TECHNICAL REPORT

Surficial Geological Mapping: Iron Mountain 7.5 Minute Quadrangle Dickinson County, Michigan and Florence & Marinette Counties, Wisconsin;

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Abstract

Surficial geologic mapping of the Iron Mountain 7.5 Minute Quadrangle, located in Dickinson County, Michigan, Florence & Marinette Counties, Wisconsin, was completed by the Michigan Geological Survey.

Mapping of the Iron Mountain 7.5 minute quadrangle has provided new, detailed information on surficial landforms and deposits within the Green Bay along the Michigan-Wisconsin Border. The map area is located in complex glacial deposits of the Green Bay Lobe of the Laurentide Ice Sheet. The complexity of the glacial deposits is in part due to high relief on the bedrock surface and complexity of underlying bedrock formations. Three ice-margins were mapped across the quad. A deep bedrock trough mapped as part of an earlier investigation (Arcadis, 2010) was further defined as well as the bedrock topography and drift thickness mapped across the quad. In addition, the mapping identified ice-walled lake plains, eskers, drumlins and terraces that were not previously mapped.

Recommended Citations

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Acknowledgements

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Introduction

In Oct. 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.

Methods

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, water-well logs, 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, was available for the Iron Mountain Quad and was used to create DEMs. The LiDAR data was a critical tool for interpretation of the subtle features like bedrock outcrops, eskers, kettles and terraces. Without the LiDAR data, many of these features would not have been recognized and many confirmed with field checks. Subsurface information concerning the thickness, extent, and stratigraphic position of surficial geologic units was obtained to the extent possible by reviewing digital well log data from the MDEQ Wellogic and historical scanned water-well log databases. Test borings using the mud rotary methods were drilled as part of this mapping project and are plotted on the maps. Cores and samples are archived at the MGRRE facility at the Michigan Geological Survey. These boring samples are essential to an understanding of the subsurface 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 digital water well data and a representative cross-section is shown on the map.

Results Iron Mountain 7.5 Minute Quad

The Iron Mountain Quadrangle is underlain by unconsolidated deposits of glacial and post-glacial origin from the Green Bay Lobe (Leverett, 1929) of the Laurentide Ice Sheet. The interlobate boundary between the Langlade Lobe and Green Bay Lobe is 10 miles to the west of the map boundary. The sediments include diamicton (till), sand and gravel, boulders 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 (~15,000 to ~12,000 yrs. before present) in age. The exact ages of the glacial deposits have not been determined in the study area but are correlated to dated features elsewhere. Over much of its path the Green Bay Lobe flow was southwesterly as evidenced by the prominent southwesterly oriented drumlins in the Menominee drumlin field in Menominee and eastern Dickinson County to the east. Starting around 13 miles to the east of the map, the Green Bay Lobe ice made a 90-degree change in direction to the WNW as it encountered the high WNW-trending resistant bedrock ridges of the Menominee Iron Range. Within the Iron Mountain Mp, this west-northwesterly ice flow direction is reflected in the numerous drumlins on the uplands and streamlined bedrock hills. A well-defined rock drumlin occurs just SE of Aurora in Section 11 in T38N, R 19E and other rock drumlins are exposed in the bottom of some sand and gravel pits. The glacial stratigraphy has been determined to the formation and member level across NE Wisconsin (Clayton, 1986; Syverson and others 2011; Mickelson, and others 1984). These formations and their relationships were difficult to recognize in the map due to the significant urban and industrial areas, limited numbers of drift exposures, extensive bedrock outcrops and limited number of deep high-quality borings for stratigraphic analysis. There is limited exposure of the glacial deposits except for the coarse-grained material exposed in the numerous sand and gravel pits in the outwash areas. A large portion of the map consists of glacial outwash and outwash terraces. A large pitted outwash plain and a series of lower outwash terraces occur along the Menominee River. As ice retreated to the east, lower outlets were formed and thus lower outwash terraces were formed. Thin loess deposits have been identified to the north, west and southwest of the map (Schaetzl and Attig, 2013; Luehmann, Schaetzl, Miller, and M. Bigsby 2012) but none were encountered in the field. Loess deposits have been noted in subsurface in the Kingsford area (Westjohn and Godsy, 1997; Luukkonen and Westjohn, 2001).

The elevation across the map ranges from 919 feet above mean sea level (AMSL) along the Menominee River to 1572 feet AMSL at the top of Millie Hill, with an average elevation of 1150 feet AMSL Three distinct bedrock controlled uplands occur north of the Menominee River: Pine Mountain, Millie Hill and Trader Hill. These uplands are mostly cored by diamicton and strewn with boulders. These boulders extend to depth into the subsurface based on the local water wells logs and the three borings drilled for this project. The diamicton is mostly reddish brown to brown. Although the larger foundation for these uplands is bedrock controlled, drift up to 140 feet thick occurs in places. The broadly N-S trending Green Bay Lobe ice margins are well defined further south in Wisconsin, where they are easily visible on topographic maps. As the ice margins extend north into Michigan they become less well defined, more discontinuous and harder to correlate. Three distinct ice margins are interpreted within the map. The well-known Two Creeks Forest bed grew in the time interval between the Early and Late Athelstane moraines (Syverson, Clayton, and Mickelson, 2011). The Winegar-Sagola-Early Athelstane Moraine (Clay ton 1986; Attig, Clayton, Mickelson 1985; and Peterson 1986) forms a high ridge in the southwestern corner of the map. This regional moraine has been correlated to the Port Huron Moraine in Michigan (Peterson, 1986; Blewett, 1991). The Silver Cliff Member of the Kewaunee Formation was deposited when the ice was at this position approximately 14,500 calendar years before present (Clayton, 1986; Syverson, Clayton, and Mickelson, 2011). Farther east, a portion of the Middle Athelstane ice margin potentially occurs as a prominent, isolated, hummocky, and apparently non-bedrock controlled upland to the SW of Pine Mountain, as well as Pine Mountain itself. This ice margin is difficult to trace across the map due to the wide outwash terraces along the Menominee River and lack of a distinct ridge south into of the Menominee River and north of Pine Mountain.

An extensive pitted outwash plain with elevations ranging from 1140 to 1120 feet AMSL formed west and south of this ice margin, which underlies City of Kingsford. A later, short term fluvial event likely occurred over this outwash surface, as evidenced by the sharp, steep, wave cut or fluvially cut scarp at 1140 feet AMSL along the northern side of this surface. A surficial gravel and cobble lag was noted in places on this surface. As the Green Bay Lobe ice retreated to the east, there must have been successive lowering of the outwash outlets to the south and southeast because of the step-like lowering of the outwash terraces as one moves toward the Menominee River in the western part of the map. Meltwater was first diverted south to an outwash channel along the ice front through a narrow gap in the bedrock, to an outwash channel south into Wisconsin at an elevation of 1100 feet AMSL. A lower terrace occurs at 1075 feet AMSL. After a major eastward retreat of the ice, it re-advanced westward to the Marenisco-Late Athelstane ice marginal position, which likely correlates with the nondescript “unnamed moraine” just north of the map (Peterson, 1986). The significant topographic change and the increased number of deep kettles to the west are interpreted to correlate to this ice margin, which continues south into Wisconsin as a well-defined ridge (Schaetzl and Attig 2013). The ice margin continues north as a distinctive irregular band that wraps around the east sides of Millie Hill and Trader Hill seen in the LiDAR topography. The Middle Inlet Member of the Kewaunee Formation was deposited when the ice was at this ice margin approximately 13,000 calendar years before present (Clayton, 1986; Mickelson and others, 2007). Again, as the ice retreated east, another series of outwash terraces formed; these occur along the Menominee River and descend in a step like fashion (1045, 1035, 1020, 997, and 960 feet AMSL), farther to the SE into the Norway Quad. The lowest of these terraces is 180 feet lower than the large outwash plain to the west. In the Kingsford area, the large pitted outwash plain overlies a lacustrine sequence of mostly silts, clays, sands and gravels that is as much as 300 feet thick. This lacustrine sequence overlies a deep bedrock trough under the City of Kingsford. A dense basal till ranging from 2-20 feet thick occurs between the thick lacustrine section and bedrock trough in places. A detailed study has been conducted in the subsurface glacial deposits at the Ford-Kingsford site (Arcadis, 2010; Godsy, Warren, and Westjohn, 2001). To the southeast of Lake Antoine in Section 17, T40N, 30W is a small patch of S to N trending, low relief, parallel ridges. Along the Menominee River in the northwestern part of the map are a number of fluvially eroded bars. Two eskers were mapped in the southwest part of the map based on LiDAR elevation data. Several ice-walled lake plains were mapped in the uplands just east of the Marenisco-Late Athelstane ice margin, on the east sides of Millie Hill and Trader Hill.

A passive seismic instrument using the Horizontal-Vertical Spectral Ratio (HVSR) method was used to gather additional bedrock control for data on bedrock topography and drift thickness. This technique uses the horizontal-to-vertical spectral ratio method to record ambient seismic noise with 3-component geophones (Lane, et al., 2008; Chandler and Lively, 2016). HVSR calibration readings were gathered at 15 wells and borings of known bedrock depth. These data were used to develop a local HVSR bedrock depth calibration curve. Exploration readings were taken at 44 locations within the map. Very good bedrock depth estimates were made in the outwash areas of the map. In the upland morainal area, however, the method yielded depth estimates that were much too shallow relative to the local bedrock elevation of the area. This disconnect is likely due to buried, over-consolidated dense glacial till which was encountered at depth in the three borings drilled for this project. The HVSR bedrock depth estimates at these three borings match well with the depths to the top of the dense till. A significant gamma-ray log kick was also seen at or near the top of this dense till. Although the glacial deposits in the Iron Mountain Quadrangle average 40 feet thick, numerous bedrock outcrops exist. The drift is maximally 363 feet over the deep bedrock trough in Kingsford. In many places, the land surface topography is controlled not by the glacial deposits, but by the underlying bedrock and bedrock structure. One important exception is a pronounced buried deep bedrock trough that underlies the large pitted outwash plain in Kingsford. Another buried bedrock trough underlies the lowland along the Menominee River in the southeastern part of the map. A poorly defined bedrock low connects the two troughs north of the Menominee River. There is high relief on the bedrock surface ranging from 730 feet to 1530 feet AMSL across the map. Bedrock outcrops and mounds appear throughout the area, even where nearby borings show over 100 feet to bedrock.

