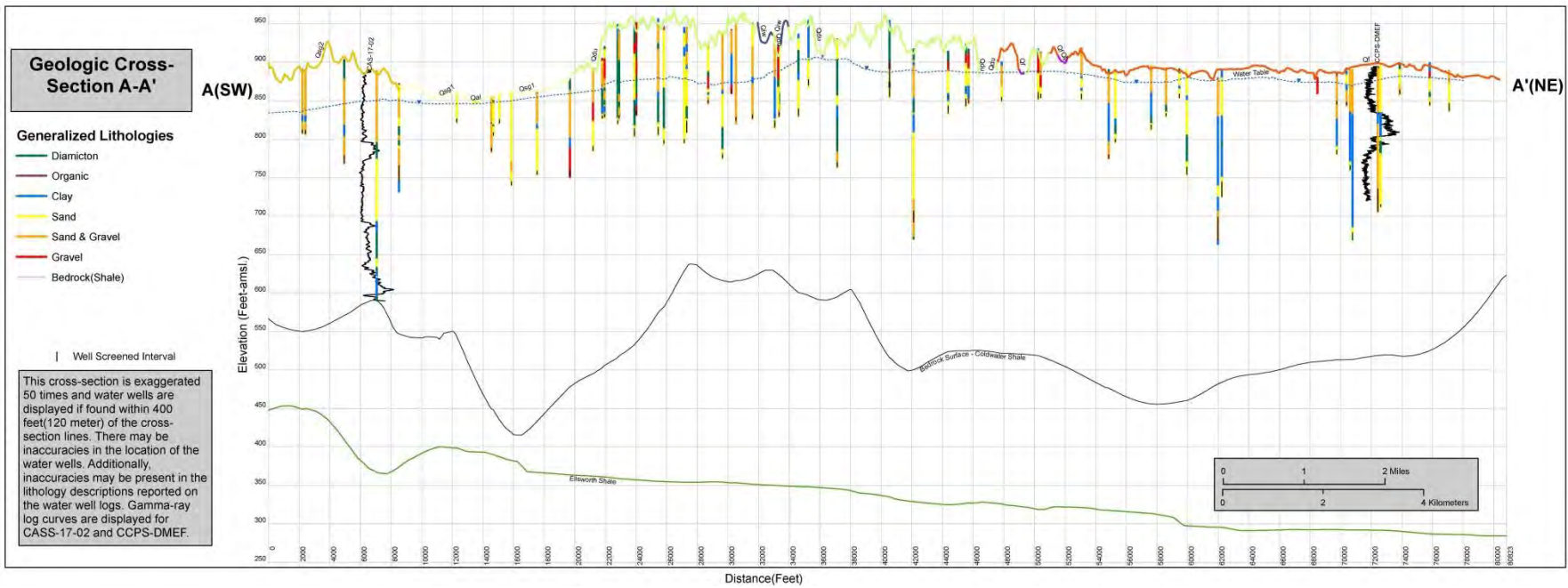


Figure 7: Cross Section, Southwest to Northeast, Decatur and Marcellus

