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Application of well log tomography to the Dundee and Rogers City Limestones, Michigan Basin, USA

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APPLICATION OF WELL LOG TOMOGRAPHY TO THE DUNDEE AND ROGERS CITY LIMESTONES, MICHIGAN BASIN, USA

By

Mellisa A. Le

A THESIS

Submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Geological Engineering

MICHIGAN TECHNOLOGICAL UNIVERSITY

2004

This thesis, "Application of Well Log Tomography to the Dundee and Rogers City Limestones, Michigan Basin, USA" is hereby approved in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in the field of Geological Engineering.

Department of Geological and Mining Engineering and Sciences

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Abstract

The Michigan Basin is located in the upper Midwest region of the United States and is centered geographically over the Lower Peninsula of Michigan. It is filled primarily with Paleozoic carbonates and clastics, overlying Precambrian basement rocks and covered by Pleistocene glacial drift. In Michigan, more than 46,000 wells have been drilled in the basin, many producing significant quantities of oil and gas since the 1920s in addition to providing a wealth of data for subsurface visualization.

Well log tomography, formerly log-curve amplitude slicing, is a visualization method recently developed at Michigan Technological University to correlate subsurface data by utilizing the high vertical resolution of well log curves. The well log tomography method was first successfully applied to the Middle Devonian Traverse Group within the Michigan Basin using gamma ray log curves. The purpose of this study is to prepare a digital data set for the Middle Devonian Dundee and Rogers City Limestones, apply the well log tomography method to this data and from this application, interpret paleogeographic trends in the natural radioactivity. Both the Dundee and Rogers City intervals directly underlie the Traverse Group and combined are the most prolific reservoir within the Michigan Basin. Differences between this study and the Traverse Group include increased well control and "slicing" of a more uniform lithology.

Gamma ray log curves for the Dundee and Rogers City Limestones were obtained from 295 vertical wells distributed over the Lower Peninsula of Michigan, converted to Log ASCII Standard files, and input into the well log tomography program. The "slicing" contour results indicate that during the formation of the Dundee and Rogers City intervals, carbonates and evaporites with low natural radioactive signatures on gamma

ray logs were deposited. This contrasts the higher gamma ray amplitudes from siliciclastic deltas that cyclically entered the basin during Traverse Group deposition. Additionally, a subtle north-south, low natural radioactive trend in the center of the basin may correlate with previously published Dundee facies tracts. Prominent trends associated with the distribution of limestone and dolomite are not observed because the regional range of gamma ray values for both carbonates are equivalent in the Michigan Basin and additional log curves are needed to separate these lithologies.

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Introduction

Purpose

Well log tomography (WLT), formerly termed log-curve amplitude slicing (LCAS), is a subsurface visualization technique that was developed at Michigan Technological University (MTU) by A. S. Wylie (2002). The technique is analogous to computed axial tomography or a CAT scan in the medical field that creates x-ray cross-sectional images or "slices" of a body and then combines them through the use of a computer to produce a three-dimensional image (Goldman, 2004). Similarly, WLT generates slices of the subsurface strata, but instead of constructing a three-dimensional depiction of the data, the slices are placed into a visualization program to be viewed in sequential order as a "movie."

The importance of WLT is that the technique improves subsurface imagery by utilizing the high vertical resolution of well log data. Wylie (2002) and Wylie and Huntoon (2003) successfully applied WLT regionally to the Middle Devonian Traverse Group of the Michigan Basin. Their results revealed the presence of previously unknown siliciclastic deltas feeding into the Michigan Basin from the east-southeast and northeast, and aided in the reconstruction of a relative water depth curve. The purpose of this study is to apply the same slicing technique to the Middle Devonian Dundee and Rogers City Limestones within the Michigan Basin, analyze well log amplitude patterns and compare these results with those from the Traverse Group. There were two primary reasons for choosing the Dundee and Rogers City, including proximity to the Traverse Group as well as the economic importance of the formations to Michigan oil production.

Background information for the study area is given below. This is followed by a literature review of past studies performed on the Dundee and Rogers City Limestones and a detailed description of their stratigraphy. Then the WLT method is described as well as a depositional model for the Dundee interval. The WLT results, discussions of slicing correlations, and conclusions are then presented. Lastly, suggestions for future work are included to further improve the delineation of new trends when slicing subsurface data.

Regional Setting

The intracratonic Michigan Basin is centered over the Lower Peninsula of Michigan and encompasses a circular surface area of 80,000 mi^2 if extended into portions of the Upper Peninsula, Ontario, Ohio, Indiana, Illinois and Wisconsin (Catacosinos et al., 1991). Figure 1 shows the outline of the Michigan Basin, bordering arches, and major anticline trends that follow the dominant northwest-southeast structural grain. Subsidence within the Michigan Basin occurred from Cambrian to Carboniferous time but was not laterally or temporally uniform (Fisher et al., 1988). Many mechanisms have been proposed to explain the irregular subsidence history of the basin including thermal contraction, metamorphic phase changes, lithospheric stretching, free thermal convection and intraplate stress mechanisms, but the origin remains uncertain (Howell and van der Pluijm, 1999).