The bedrock geology exposed at the surface and underlying the glacial deposits in the Iron Mountain Quadrangle is very complex and its study is beyond the scope of this surficial geological map. But we are certain that the bedrock has had a significant and controlling effect on the overlying glacial deposits and hence, we will discuss it briefly. The bedrock geology map shown to the left is simplified due to space limitations. The Iron Mountain Map lies over a major Precambrian terrain boundary named the Niagara fault (suture zone), which runs WNW-ESE across the southern part of the map. This suture zone is part of the significant continental collision boundary of a mountain building event called the Penokean Orogeny about 1.8 billion years ago (Schulz and Cannon, 2007). North of the fault are mostly complexly faulted and folded Precambrian metasedimentary rocks (Michigamme Slate, Vulcan Iron Formation, Randville Dolomite, Sturgeon Quartzite, Fern Creek Tillite and others). The Menominee Iron Range is part of this metasedimentary package and has resulted in the significant historical iron mining district centered around the city of Iron Mountain, specifically along the uplands of Pine Mountain, Millie Hill and Trader Hill; these hills are the result of the complex faulting and folding. South of the Niagara fault are mostly younger metavolcanics and granitic intrusions (Quinnesec Formation, Hoskins Lake Granite and Marinette Quartz Diorite). Much later, Cambrian sands were deposited, leading to Cambrian Sandstone units. Today, these sandstone outliers appear to be mostly preserved on or near the uplands, and are much more extensive than previous geological maps have indicated. Past local quarrying of the sandstone has produced the distinctive building stone that is common in Iron Mountain. Numerous bedrock outcrops occur across the map. Most of these are due to resistant Precambrian and Cambrian units, especially the Badwater Greenstone and the Hoskins Lake Granite, which tend to form bedrock highlands and outcrops belts. The Michigamme Slate subcrop and outcrop tends to result in bedrock lows.

Most of the map is within the Menominee River watershed. The northwestern corner of the map is within the Pine River watershed, the northeastern corner is within the Pine Creek watershed, the southwestern corner is within the North Branch of the Pemebonwon River watershed, the southeastern corner is within the Spikehorn Creek watershed and the western edge is within the Little Popple River watershed. The Menominee River in places flows over broad lowlands, as in the southeastern part of the map. In other places, it has carved through thick outwash sequences or more resistant bedrock, forming rapids and waterfalls. At Horserace Rapids, the river is cut through a narrow bedrock gorge. Prior to industrial development, there were numerous rapids and several waterfalls along the Menominee River. Dams were later placed at some of these waterfalls. Significant sand and gravel mining operations occur within the map. Most of the gravel pits are associated with pitted outwash plains and outwash terraces. Significant additional sand and gravel deposits may potentially occur within in these deposits and along the newly mapped eskers.

Bedrock outcrops from previous geological maps (Bayley and others, 1966) were digitized by John Esch and William Cannon of the USGS. Additional bedrock outcrops were mapped based on reconnaissance field work, LiDAR topographic data, aerial photography, and NRCS SSURGO soil survey data. Three mud rotary borings were drilled as part of this mapping project (DIC-17-01, DIC-17-02, DIC-17-03). Mud rotary drilling is not optimal for geological mapping but was chosen due to the high volume of boulders and cobbles at the surface and subsurface in the upland areas. Cuttings were collected every 5 feet, or more frequently if a drilling change occurred. All borings were gamma-ray logged. A significant gamma-ray kick occurred near the top of buried dense till in each hole. Two additional borings were being drilled at a site within the map while the mapping was being conducted (GM-88 and GM-62RC). Rotosonic cores were observed and a gamma-ray log was run on one of them. Their logs are shown below. Although an optically stimulated luminescence (OSL) sample DIC-17-01 OSL was collected for age dating on the edge of the uppermost pitted outwash terrace, results were not available at the time of map publication.

Uses of Surficial Geologic Maps

Surficial geology map shows the geological materials such as diamicton or till (sometimes called hardpan by losers), sand and gravel, or clay found within 5 feet of the ground surface. In many cases these surface units extend to much greater depths. The map shows the areal distribution of the different types of glacial deposits and landforms as described in the map explanation. Features such as drumlins and 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 future similar changes for long-term planning efforts, such as land use planning or waste disposal.

Surficial geology maps can assist anyone wanting to know what lies 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. 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 of 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 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 Iron Mountain 7.5 minute quadrangle has provided new, detailed information on surficial landforms and deposits within the Green Bay along the Michigan-Wisconsin Border. The map area is located in complex glacial deposits of the Green Bay Lobe of the Laurentide Ice Sheet. The complexity of the glacial deposits is in part due to high relief on the bedrock surface and complexity of underlying bedrock formations. Three ice-margins were mapped across the quad. A deep bedrock trough mapped as part of an earlier investigation (Arcadis, 2010) was further defined as well as the bedrock topography and drift thickness mapped across the quad. In addition, the mapping identified ice-walled lake plains, eskers, drumlins and terraces that were not previously mapped.

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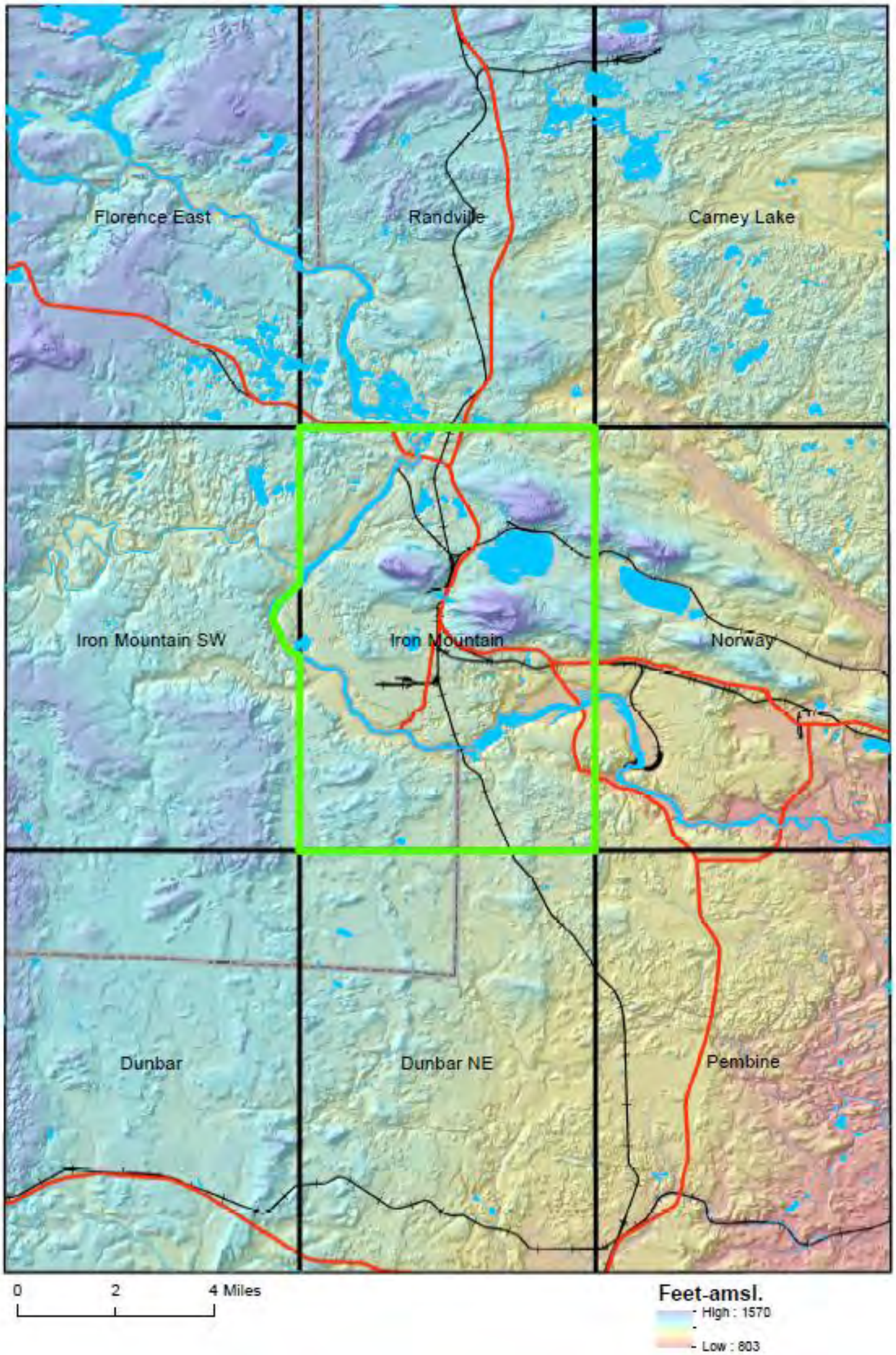
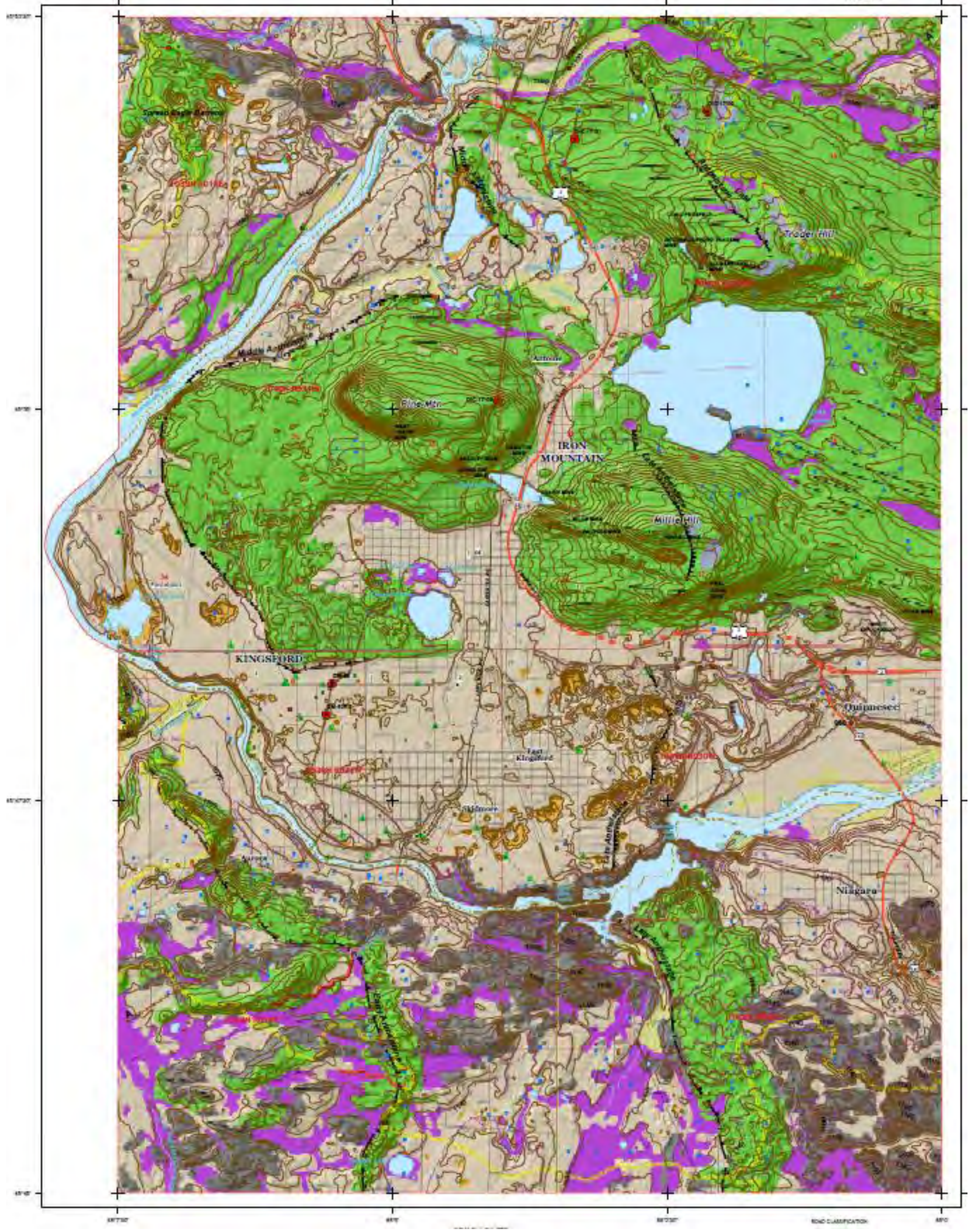
Regional Shaded Relief