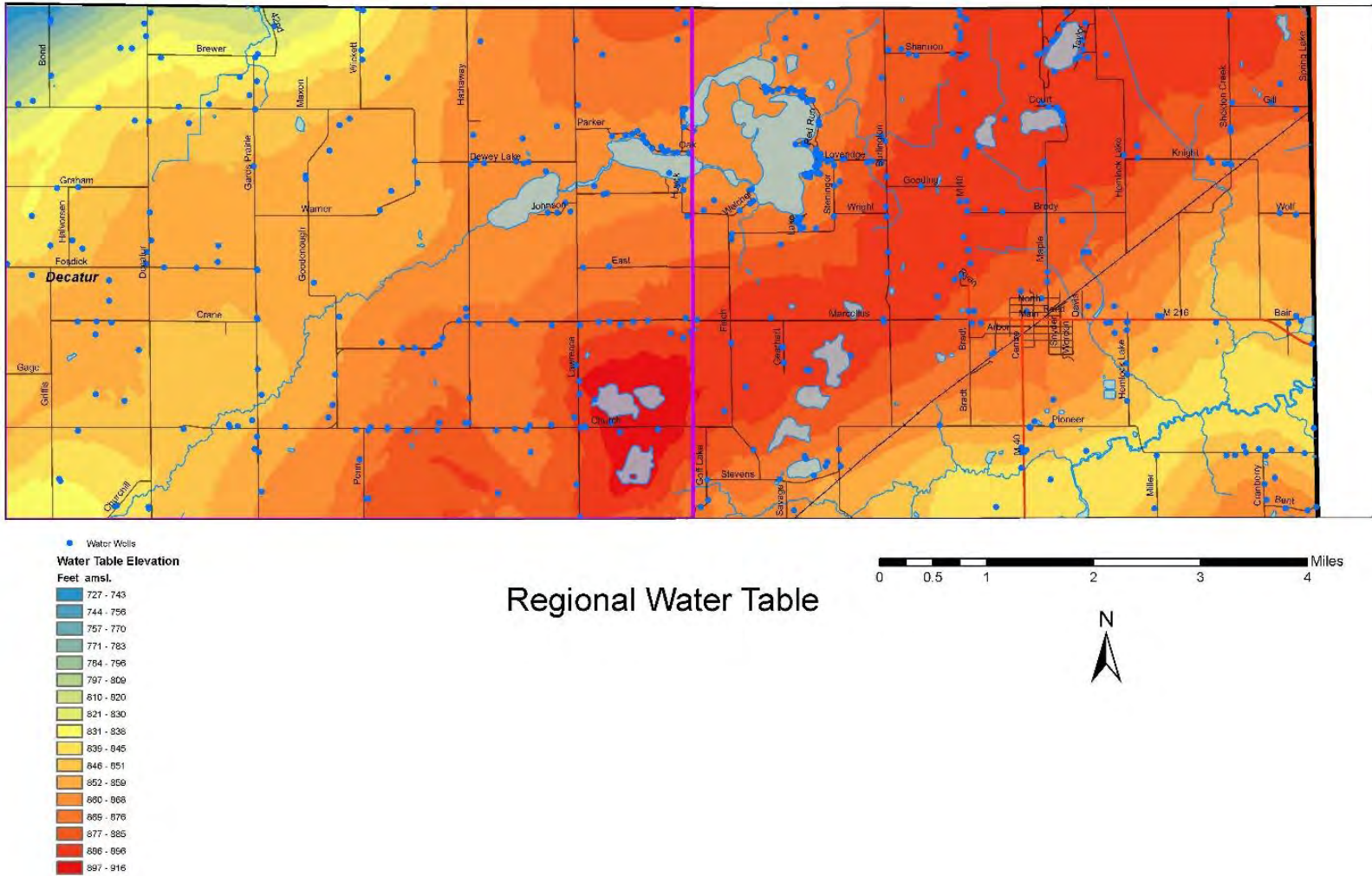


Figure 8: Regional Water Table

CAS-17-02