The inwardly dipping sediments that fill the basin are sandwiched between Precambrian basement rocks and recent Pleistocene glacial deposits (Figure 2). This fill is comprised of Paleozoic (Cambrian to Pennsylvanian) carbonates, evaporites and clastics but the basin interior also contains younger, terrestrial Jurassic red beds. As shown in Figure 1, the Paleozoic and Jurassic bedrock geology form a concentric pattern, with progressively older rocks subcropping toward the perimeter. These rocks approach a thickness of 16,000 ft toward the basin depocenter but rarely outcrop at the surface because of the thick glacial drift, in some areas totaling 1,200 ft. Initially, these glacial deposits masked study of the underlying geology until oil exploration increased the quantity of and accessibility to subsurface data (Catacosinos et al., 1991).

Michigan Basin Oil

The earliest discovery of oil within the Michigan Basin occurred in 1858 at Oil Springs, Ontario (Dolton, 1995). Oil production within the state of Michigan did not occur until 1886 at Port Huron field in St. Clair County. Then in 1925, a large pool within Saginaw County, Michigan initiated heightened oil exploration and production within the basin (Catacosinos et al., 1991). Since this time more than 46,000 wells have been drilled within the Michigan Basin, cumulatively producing over 1.2 billion barrels of crude oil and condensate (Petroleum Technology Transfer Council- PTTC, 2004). Distribution of current Dundee-Rogers City production wells is shown in Figure 3. The Dundee-Rogers City unit accounts for approximately one-third (over 351 million barrels) of the total oil production within the basin. This figure surpasses all other cumulative totals for a single formation through 1986 but is closely trailed by production from the Salina-Niagaran formations, having produced 325 million barrels through 1986 (PTTC, 2004).

Literature Review

A description of the Middle Devonian "Dundee Limestone" was first published in 1895 by Alfred C. Lane based on the fieldwork of Charles E. Wright. In Lane's account, rock samples from deep borings were correlated to outcrops in various locations including Monroe County, Mason Creek quarries (Monroe County), and north of Mackinaw City. Lane identified the upper limit of the Dundee Limestone as "separating a great series of bluish grey or black, largely argillaceous rocks [Bell Shale], from a great series of buff, yellow or almost white, largely calcareous ones." Acid tests were then used to locate the lower limit, separating the Dundee Limestone from the underlying dolomite [Detroit River Group] (Lane, 1895).

The economic importance of the Dundee became apparent after oil production began in 1927 (Gardner, 1974), and this initiated subsequent studies on the formation. Subjects covered by these studies include the nature of the Dundee contacts (Newcombe, 1930); studies of the Dundee within individual oil fields, regions or counties (Newcombe, 1932; Addison, 1940; Landes, 1944; Landes, 1948; Kellum, 1958; Bush, 1983; Little, 1986; Curran and Hurley, 1992); investigations of fossils within the Dundee unit (Bassett, 1935; Ehlers and Radabaugh, 1938; Radabaugh, 1942;); mapping the Dundee distribution (Radabaugh, 1942; Cohee and Underwood, 1945; Lilienthal, 1978), studying dolomitization (Tinklepaugh, 1957; Bloomer, 1969); facies (Montgomery, 1986); stratigraphic correlations (Sanford, 1967); structure (Beckman and Whitten, 1969); stratigraphy (Gardner, 1974); as well as broad overviews of the Dundee in the context of the Michigan Basin (Fisher et al., 1988; Catacosinos et al., 1991).

A fundamental outcome of these studies was the revisions made to Lane's original stratigraphic nomenclature for the Middle Devonian Dundee unit. The first modification was the separation of the Dundee into two formations by Ehlers and Radabaugh (1938) based on a faunal distinction between the lower and upper Dundee in Presque Isle County. The upper formation, directly below the Bell Shale of the Traverse Group, was termed the "Rogers City limestone." Species of fossils in this unit closely correlated with the "Winnipegosan dolomite" in Manitoba, Canada and were different than those fossils of the underlying formation (Radabaugh, 1942). This lower formation was termed the "Dundee limestone" (Ehlers and Radabaugh, 1938). Cohee and Underwood (1945) applied this division on a regional scale via mapping the thickness of both the Rogers City and Dundee over the Michigan Basin primarily using drill cuttings. Not all workers, however, were able to distinguish the Rogers City from the Dundee and informally used the term "Dundee" to describe both limestone units (Kellum, 1958; Bloomer, 1969; Lilienthal, 1978; Little, 1986; Fisher et al., 1988; Catacosinos et al., 1991).