IRON MOUNTAIN QUADRANGLE
MICHIGAN - WISCONSIN
7.5-MINUTE



Holocene

🟪	Qp	***Peat and Muck.*** *Isolated, poorly drained depressions or flood plains. Underlain by bedded sand and gravel, silt and clay, or diamicton.*
🟨	Qal	***Alluvium.*** *Alluvium along Menominee River and other streams consisting of bedded sand and gravel to bedded silt and clay. Age of near surface sediment Holocene. Maybe underlain by Pleistocene alluvium. Floodplain sediment in modern floodplains.*

Pleistocene

🟧	Qke	***Kettle.*** *Depression formed by melt-out of former buried ice blocks.*
🟫	Qow	***Outwash.*** *Bedded sand and gravel with hummocky or pitted surface formed by collapse of buried ice blocks. May contain areas of Qd.*
🟦	Qiw	***Ice-walled lake plain.*** *Flat topped hill within an area of ice-marginal stagnation deposits. During deglaciation, a lake bounded by debris covered ice formed and accumulated sediment. Surficial sediment may consist of sand and gravel or bedded silt and clay.*
🟥	Qe	***Esker.*** *Linear to sinuous ridged composed of sand and gravel. Deposited in tunnel at base of glacier or ice-walled channel during deglaciation.*
🟩	Qd	***Diamicton (till).*** *Reddish brown sandy diamicton on upland surfaces. Boulders occur at land surface and subsurface. Diamicton may be missing in places where sand and gravel or other materials are present at the surface.*
⬛	Rock Outcrop	***Bedrock.*** *Precambrian metasedimentary and metamorphic rock and outliers of Cambrian sandstone.*

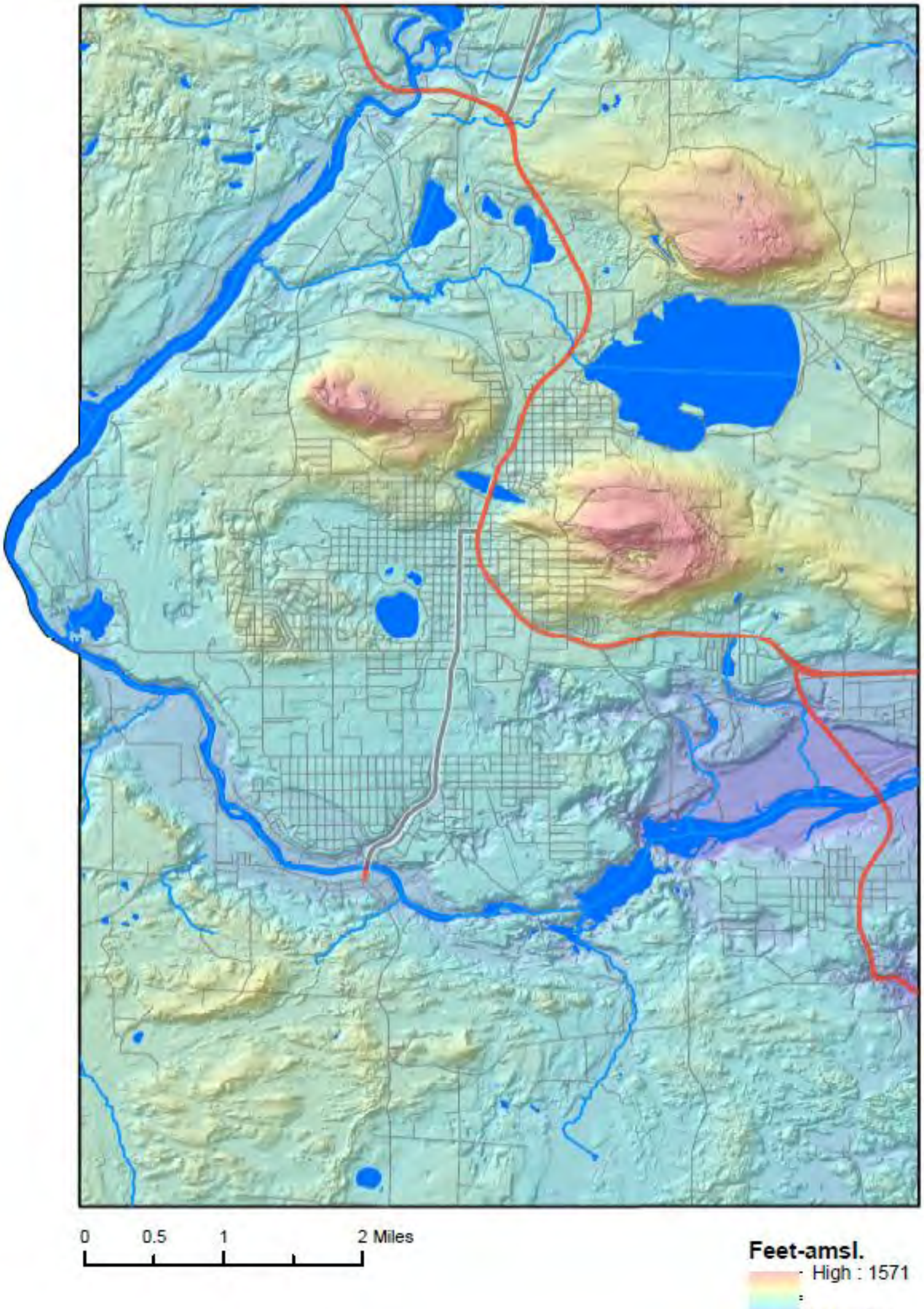
Boreholes

- 🔴 Boreholes
- ● Hand Augered Borings/Road Cuts
- ▲ HVSR Stations

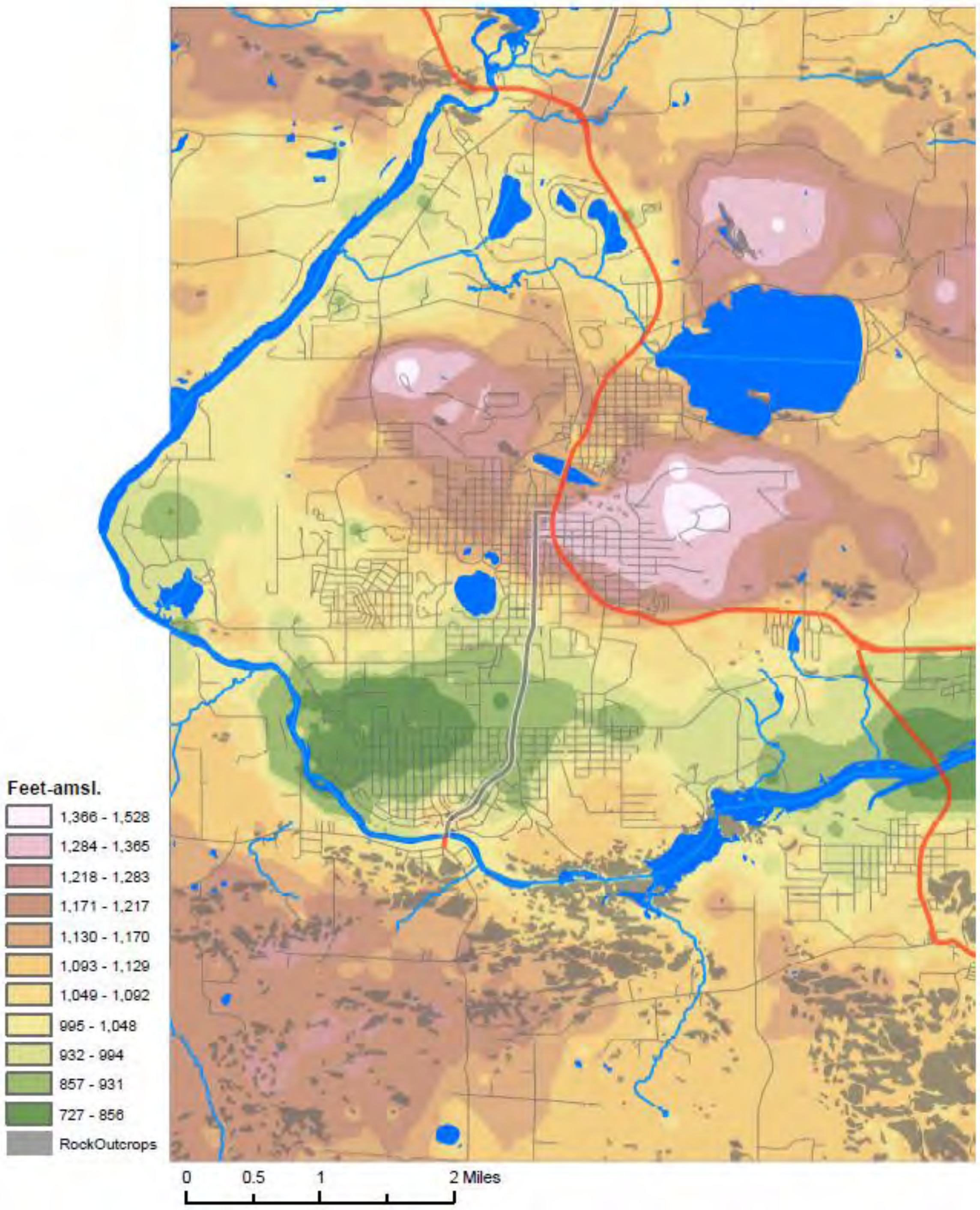
- ★ OSL Dating Sample Location
- ● Water Wells
- ⚒ Iron Mines
- ▪ EnvironmentalBorings
- ▬ Cross Section
- ━ Watershed Boundaries
- ― Outwash Terraces