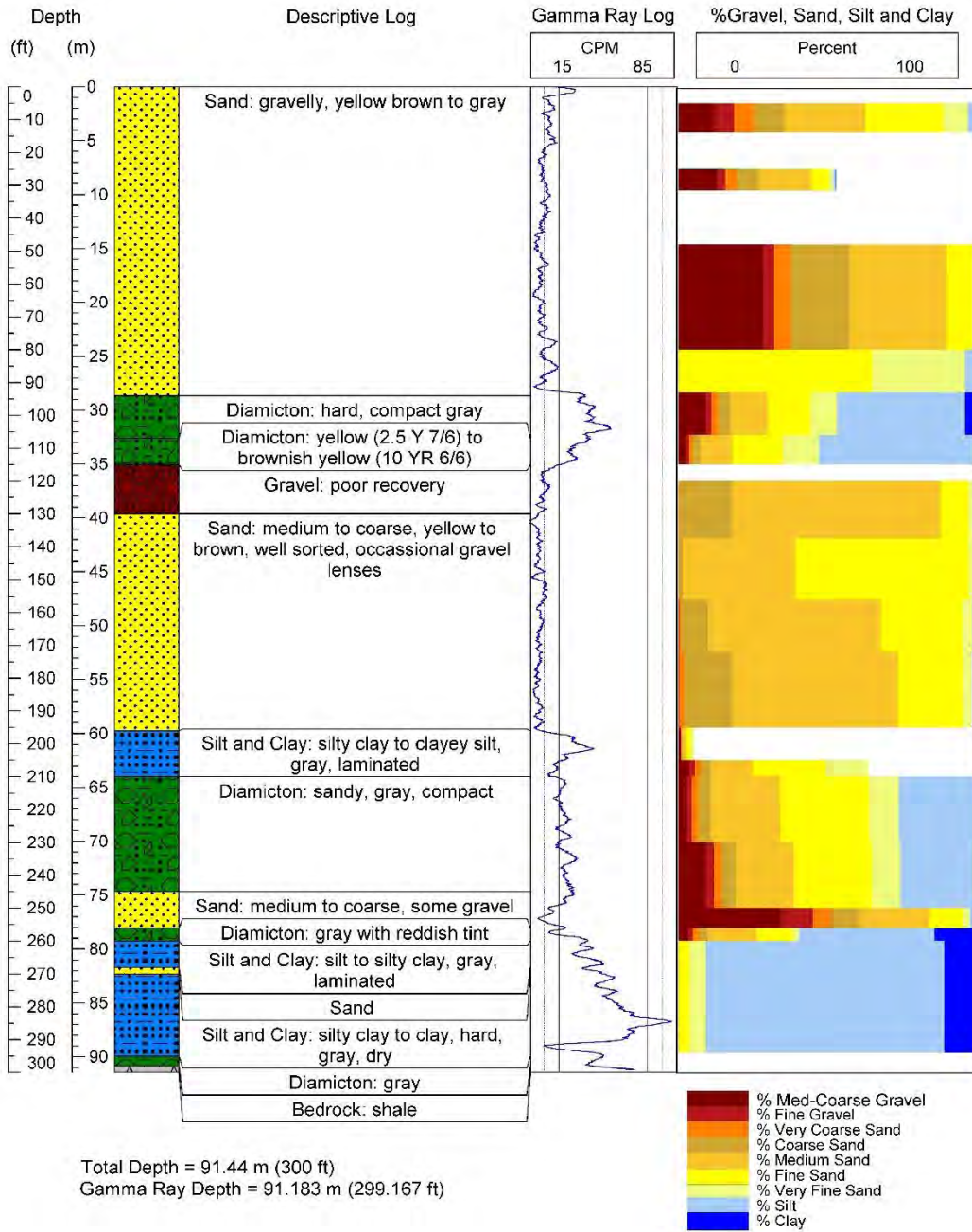


Figure 9: Wireline Core Log and Sieve Analysis (CAS-17-02)