In response to the lack of continuity regarding Dundee terminology, Gardner (1974) proposed another revision. He used the term "Dundee Formation" to describe the rocks between the Bell Shale and the Detroit River Group. Within this formation, Gardner identified two members, the Rogers City and the Reed City. In 1986, Montgomery noted that the stratigraphic nomenclature remained "disjointed" and attributed the inconsistency to basing the formation and member names on either stratigraphic position, facies, diagenetic lithology or geographic position. In addition to these four factors, the writer notes that nomenclature is also dependent on whether the study is based on well cuttings, driller's logs, cores, fauna, mechanical log curves or a combination of these resources. In this paper, the term Rogers City Limestone and Dundee Limestone are used to describe separate formations (Figure 4) in concordance with the American Association of Petroleum Geologists (AAPG) Midwestern basin and arches correlation chart (Shaver, 1984). The Reed City will be considered a Member within the Dundee Limestone. A more detailed account of the literature with respect to the stratigraphy of the Middle Devonian units (Figure 4) is given in the following section.

Stratigraphy

Detroit River Group

The upper Detroit River Group directly underlies the Dundee Limestone (Figures 2 and 4) and is composed of a cyclic series of shallow-water dolomite, limestone, sandstone, anhydrite and salt, excluding shale (Lilienthal, 1978). In the Lower Peninsula, the Detroit River Group is everywhere present except in the extreme northern and southeastern regions (Figure 5). The contact between the Detroit River Group and the Dundee Limestone is irregularly marked by an erosional unconformity and is difficult to distinguish due to lithology similarities (Landes, 1951; Baltrusaitis, 1974). Lilienthal (1978) stated that this pick is often placed a few feet below the top of the Detroit River Group at the first anhydrite or is based upon other lithology characteristics when this anhydrite is not present. Gardner (1974) was one of the workers that used the anhydrite to define the contact except in the absence of anhydrite toward the southeast region of the basin, where he instead used a thin potassium-bentonite ash bed as described below. In this paper, the base of the Dundee is also picked at the first anhydrite within the Detroit River Group.

Kawkawlin Bentonite

The uppermost unit of the Detroit River Group contains a volcanic bentonite ash bed (Figure 4). Baltrusaitis (1974) proposed the name Kawkawlin Bentonite for this chronostratigraphic surface after the type well located in the Kawkawlin oil field, Bay County, Michigan. This bentonite can be regionally correlated to the Tioga Bentonite of southwestern Ontario (Baltrusaitis, 1974) and northern Indiana (Doheny et al., 1975). As shown in Figure 6, the ash-fall bed appears as a “spike” on gamma ray logs. Baltrusaitis

(1974) also identified a second ash bed above the Kawkawlin Bentonite, possessing a similar gamma ray signature but having a slightly different composition. This additional bentonite spike is not present in Figure 6 but can be observed in other gamma ray log curves throughout the basin.

Dundee Limestone

The Dundee Limestone is present throughout most of the Lower Peninsula. The formation outcrops in the northernmost counties, subcrops beneath the glacial drift in southeastern Michigan and is absent due to erosion in the southwestern tip of the Lower Peninsula (Figure 5). The Dundee Limestone is described as a "buff-to-brownish gray, finely to coarsely crystalline limestone" (Lilienthal, 1978; Catacosinos et al., 1991). In the westernmost regions of the basin, the Dundee is typically dolomite whereas both limestone and dolomite are present in the basin center. Primary and secondary porosity zones within the limestone and dolomite play a significant role in Dundee oil and gas production (Lilienthal, 1978).

The contact between the Dundee Limestone and the overlying Rogers City was originally described as conformable (Ehlers and Radabaugh, 1938; Tinklepaugh, 1957). Radabaugh (1942) made a detailed map of the northern Rogers City outcrop and showed that the limestone thinned from north to south across the basin but could not confirm if the absence of the Rogers City was due to erosion or non-deposition. A more recent publication by Curran and Hurley (1992), in their study of the West Branch oil field in Ogemaw County, stated that this contact is a disconformity, distinguished by a bored hardground due to a period of non-deposition that pyritized the top of the Dundee.

Reed City Member

The Reed City is a Member within the Dundee Limestone and is only present in the westernmost Michigan Basin (Figure 4A) and consequently could not be used as a regionally correlative surface for slicing. Gardner (1974) described the Reed City as a porosity zone containing both laminated anhydrite and massive dolomite deposited during a brief period of Dundee sea regression. This porosity zone is important because it produces both oil and gas (Lilienthal, 1978) and helps define the Dundee depositional environment.

Rogers City Limestone

The initial separation of the Rogers City Limestone from the Dundee Limestone was based on quarry exposures at Rogers City in Presque Isle County (Ehlers and Radabaugh, 1938). Shortly after this initial publication, Addison (1940) described the Rogers City based on subsurface lithology data at Buckeye oil field in Gladwin County. Addison noted that the Rogers City was darker and denser than the Dundee. Similarly, Landes (1944) described the Rogers City to be “waxy” and darker than the Dundee at Porter oil field in Midland County. Within this oil field, distinguishing between the Rogers City and the Dundee had economic importance as oil was produced directly beneath the Dundee-Rogers City contact (Landes, 1944).