- ┳┳ Ice Margins
- ━ Drumlins
- ▨ Sand & Gravel Pits

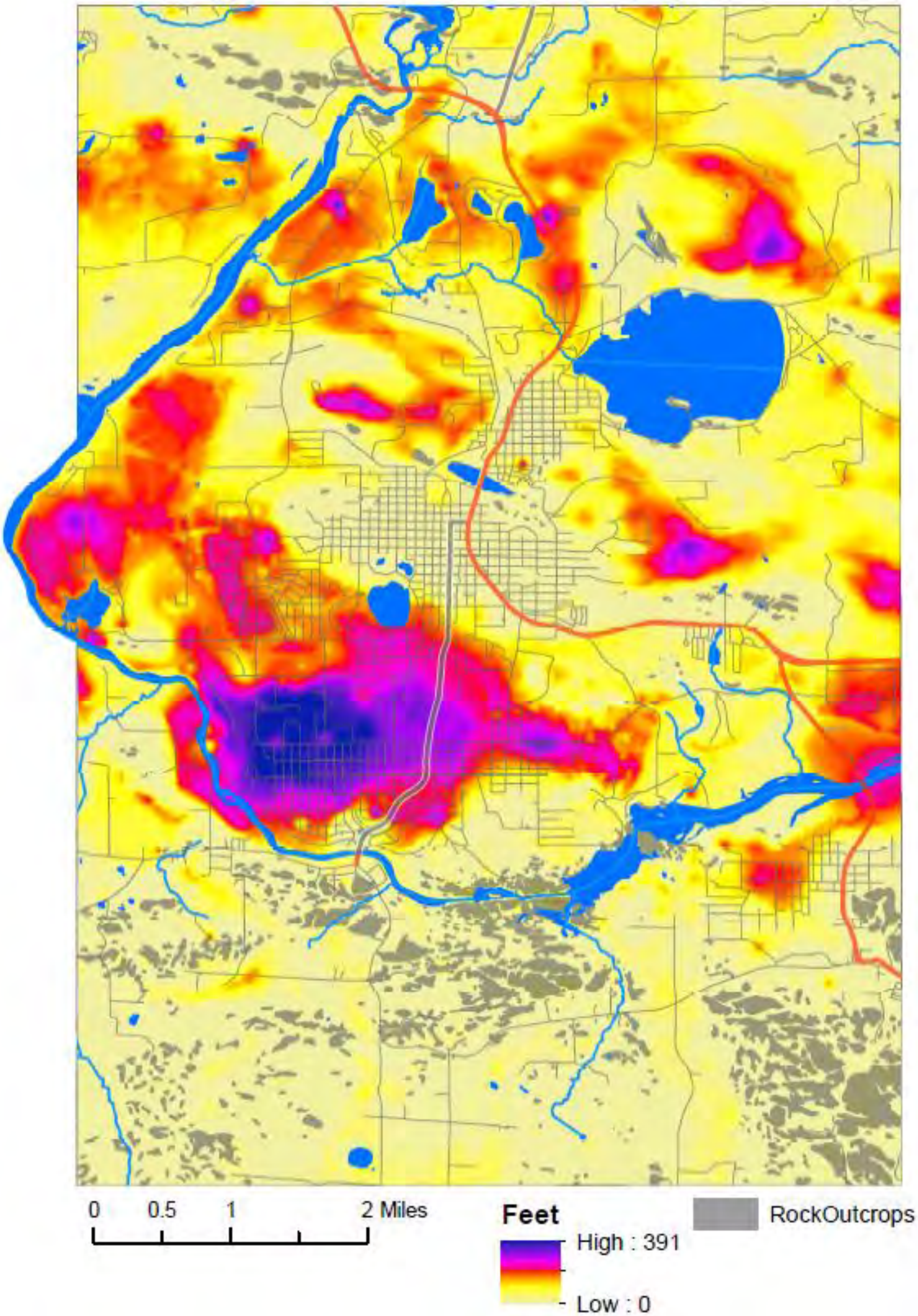
Shaded Relief



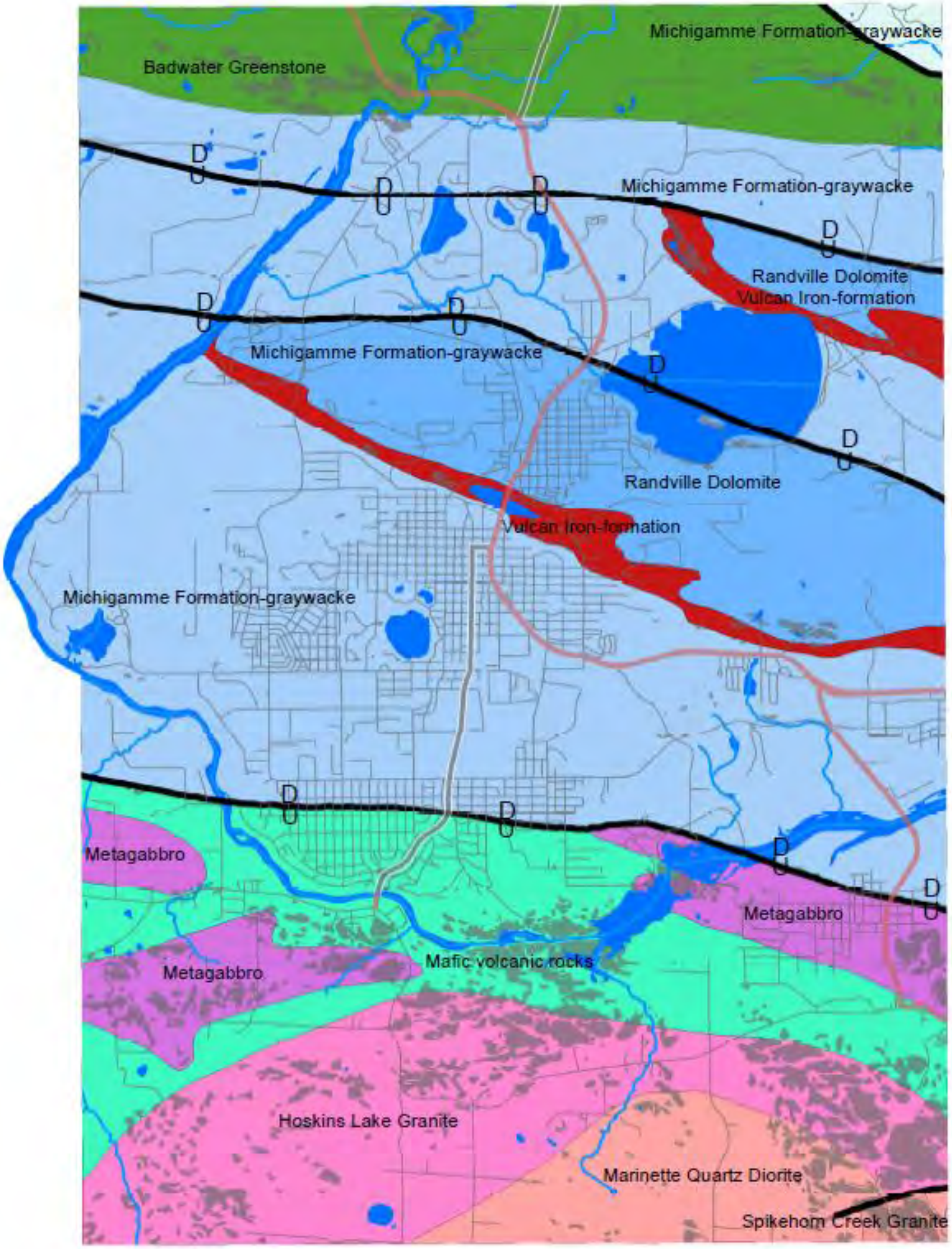
Bedrock Topography



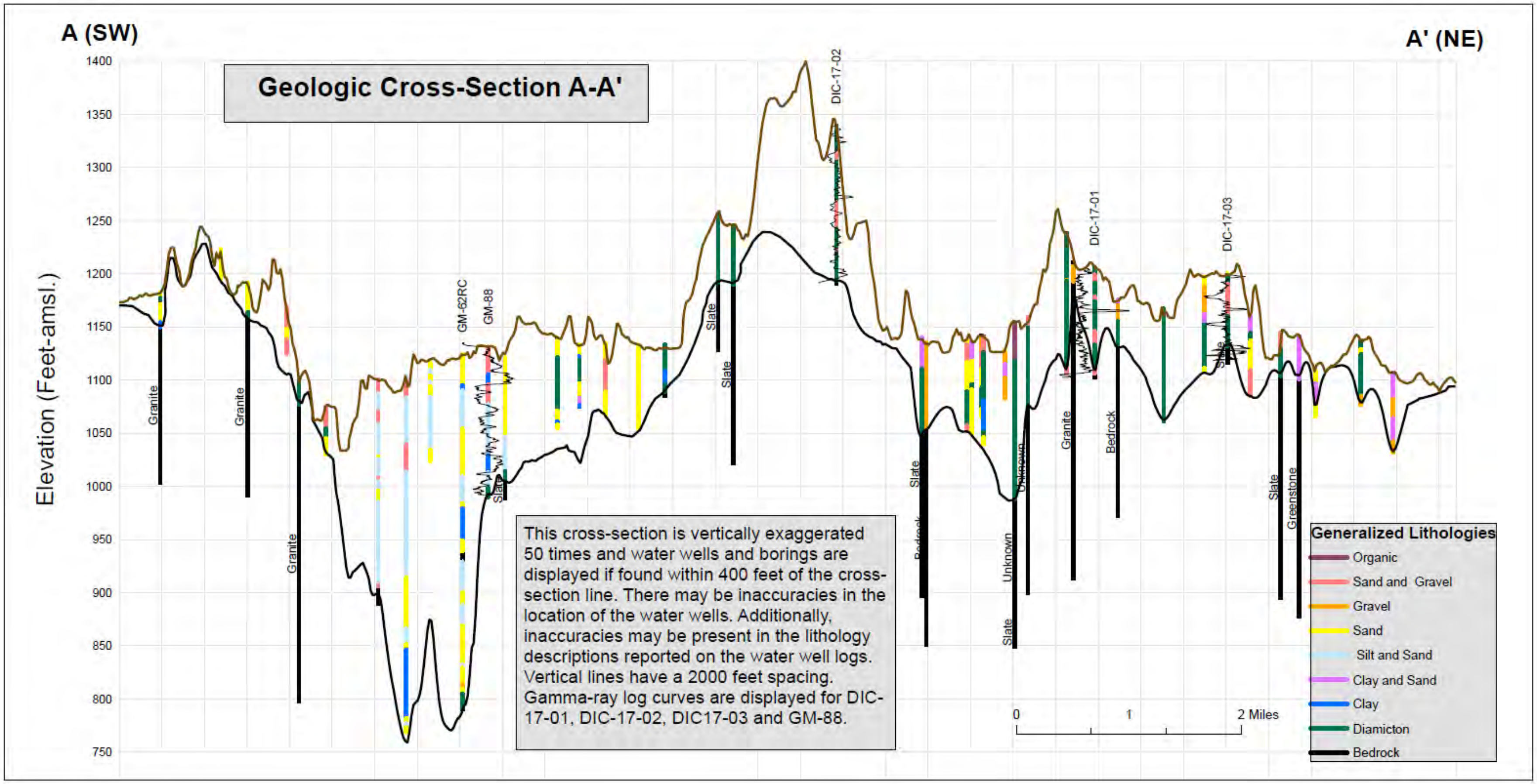
Drift Thickness



Bedrock Geology Simplified - USGS

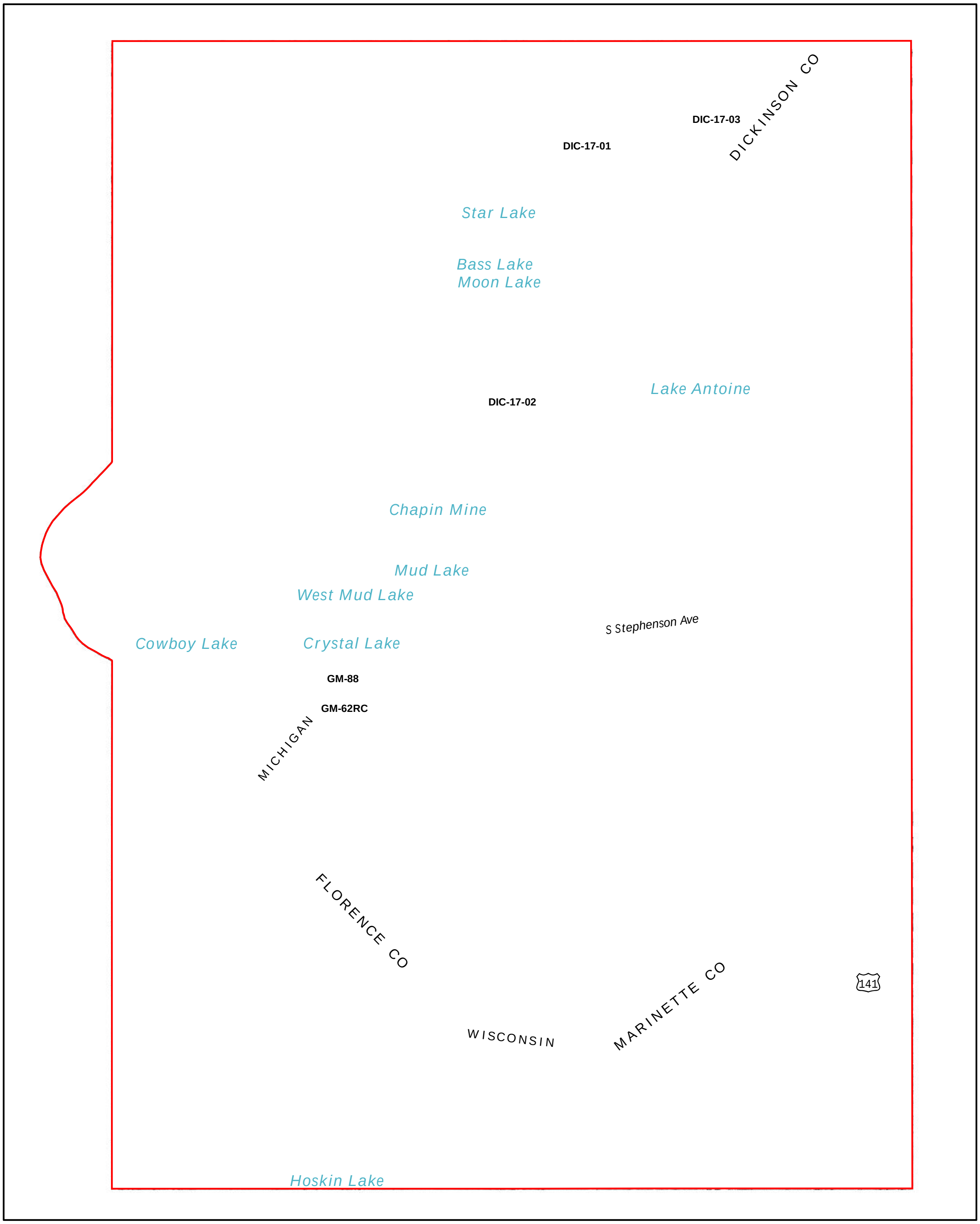


Cannon, William F., 1999, Digital Geologic Map of the Penokean Continental Margin

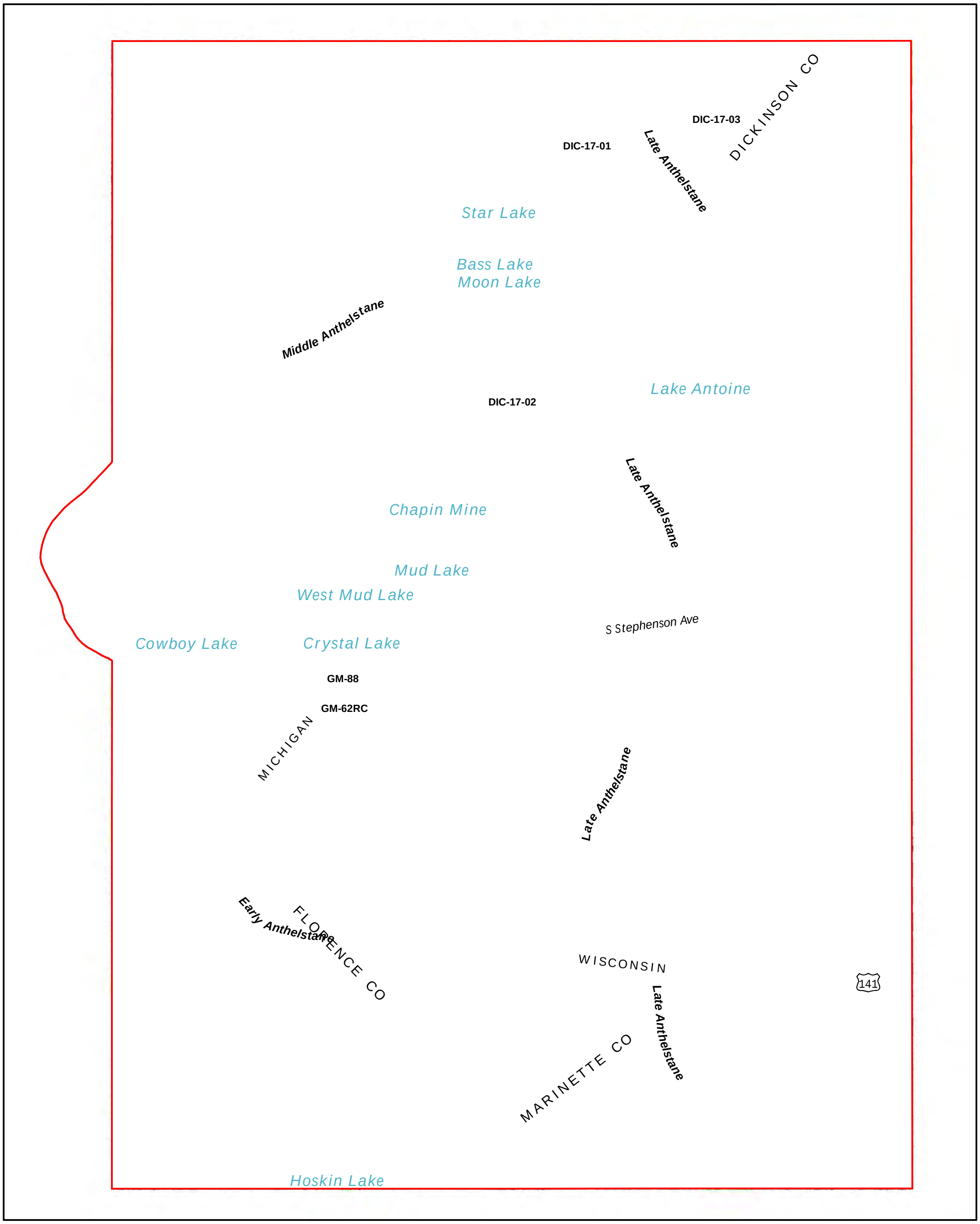


Geologic Cross-Section A-A'