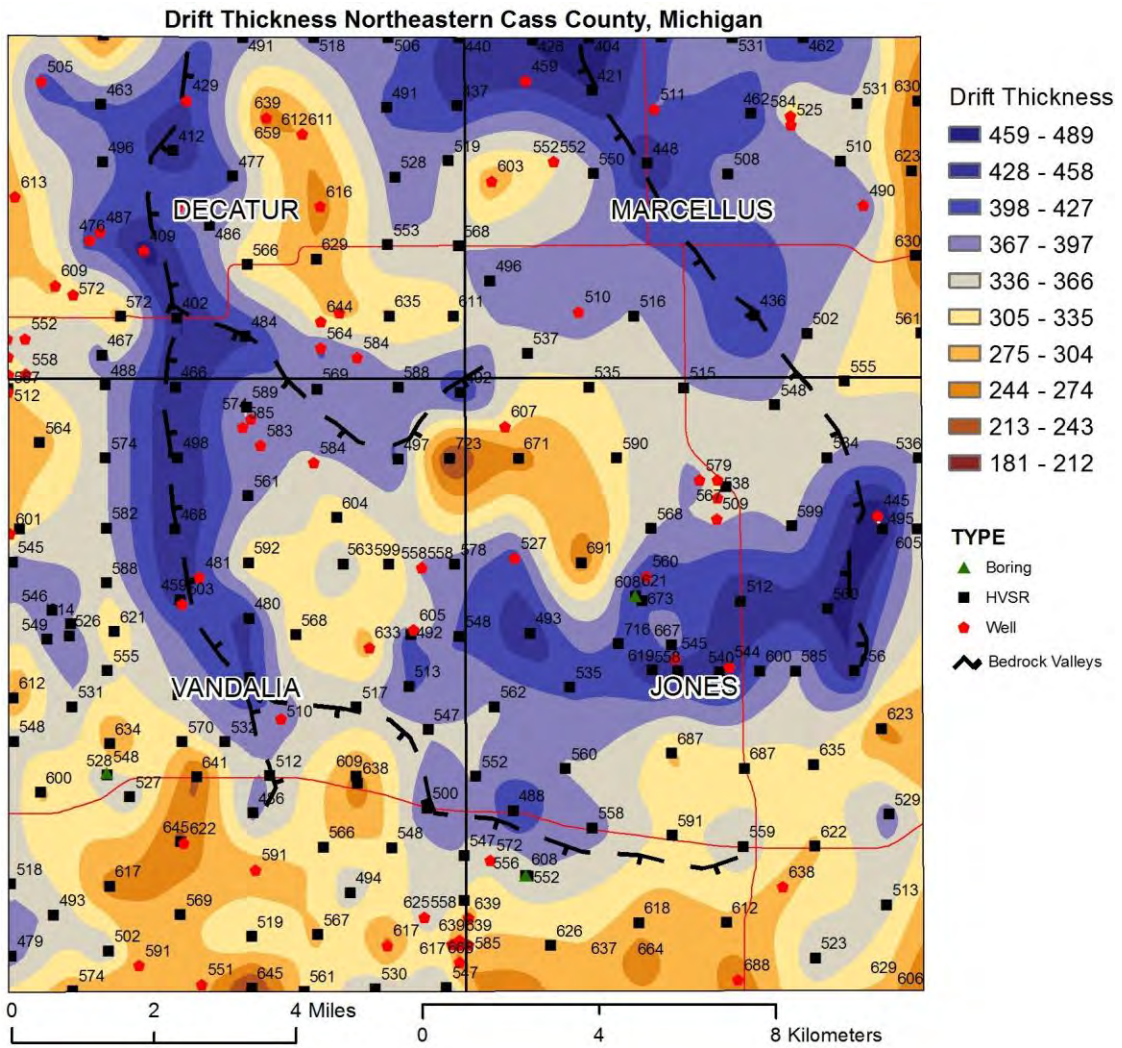


Figure 10: Drift Thickness, Decatur, Marcellus, Vandalia, Jones

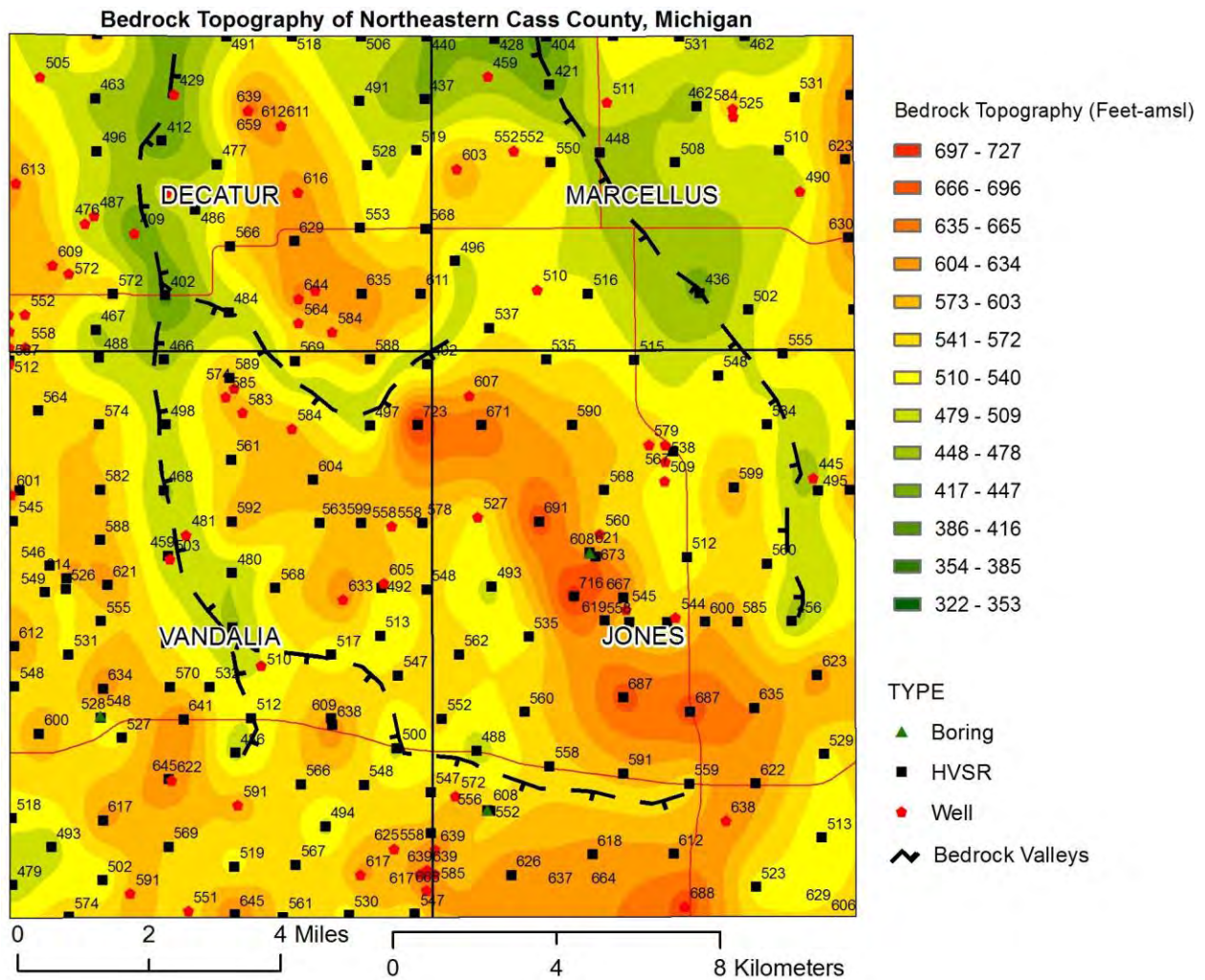