The contact between the Rogers City and the overlying Bell Shale is readily apparent on gamma ray log curves (Figure 6). This contact was originally described as a disconformity (Ehlers and Radabaugh, 1938) based on local removal of 46 feet of Rogers City at Michigan Limestone and Chemical Company quarry in Presque Isle County.

Other workers such as Radabaugh (1942) and Ehlers and Kesling (1970) confirmed this disconformity, but relied upon data at the margin of the basin. Addison (1940) stated that the thickness of the Rogers City did not vary over an anticlinal structure in the Buckeye field of central Michigan. From this observation he concluded that the contact between the Bell Shale and the Rogers City appeared to be conformable. Gardner (1974) concluded that an unconformable relationship exists between the Rogers City and the Bell Shale at the basin margin but is conformable in the deeper, central region of the basin.

Bell Shale

The Bell Shale is the basal member of the Traverse Group and directly overlies the Rogers City Limestone. When the Rogers City is not present, in areas such as western and southern Michigan, the Bell Shale overlies the Dundee Limestone. In 1901, Amadeus W. Grabau first used the term "Bell Shale" when describing bluish colored shale in abandoned clay pits in southeastern Presque Isle County (Ehlers and Kesling, 1970). The Bell Shale Formation studied at quarries and from cores in Presque Isle and Alpena Counties, was deposited on an erosional surface at the top of the Rogers City Limestone.

The lower section of the Bell Shale contains crinoid fragments indicating turbulent water conditions whereas fossils in the upper section depict a calmer, deep-water environment (Ehlers and Kesling, 1970). Bloomer (1969) described a small calcareous unit (lag deposit) at the base of the Bell Shale in the southwest region of the basin and traced it moving upward through the Bell Shale toward the northeast. He interpreted this trend to be the product of a northern sea transgressing across the basin.

Well Log Tomography Introduction

Well logs are records of subsurface drilling and include driller's logs, sample logs, mud logs and wireline logs. Driller's logs contain observations involving rocks and fluids that emerge during drilling. Sample logs are physical pieces of subsurface rock taken from the borehole and consist of either cuttings or cores. Mud logs describe the lithology of cuttings and are recorded at the well site by a geologist. Wireline logs record various properties in the subsurface and include electric, radioactivity or acoustic logs (Van Dyke, 1997).

The WLT method employs wireline logs. Wireline tools can record data at every foot within a borehole. However, as described by Wylie (2002), common practice is to average wireline log curve amplitudes when correlating well data. Consequently, Wylie's primary objective for creating the slicing program (WLT) was to analyze well log curves without compromising their vertical resolution (Wylie, 2002; Wylie and Huntoon, 2003). A schematic of the slicing technique is shown in Figure 7 for the combined Dundee-Rogers City Limestones. By creating a slice at every foot, the full vertical resolution contained within the log curve data is preserved in each well. The log curve amplitude for each well along a slice are then plotted and contoured in plan-view.

This study uses the gamma ray wireline log that records the natural radioactivity of a formation due to the presence of three radioisotopes, uranium (^{238}U), potassium (^{40}K) and thorium (^{232}Th). As the isotopes of U, K and Th decay, they emit short bursts of electromagnetic energy that can be measured by a gamma ray sensor. The American Petroleum Institute unit (APIU) is used as a measurement for gamma ray logs and is based on an artificial formation located in Houston, containing known values of U, K and

Th. A basic gamma ray log records the combined energies from U, K and Th whereas a spectral gamma ray log separates the signal into its three components. Basic gamma ray logs were only available for this study with the exception of the Prevost et al. #1-11 well, permit 37770 in Bay County that had both a spectral and basic gamma ray log. Values from the spectral gamma ray log were too low to detect the source components using the Schlumberger CP-19 mineral identification chart (Schlumberger, 1986) and consequently will not be further discussed.

Gamma ray logs are useful for lithology studies because different types of sedimentary rocks exhibit a general range of gamma ray responses. Dewan (1983) stated that generally, pure limestone and anhydrite measure 15-20 APIU, dolomite and sandstones range between 20-30 APIU, and shales and volcanic ash (potassium-bentonite) measure high, on average 100 APIU. The Dundee-Rogers City gamma ray log curve for the Croton #1-30 well, permit 41892 located in Newaygo County, is shown in Figure 8. The lithology from a core analysis by Gardner (1974) on a nearby well is also shown. In this well, anhydrite primarily ranges from 10-14 APIU, limestone averages 16 APIU and dolomite covers a broad range, between 10-50 APIU. The Bell Shale, located at the top of the figure, continues off-scale and averages approximately 120 APIU.

Methods

Part 1

Preparation of Digital Log Files

The initial step in the preparation for performing WLT is to gather all the Log ASCII Standard (LAS) files within the area of interest, in this case, the Lower Peninsula of Michigan. These files were obtained digitally from commercial entities such as Maness Petroleum Corporation (Mt. Pleasant, Michigan) or were digitized in-house at MTU from paper logs. Over 900 digital well logs within the Lower Peninsula were reviewed from the Spatial Subsurface Visualization Laboratory database at MTU (Figure 5) and are listed in Appendix A.