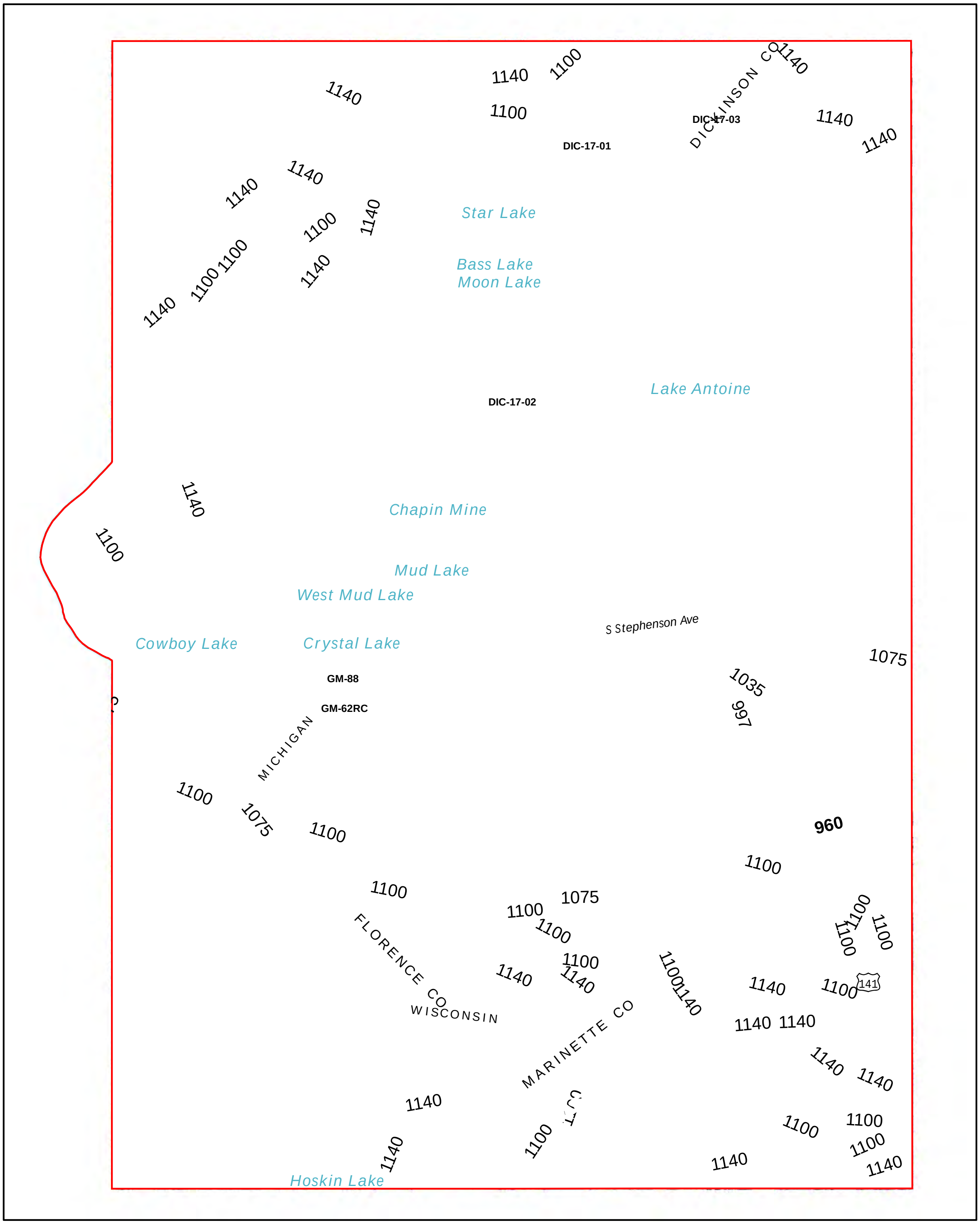
This cross-section is vertically exaggerated 50 times and water wells and borings are displayed if found within 400 feet of the cross-section line. There may be inaccuracies in the location of the water wells. Additionally, inaccuracies may be present in the lithology descriptions reported on the water well logs. Vertical lines have a 2000 feet spacing. Gamma-ray log curves are displayed for DIC-17-01, DIC-17-02, DIC17-03 and GM-88.