Figure 11: Bedrock Topography, Decatur, Marcellus, Vandalia, Jones

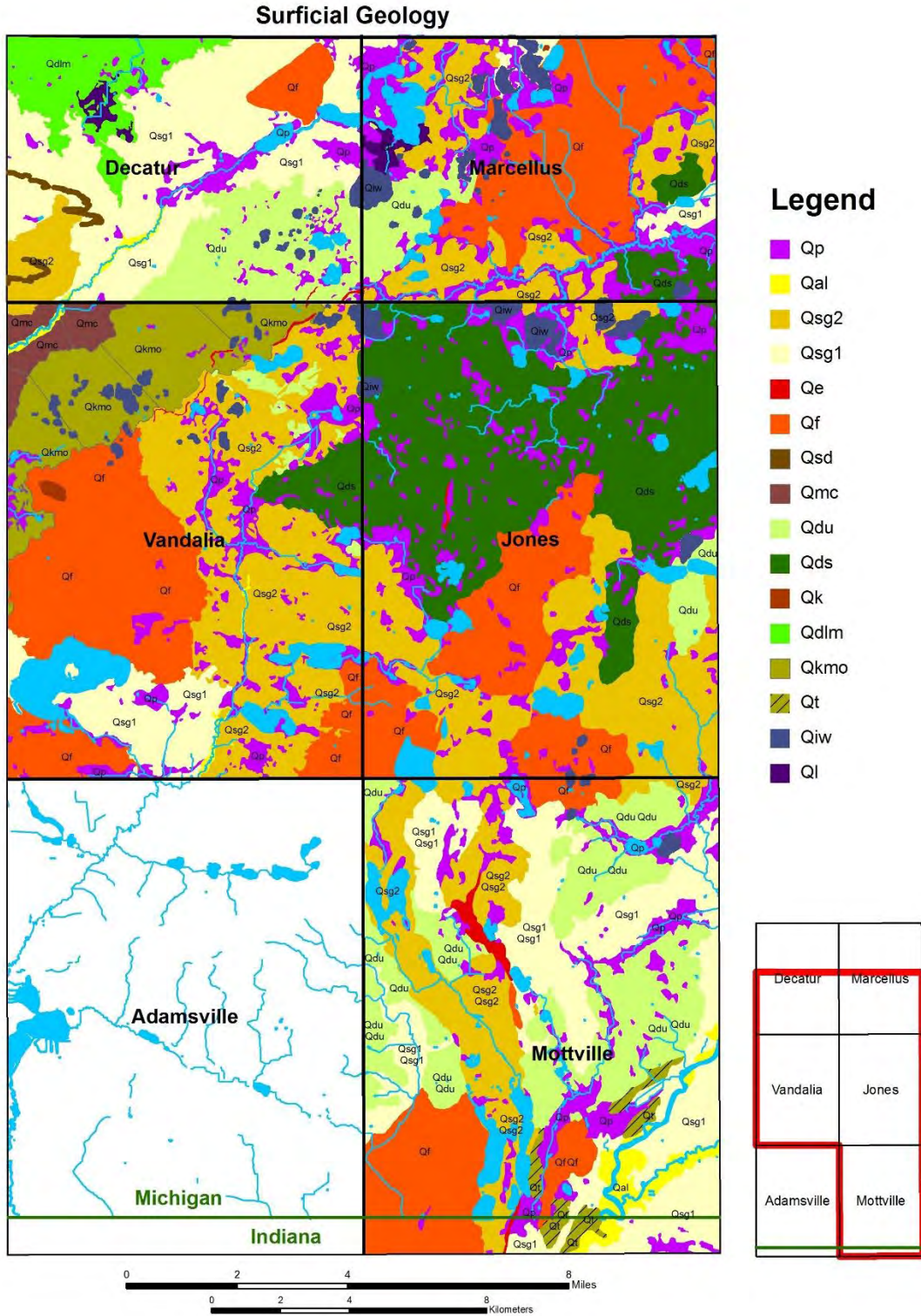


Figure 12: Regional Surficial Geology (MGS Five Quadrangles mapped 2015-2017 and published in 2017)

Quaternary Geology of Michigan (Farrand, 1982)