The 295 final wells used for slicing were selected based upon two primary criteria. Most importantly, the wells had to contain a gamma ray curve throughout the entire Dundee and Rogers City interval. Incomplete or missing gamma ray curves accounted for twenty percent of those wells needing to be discarded. Secondly, groupings of wells within close proximity to one another were eliminated in order to obtain a uniform distribution over the basin. For example, after reviewing each well from an oil field or cluster within a county, only one or two representative wells were chosen instead of keeping every well that met the first criterion. This eliminated seventy-five percent of the LAS files. The remaining five percent of excluded LAS files were removed based on duplicate or triplicate files, deviated well, digitizing errors, outliers, or wells that appeared questionable to the writer.

Formation Tops Data

The WLT technique slices log curve data between two correlative surfaces. Wylie and Huntoon (2003) stated that if these bounding surfaces can be defined as unconformities, sequence boundaries, parasequence boundaries, flooding surfaces, condensed sections or ash beds, then the slicing image results would be chronostratigraphically significant. An example of a chronostratigraphic surface would be the images that a satellite captures of the modern depositional surface.

Originally, the Dundee and Rogers City Limestones were not separated in this study because the location of their contact, based on previous publications, could not be identified with a high level of certainty using gamma ray logs. The top of the combined “Dundee” limestone was picked at the inflection point on the gamma ray log curve between the Bell Shale and the “Dundee” for every well (Figure 5). The inflection point was chosen as the contact because the complete change from shale to limestone on the logs was typically within the 3-4 ft vertical resolution range for the gamma ray data (Dewan, 1983). In general, the top of the “Dundee” was easier to identify in the center of the basin than in the southwest where the Bell Shale unit pinches or laps out (Figure 9A). Most of these picks were equivalent to the top values within the Department of Natural Resources (DNR) database.

The base of the “Dundee” was defined at the first anhydrite within the Detroit River Group. This pick was most consistent when the density log curve was available (Figure 5) and became more difficult in the southeastern part of the basin where log signatures for both units become exceedingly similar (Figure 9B). These top picks were fairly consistent with the DNR database.

The top boundary of the “Dundee” is marked by an abrupt lithology change as well as an unconformity at the basin margins (Gardner, 1974). This correlative surface may be chronostratigraphically significant although Bloomer (1969) stated that, “the Dundee [including Rogers City] is not time equivalent” due to varying rates of deposition, such that increased distance from this surface would decrease the time significance of a given slice. Similarly, slices from the base of the “Dundee” only illustrate approximate time surfaces.

Borehole Corrections

Borehole effects are important to note in this study as they can affect the gamma ray response. Conditions for calibration of the gamma ray tool are defined by Dewan (1983) to include a hole diameter of 8-in, 10-lb drilling mud, and an eccentered logging tool with a 3 5/8-in diameter. A dampened gamma ray response can be attributed to an increase in either the hole diameter or mud weight, or with the use of a centralized logging tool. Conversely, a smaller hole would shift the log curve toward higher gamma ray values (Dewan, 1983).

Charts such as the Schlumberger Por-7, provide correction factors that account for borehole effects using the hole diameter, mud weight and tool position (Schlumberger, 1986). Although the mud weight was typically recorded in the LAS files, neither the hole diameter or tool position were available in the LAS files or on paper logs of the wireline data. Consequently, a typical borehole correction could not be performed and is noted as a source of error in the data set.

Casing sizes, ranging from 4 1/2-in to 13 5/8-in, for 217 wells within the “Dundee” interval were available. By observing the gamma ray values for individual wells within the basin, there appeared to be no direct correlation between the casing size and the gamma ray amplitude. The casing sizes were then used as a proxy for borehole diameter and plotted against the gamma ray response for each well to observe possible relationships that could aid in applying a borehole correction. Figure 10 illustrates two cross-plots used to determine the necessity for a borehole correction. The figure includes (A) the average gamma ray value for the "Dundee" interval in each well plotted as a function of casing diameter and (B) standard deviation of the gamma ray values for the "Dundee" interval in each well plotted as a function of casing diameter. From these graphs, there is no apparent relationship between the casing size and the gamma ray values. Figure 11 highlights a trend between the distribution of low casing sizes and the standard deviation of the gamma ray values for each well. The cause of this relationship in the center of the basin, but not consistently over the entire basin, is unknown.

Normalization

Neinast and Knox (1974) and Hunt et al. (1996) stated that more than half of wells studied need to be normalized. Normalization is a correction applied to erroneous well log data to ensure that there is consistency between wells regarding the amplitude of the log curve response. The WLT technique examines amplitude changes rather than absolute amplitude values, but normalization was investigated because different types of errors can alter the amplitude change. "The basic sources of error are tool malfunction, incorrect tool design, inconsistent shop and field calibration, and operator error" (Neinast and Knox, 1974). In addition to these sources, Shier (1997) showed significant varying gamma ray responses based on a combination of logging contractors, drilling medium, and tool vintages. Hammack and Fertl (1974) described subsurface conditions that cause increased gamma ray amplitudes such as previously perforated intervals with salt present from old drilling fluid, fluid movement behind casing, and the presence of radioactive sandstones and carbonates. Hammack and Fertl also stated that "interpretation of gamma ray logs is straightforward if correctly calibrated and proper time constant and logging speed are used," although these log constraints are typically unknown for well logs within the Michigan Basin.