Iron Mountain Quad Hillshade



Iron Mountain Quad Qd, Ice Margins, Eskers, Ice- Walled Lake Plains and Drumlins

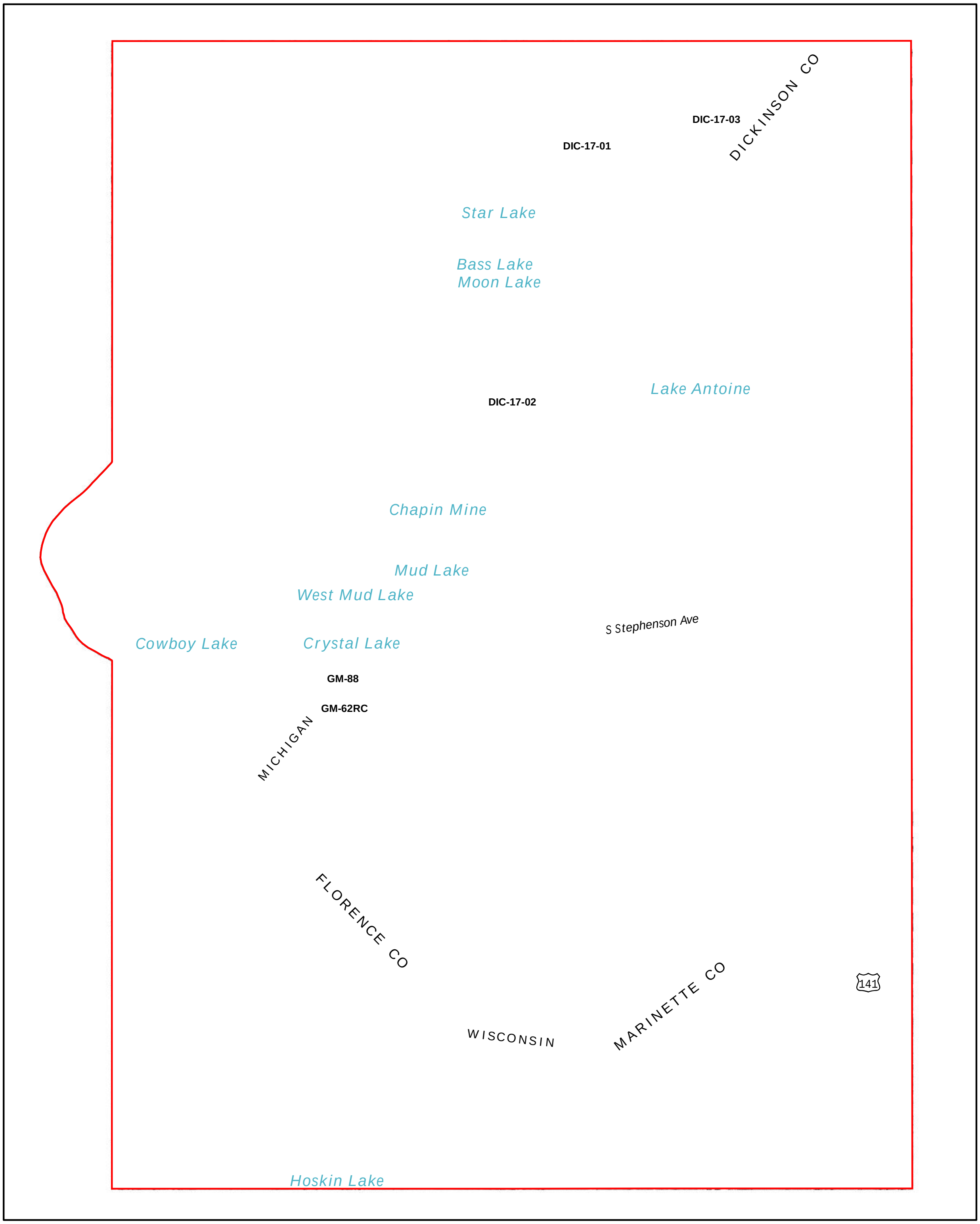


Iron Mountain Quad Qow,Qke, Qal, & Terraces

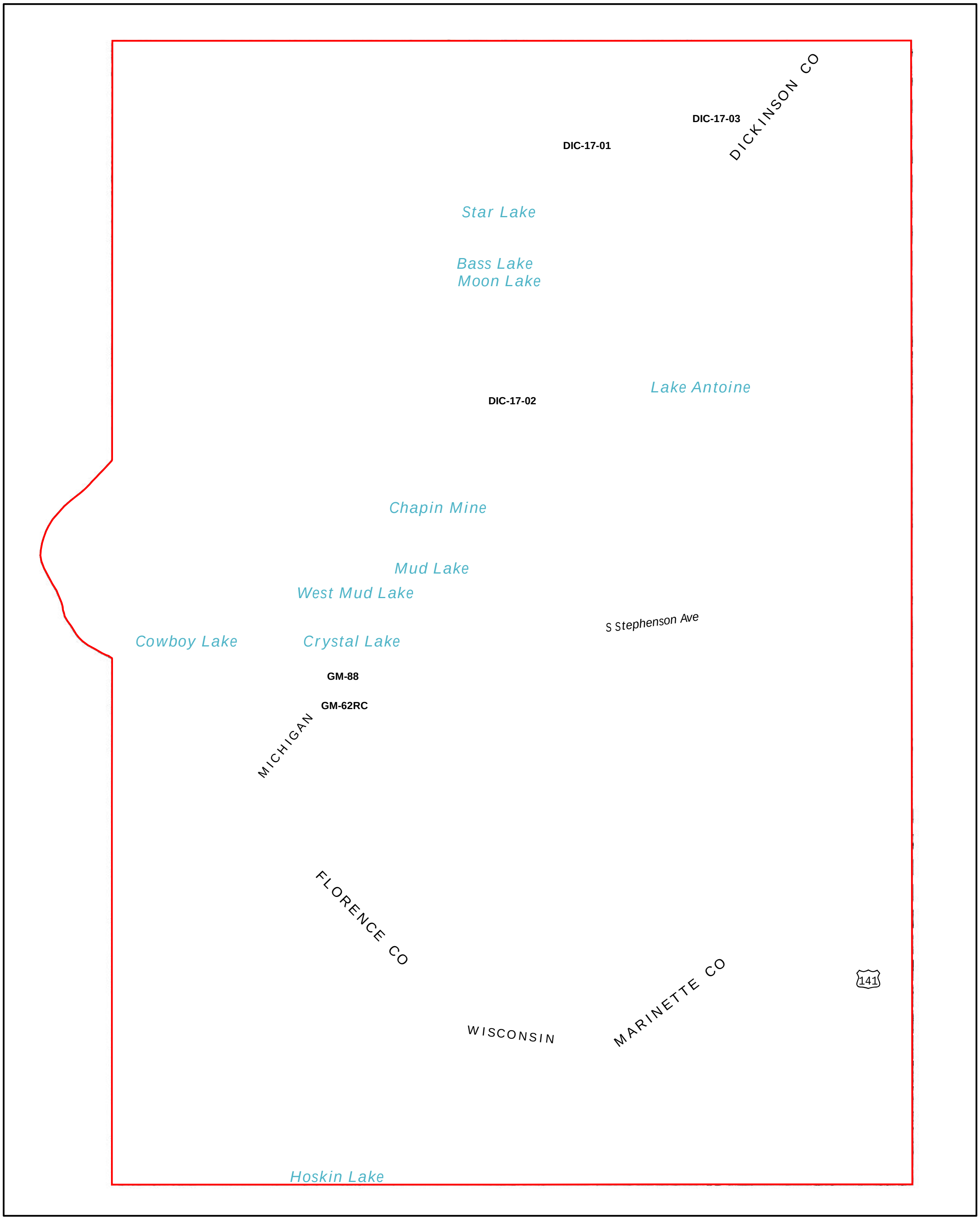
▨ RockOutcrops

0 0.5 1 2 Miles

N



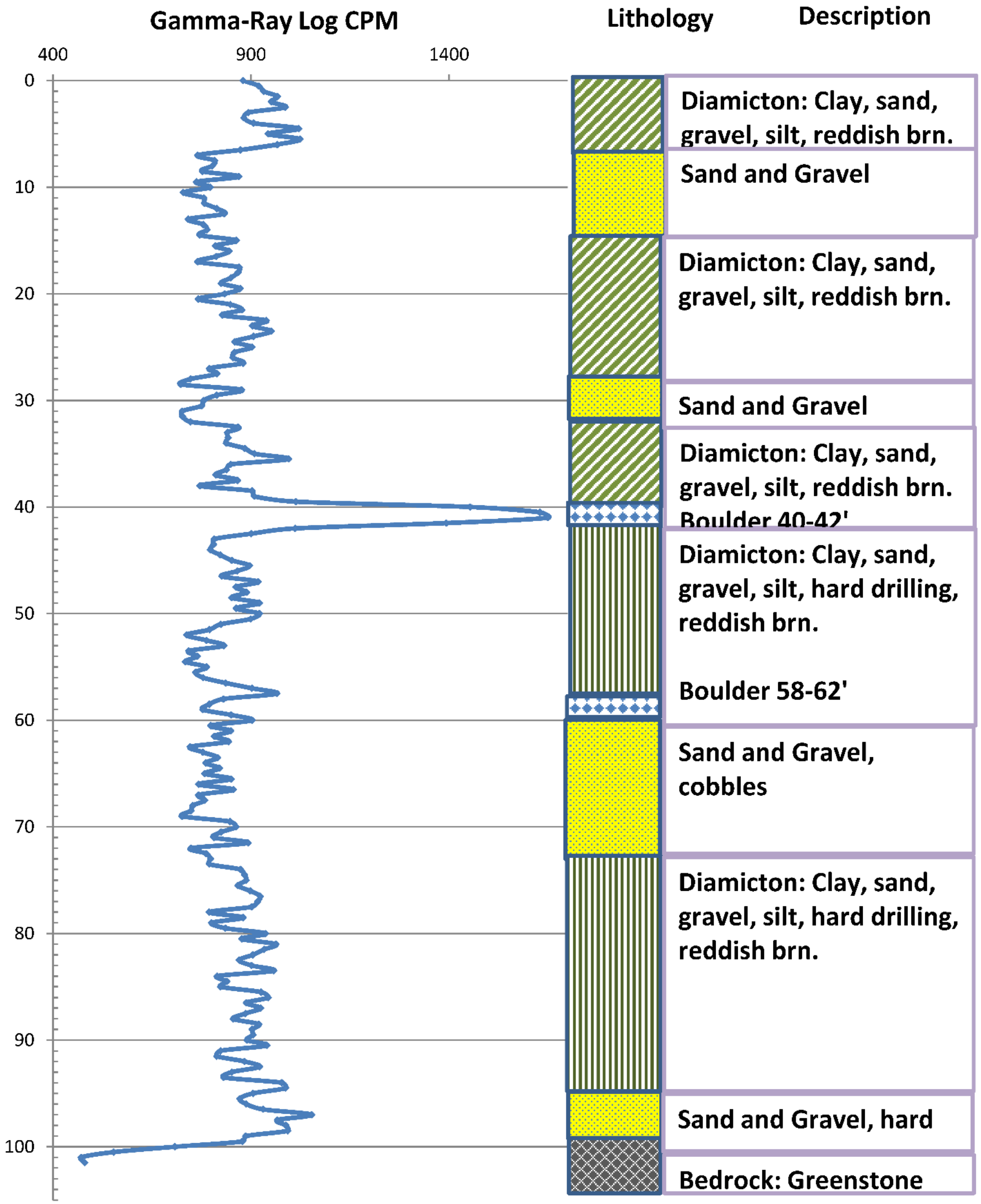
Iron Mountain Quad Sand & Gravel Pits



Iron Mountain Quad Borings, Hand Augered Borings/Road Cuts, HVSR Stations & OSL Sample