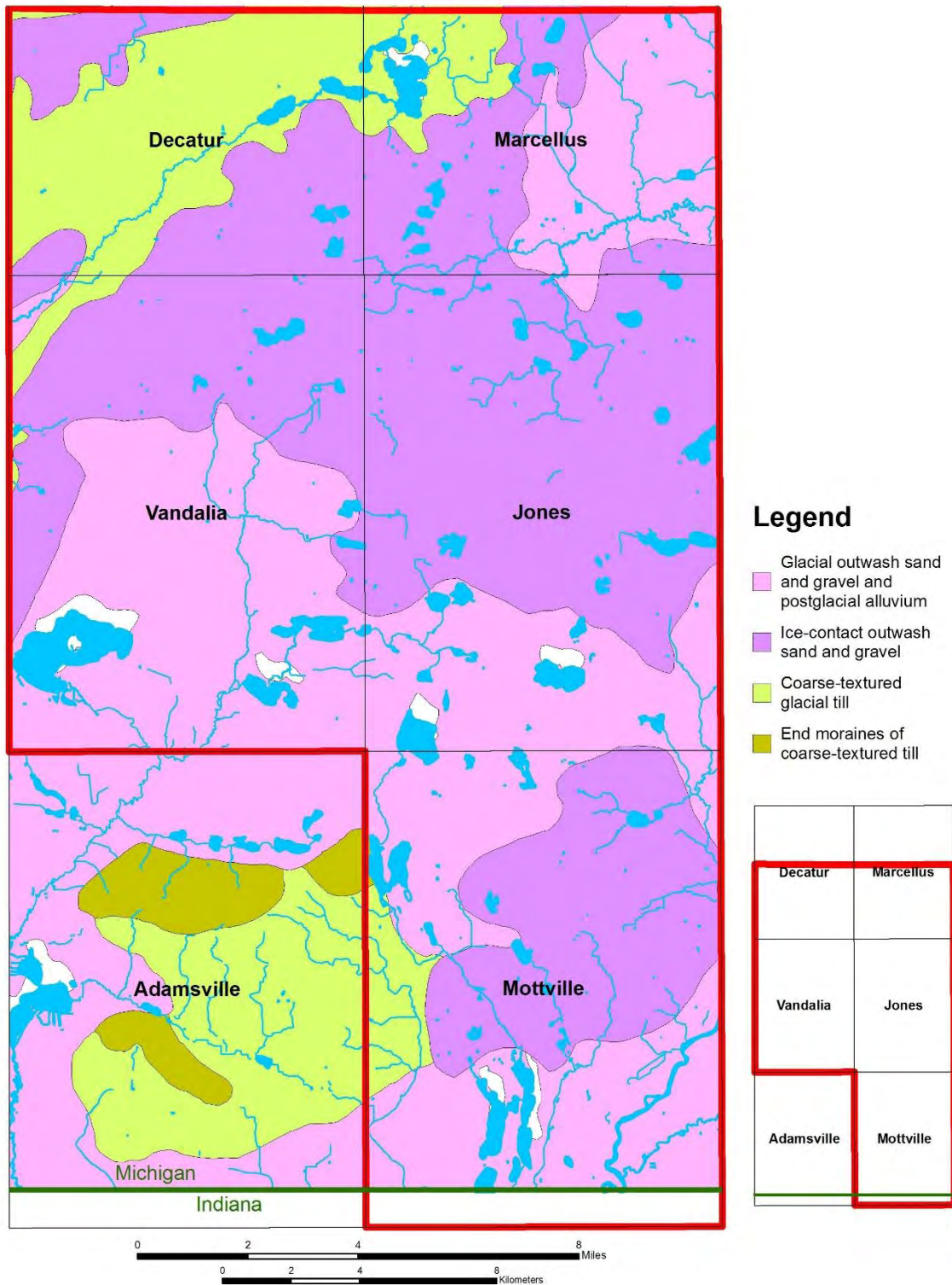


Figure 13: Regional Quaternary Geology (Farrand, 1982)-Comparison with 2017, new mapping products