The normalization process includes defining a standard curve signature from either one well or a combination of representative wells. This "standard" can be based on a unit of sufficient lateral extent such as a shale layer, a low porosity carbonate or thick sandstone with low porosity. Each well used in the study is then normalized with the standard (Hunt et al., 1996). In this study, a standard formation either above or below the Dundee-Rogers City interval was difficult to identify because of lithology changes across the basin and incomplete digital gamma ray log curves. The Dundee-Rogers City interval was then analyzed to determine if it had a unique log curve signature that could be used as the standard to correct erroneous log amplitudes. This analysis consisted of creating frequency histograms of the gamma ray values within the Dundee-Rogers City interval for individual wells throughout the basin. Appendix B shows 18 histograms to illustrate the internal complexity of the Dundee-Rogers City interval. Consequently, normalization using one standard for the entire basin could not be performed because the correction was beyond the scope of this study and is noted as a source of error.

As a broad normalization for the 302 wells that were preliminarily sliced, a composite frequency histogram was constructed using the average gamma ray value for the Dundee-Rogers City interval in each well (Figure 12A). Of the 302 wells, all but seven wells fell within two standard deviations that equal about 95 percent of the data. Four wells were within the third standard deviation (99.7 percent of data) and three wells were far beyond the mean value. All seven wells were further analyzed and excluded from the final slicing (Figure 12B).

Slicing using Slice 2: "Dundee" Interval

Slice 2 is a Visual Basic computer program created at MTU by C. Asiala. This program is a modified version of the LogMovie program, also created by Asiala, which was used to slice the Traverse Group (Wylie, 2002; Wylie and Huntoon, 2003). The major difference between the original LogMovie and the Slice 2 program is that Slice 2 uses the Golden Software Surfer program to create contour maps of the log data whereas LogMovie used Production Analyst.

There are four forms and one module that comprise the Slice 2 program. The forms include Files and Parameters, Testing Options, LAS Database and Analysis. The Files and Parameters form (Figure 13) requires the user to define various aspects of the slicing components including the location of the LAS files, basemap parameters, color scale and contour interval, the log curve to be sliced and the direction of slicing (bottom-up or top-down). The Testing Options form allows the user to complete the slicing in separate steps (create test files, slice files, surfer plots or a surfer poster). The LAS Database form retrieves the gamma ray values from the LAS files and inputs them into an Access database. The Analysis Form relies on this Access database to create a text file, where separate permit numbers define each row, and every column contains the gamma ray value for one slice. This form also alerts the user to any errors before the slicing images are created. The Mod1 module contains Surfer script commands for gridding the data and generating the slicing contour maps.

The parameters used for slicing the "Dundee" interval include top-down slicing, natural neighbor gridding algorithm (Appendix C), and varying contour intervals (3, 6, 12 and 15 APIU) and color scales. Confidence in the top pick for the "Dundee" surface justified performing the top-down method. The gridding algorithm was chosen such that the contouring would not extend beyond the well control because the "Dundee" thickness varies considerably throughout the basin (0-400+ ft). The first slicing trials used higher contour intervals (12 and 15 APIU) and a color scale similar to the Traverse Group study (blues: <40 APIU, green-yellow: 40-80, brown-red: 80-150) (Appendix D). The contour interval was reduced in subsequent slicing to enhance the trends in the data. The smallest contour interval used, 3 APIU, provided the best resolution because of the narrow "Dundee" gamma ray range (3-30 APIU). This interval is equal to the absolute magnitude deviation for clean carbonates, ±2-4 APIU (Dewan, 1983), but was still used to observe general trends. The contour color scale, for a three-foot contour interval using ten colors over a 0-30 APIU range, was repeatedly adjusted to better highlight trends within the data. The final color scale chosen incorporates varying shades of blue as well as green for the uppermost limits. These colors are comparable to the Traverse Group blue shades (<40 APIU) (Appendix D).

Part 2

Kawkawlin Bentonite Top Data

To expand upon the initial WLT results, bottom-up slicing was performed using the Kawkawlin Bentonite as a chronostratigraphic surface. The ash bed is positioned below the base of the Dundee Limestone and slicing from this surface initially generates contour images for the uppermost section of the Detroit River Group before ascending into the Dundee. The Kawkawlin Bentonite was generally easy to identify using the gamma ray log and was picked at the peak (highest APIU) of the bentonite spike because the layer is thinner than the three-foot vertical resolution of the gamma ray log curve (Dewan, 1983).