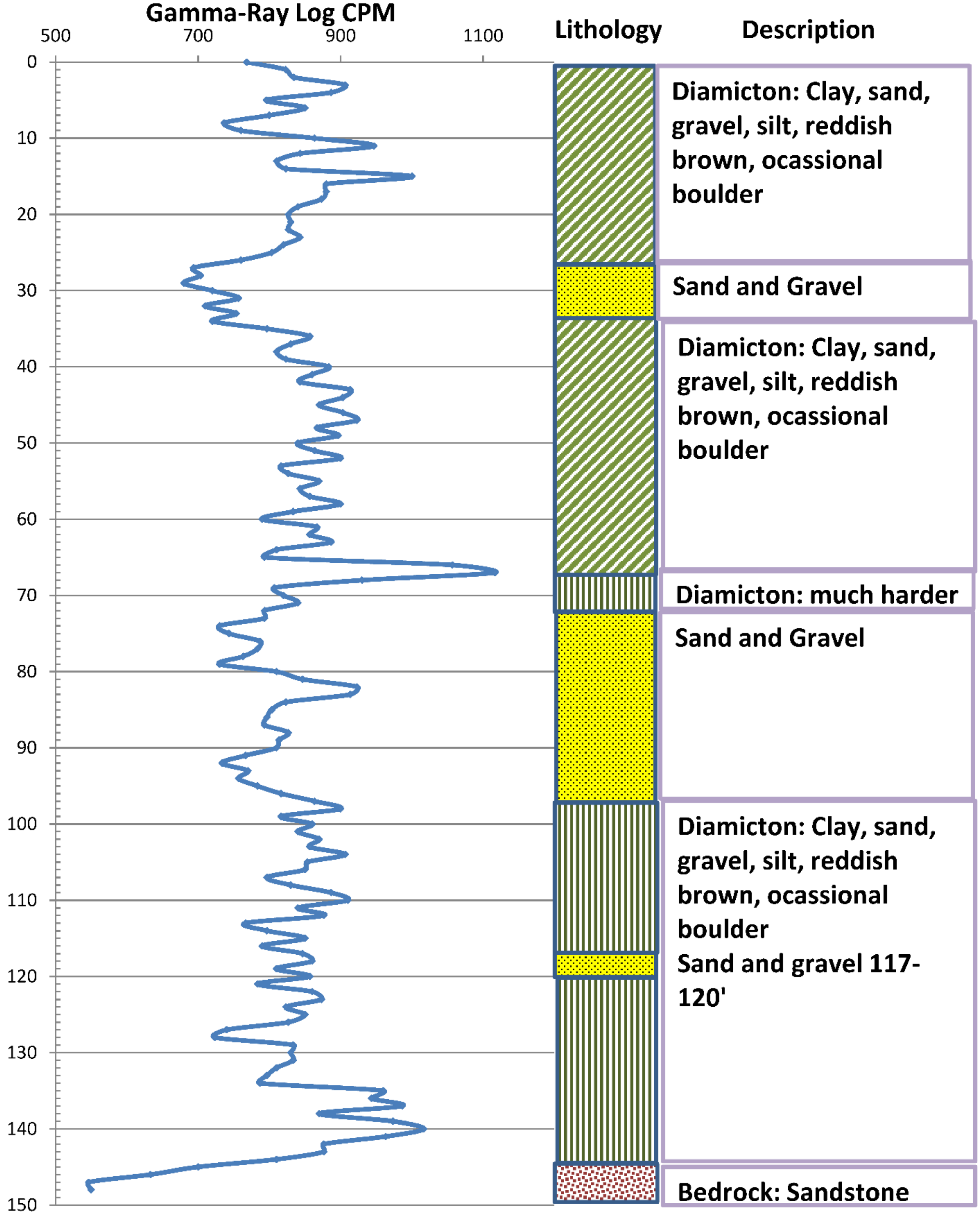
DIC-17-01

Iron Mountain Quad Boring   Total Depth 105 Feet   (45.862084, -88.055619)



DIC-17-02

Iron Mountain Quad Boring　Total Depth 150 Feet　(45.834251, -88.067306)



Diamicton: Clay, sand, gravel, silt, reddish brown, ocassional boulder

Sand and Gravel

Diamicton: Clay, sand, gravel, silt, reddish brown, ocassional boulder

Diamicton: much harder

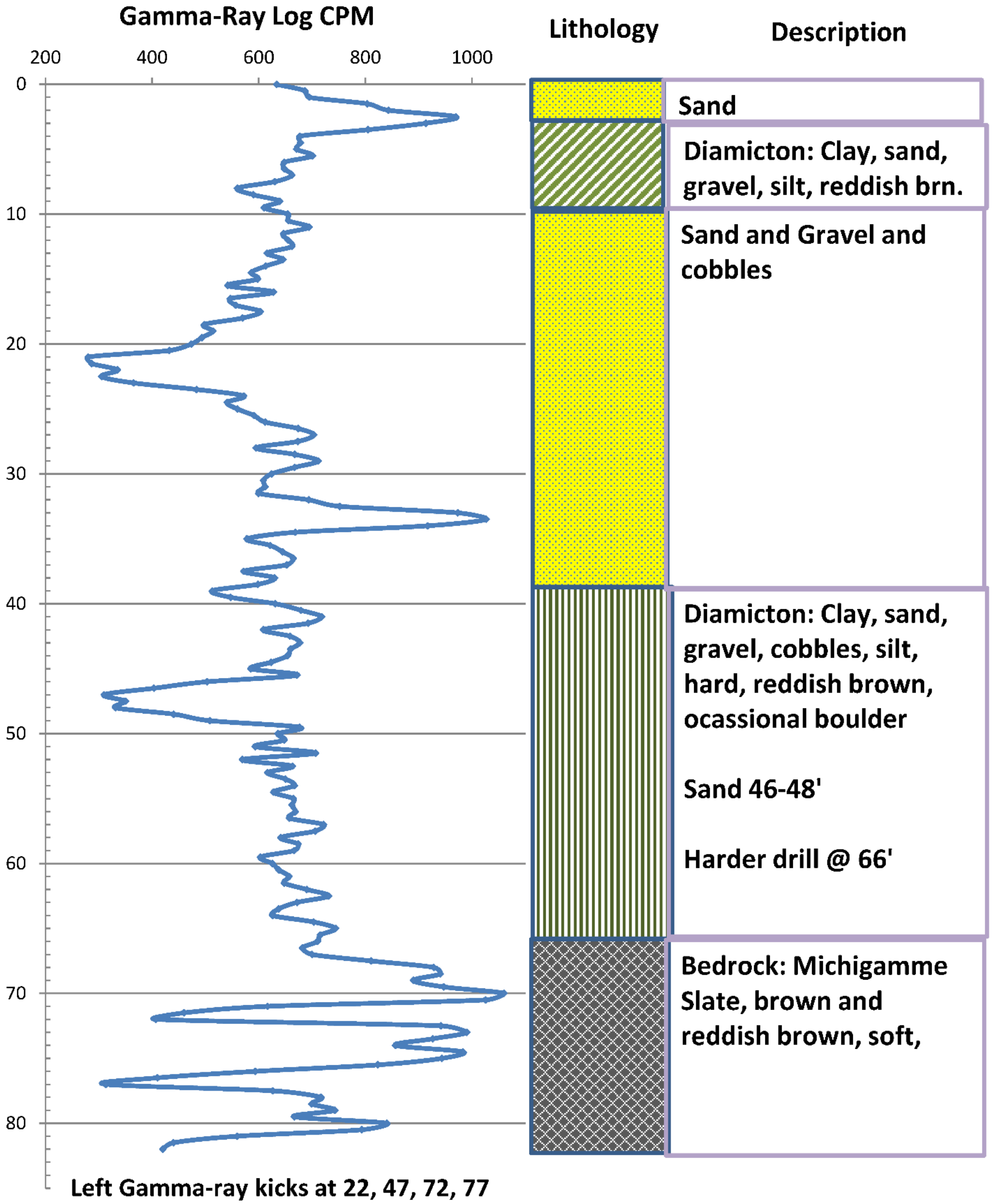
Sand and Gravel

Diamicton: Clay, sand, gravel, silt, reddish brown, ocassional boulder
Sand and gravel 117-120'

Bedrock: Sandstone

DIC-17-03

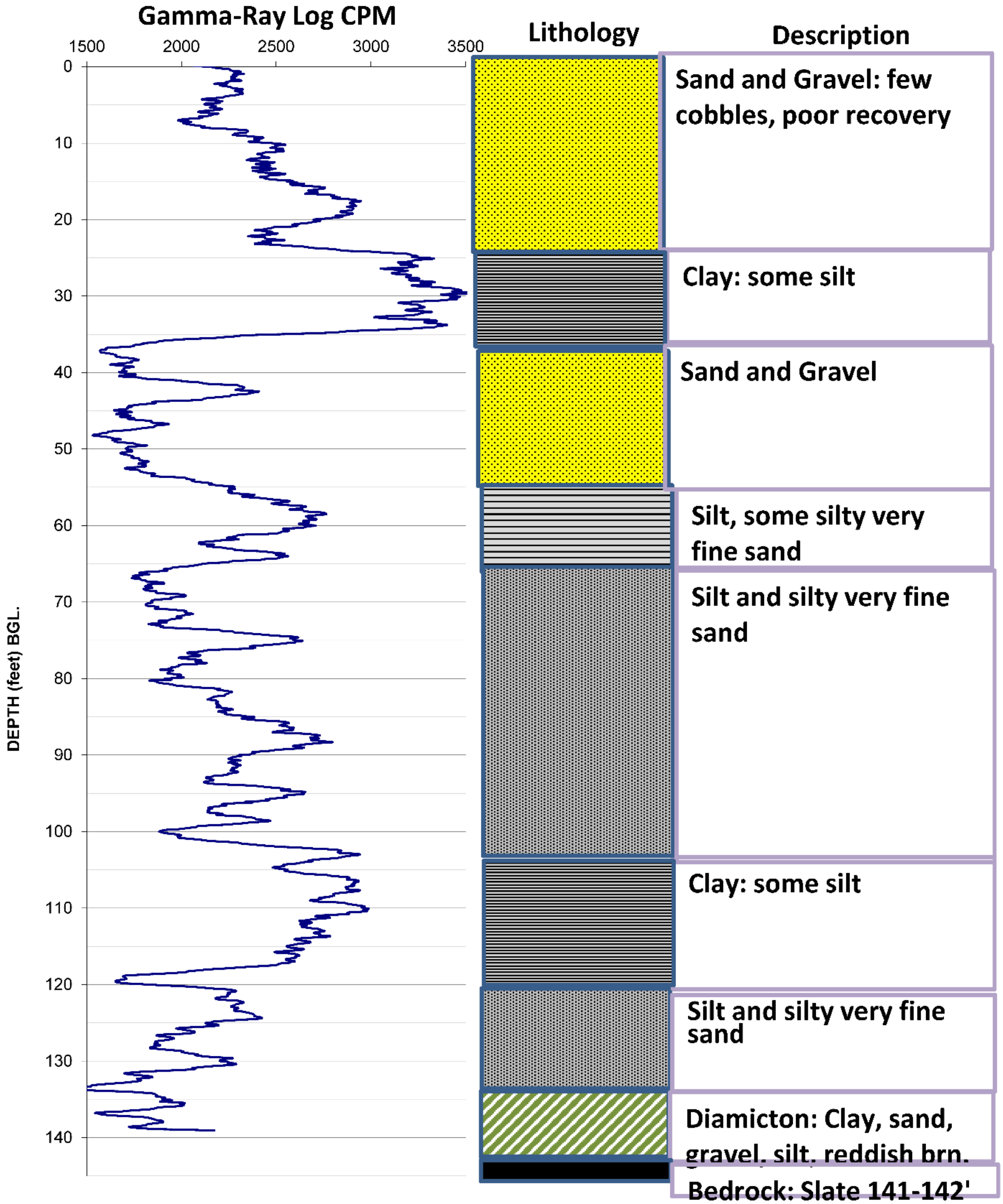
Iron Mountain Quad Boring Total Depth 85 Feet (45.865008, -88.035404)