From the 295 logs used in this study, 172 had an evident bentonite pick. The remaining wells either showed no spike, from the inability of the gamma ray log to consistently resolve the thin ash bed (Baltrusaitis, 1974); or contained more than one spike, making the Kawkawlin Bentonite indistinguishable from similar high gamma ray values. A structure contour map for the 172 wells containing the Kawkawlin Bentonite is shown in Figure 14 and illustrates the difficulty in identifying the Kawkawlin Bentonite in the northern part of the basin.

Slicing using Slice 2: Kawkawlin Bentonite Bottom-up

The bottom-up slicing from the Kawkawlin Bentonite used the parameters established during the previous “Dundee” slicing. These parameters include the natural neighbor gridding algorithm, a three APIU contour interval and the “blue” color scale. As the Kawkawlin Bentonite is a chronostratigraphically significant surface, the images generated from the bottom-up slicing represent the paleogeography of the sediment natural radioactivity during late Detroit River deposition (Wylie, 2002; Wylie and Huntoon, 2003).

Part 3

Rogers City and Dundee Tops Data

A complete analysis of the "Dundee" resulted in the separation of the Rogers City Limestone from the Dundee Limestone for the final slicing. The Rogers City interval across the basin was difficult to identify based solely on gamma ray logs. Consequently, the extent of the unit in this study was modeled after a map of the Roger City thickness prepared by Cohee and Underwood (1945) based on well cuttings. From this correlation, 216 of the 295 total wells were identified as containing the Rogers City Limestone. The predetermined "Dundee" top pick was used as the top surface for the Rogers City and the lower surface, the new Dundee Limestone top, was estimated based on the Cohee and Underwood (1945) isopach values.

Baltrusaitis (1974), in his study of the Kawkawlin Bentonite and its chronostratigraphic significance, stated that the top of the Rogers City Limestone "very closely represents a time line." If this statement is true, the slicing results from the Rogers City top pick should closely represent time surfaces during deposition. Curran and Hurley (1992) described the base of the Rogers City as a sequence boundary in the center of the basin. This suggests a possible basin-wide chronostratigraphic basal surface although slices from the bottom of the Rogers City can only represent approximate time surfaces as this surface was estimated.

From the Dundee and Rogers City correlative surfaces, structure contour and isopach maps were created. The Rogers City and Dundee structure contour maps are shown in Figure 15 and 16 respectively. The shape of the Dundee structure contours are similar to the structure contour map previously published by Catacosinos et al., 1991. The Rogers City and Dundee isopach maps are shown in Figures 17 and 18 respectively. Curran and Hurley (1992) published an isopach map similar in shape to the Dundee isopach map.

The location of each contact from tops picks described in the above sections is illustrated in relation to one another on a SW-NE cross-section (Figure 19). This figure shows the thickening of the Rogers City and Dundee toward the northeast and the pinching out of both the Bell Shale and the Rogers City units toward the southwest. The disjointed Kawkawlin Bentonite surface is also demonstrated by the absence of the gamma ray "peak."

Slicing using Slice 2: Rogers City and Dundee Intervals

After separating the Rogers City Limestone from the Dundee Limestone, both units were sliced using the top-down and bottom-up methods. The slicing parameters used were equivalent to those described for the Kawkawlin Bentonite. Recent work by Curran and Hurley (1992) stated that the contact between the Rogers City and Dundee Limestone is a disconformity, indicating that the slices generated from this surface should be chronostratigraphically significant if the rate of deposition remained constant throughout the basin. As stated earlier, Bloomer (1969) determined that deposition was not constant during Dundee time. Review of the Dundee Limestone and Rogers City Limestone surfaces indicates that the slices created using the WLT method should create general trends in the gamma ray amplitudes over the basin as opposed to the actual paleogeography.

Depositional Model

The Michigan Basin's paleogeography during Dundee-Rogers City time (376-380 Ma) was approximately 20°S and modeling of the tropical paleoclimate illustrates that the mean temperature would have averaged 75° Fahrenheit (24° Celsius) (Golonka et al., 1994). Gardner (1974) presented a comprehensive interpretation for this Middle Devonian depositional environment using well cuttings, cores, driller's logs and gamma ray-neutron wireline log curves. In his conceptual model, the basin was divided into three zones, where sediments in the western region of the basin indicate a sabkha-lagoon environment, separated from an eastern open marine environment by a north-south trending shell bank (Figure 20A). A westward transgressing sea and an intermediate regression during Reed City deposition controlled this environmental differentiation (Gardner, 1974).

Many workers applied the Rogers City-Dundee depositional model proposed by Gardner (1974) to their own studies (Lilienthal, 1978; Bush, 1983; Fisher et al., 1988; Catacosinos et al., 1991; Howell and van der Pluijm, 1999). Prior to Gardner's (1974) division of the Michigan Basin, Cohee and Underwood (1945) illustrated a similar north-south separation based on Dundee and Rogers City oil production. Wells west of Gladwin and Midland counties produced primarily from the Rogers City whereas, wells east of this divide produced from the Dundee. Montgomery (1986) and Curran and Hurley (1992) separated the Rogers City and Dundee depositional environments in the center of the basin. The Rogers City Limestone was described as open-marine, and the Dundee Limestone as patch reefs (Montgomery, 1986) or a shallow platform environment (Curran and Hurley, 1992).