Left Gamma-ray kicks at 22, 47, 72, 77 and 82 feet are due to drill pipe joints

Ford-Kingsford Products GM-88

Iron Mountain Quad Total Depth 142 feet (45.804173, -88.092462)

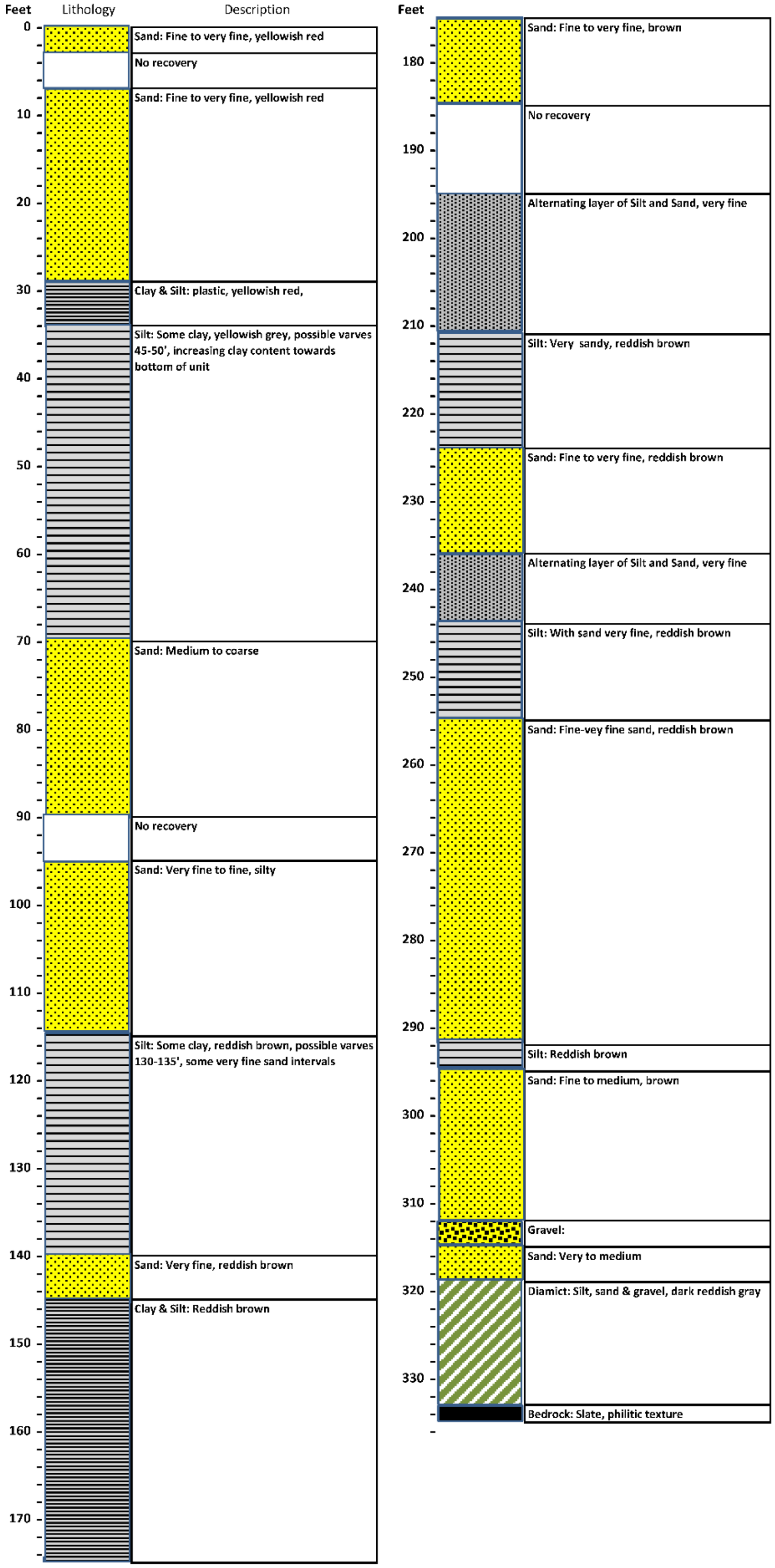


Logged inside 6" OD Rotosonic Casing. Left gamma-ray kick @ every 10' starting at 10 likely due to casing joints

Rotosonic
Boring

FORD KINGSFORD GM-62RC

Total Depth: 335 Feet
Iron Mountain Quad
Latitude: 45.800946
Longitude: -88.09338



Sand: Fine to very fine, yellowish red

No recovery

Sand: Fine to very fine, yellowish red

Clay & Silt: plastic, yellowish red,

Silt: Some clay, yellowish grey, possible varves 45-50', increasing clay content towards bottom of unit

Sand: Medium to coarse

No recovery

Sand: Very fine to fine, silty

Silt: Some clay, reddish brown, possible varves 130-135', some very fine sand intervals

Sand: Very fine, reddish brown

Clay & Silt: Reddish brown

Sand: Fine to very fine, brown

No recovery

Alternating layer of Silt and Sand, very fine

Silt: Very sandy, reddish brown

Sand: Fine to very fine, reddish brown

Alternating layer of Silt and Sand, very fine

Silt: With sand very fine, reddish brown

Sand: Fine-vey fine sand, reddish brown

Silt: Reddish brown

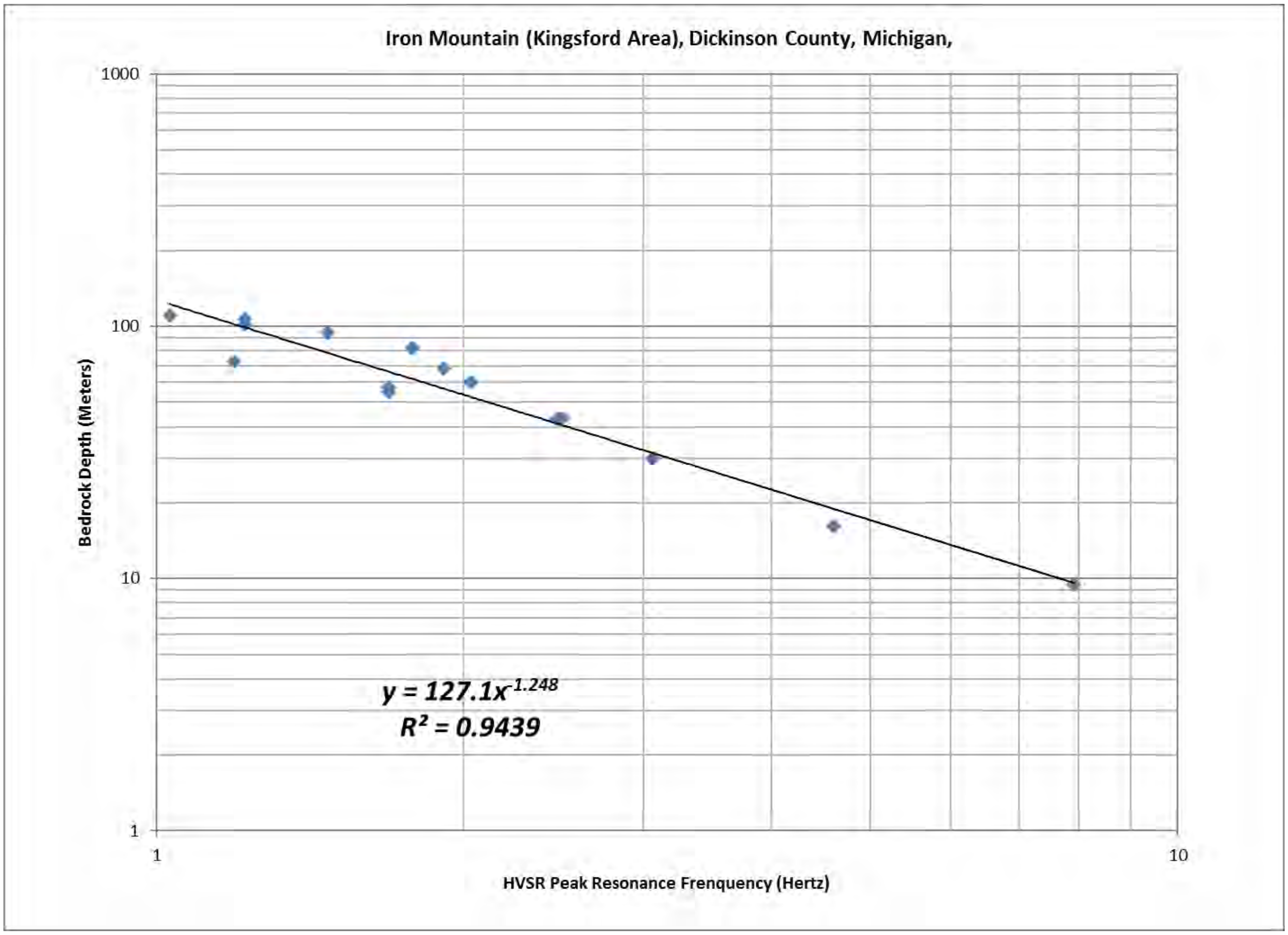
Sand: Fine to medium, brown

Gravel:

Sand: Very to medium

Diamict: Silt, sand & gravel, dark reddish gray

Bedrock: Slate, philitic texture



Iron Mountain area HVSR Calibration Curve