The most recent interpretation of the late Dundee depositional environment was presented by Taylor (2001) and closely resembles Gardner's model (Figure 20B). Taylor used a high density of well log curves to separate the sabkha from the lagoon environment and identify smaller scale features such as tidal channels, barrier islands and patch reefs. The drawback to typical models such as those shown in Figure 20 is that they only provide one generalized representation of the depositional environment whereas the WLT technique attempts to depict the evolution of depositional patterns.

Results

A summary of the top-down and bottom-up sliced intervals is shown in Figure 21. The total number of slices created for each unit is equal to the number of feet in the thickest interval. Once the slicing exceeds the interval thickness for a particular well, the well is “dropped.” The gamma ray contours are not extrapolated past the dropped wells, causing the contoured area to shrink as slicing advances. Due to this progressive loss of well control, presentation of the slice images will concentrate on the initial slices. Consequently, both slicing directions (top-down and bottom-up) were implemented to better observe changes in the gamma ray amplitude trends within the entire Rogers City and Dundee units. Each of the six intervals analyzed has a respective figure that presents slice “snapshots” generated from the WLT slicing program. The slice images are described below and are followed by a discussion of the results.

“Dundee” Limestone: Top-down Slice Images

Top-down slicing results from the contact between the Bell Shale and the “Dundee” are shown in Figure 22. The contour interval is 15 APIU and the color scale ranges from 0-150 APIU similar to the Traverse Group study. The first slice occurs at the inflection point between the shale and limestone and contains the highest gamma ray values. Progressing down toward the Detroit River Group, the gamma ray values consistently remain below 30 APIU. Based on these values, the “Dundee” is composed of relatively uniform carbonates that lack naturally radioactive material such as clay. The only trend illustrated from the slice images is the appearance of lower gamma ray values in the northern region of the basin (Figure 22, slice 25), that elongate southward (slices

46 to 70) forming a trend similar in shape and position to the shoal bank in Gardner's (1974) depositional model. Reworking of carbonate sediments by wave action within a shoal environment could remove the natural radioactive material to produce a slightly "cleaner" gamma ray region.

Kawkawlin Bentonite: Bottom-up Slice Images

Bottom-up slicing from the Kawkawlin Bentonite is shown in Figure 23. The first slice occurs at the gamma ray peak and slicing continues through the Detroit River into the Dundee. The thickness of the Detroit River between the Kawkawlin Bentonite and the base of the Dundee is relatively consistent throughout the basin (Figure 19) although variations cause the slices to cut across the Detroit River-Dundee contact and ultimately become less accurate as slicing progresses away from the bentonite surface.

Selecting a set of representative slice images was difficult because the contour patterns were constantly changing. The Kawkawlin Bentonite is present in the first three slices, appearing as green contours (24-30 APIU). For most of the slices (1 to 148) the average gamma ray values range from 3-15 APIU increasing to 9-21 APIU for the remaining slices (179 to 213). The most prominent characteristic within the slices is a very low (3-9 APIU) or "clean" gamma ray region in the northwestern portion of the basin. This region occasionally extends toward the southeast while remaining present in the northwest. Following Gardner's (1974) interpretation of the uppermost section of the Detroit River Group, this low natural radioactive region in the northwest correlates to the location of a deep saline sea.

Dundee Limestone Slice Images

Dundee Top-down Slicing

Top-down slicing of the Dundee Limestone toward the Detroit River Group is shown in Figure 24. The Dundee interval contains the greatest well control, resulting in a broadened view of the gamma ray patterns. The first slice is separated into two regions as a result of the different lithologies overlying the Dundee Limestone. The Rogers City-Dundee contact is illustrated by the lower gamma ray values, whereas the Bell Shale/Traverse Group-Dundee contact in the absence of the Rogers City is illustrated by the higher gamma ray values. As the time significance of the Dundee surface is uncertain, subsequent slice images are assumed to only show general trends.

A subtle north-south linear trend down the center of the basin occurs in the first 45 slices near the top of the Dundee interval. Similar to the “Dundee” top-down slice images, this low natural radioactive region correlates to the shelf region defined by Gardner (1974) and Taylor (2001). The highest APIU values (24-30 APIU) are restricted primarily to the southeastern region of the basin (slices 1-62) and migrate toward Saginaw Bay in later slices.

Dundee Bottom-up Slicing

Slicing from the base of the Dundee Limestone toward the top of the unit is shown in Figure 25. The average gamma ray values at the base of the Dundee range from 12-24 APIU (slices 1-50) and decreases to 9-18 APIU as the slicing progresses upward through the Dundee (slices 72-185). There are no prominent and continuous trends within this interval. A reason for this may include slicing from a non-correlative surface, as the anhydrite pick is difficult to make in some areas of the basin. The environment of deposition during this period could also have been relatively unchanging, apart from the small shift to lower average gamma ray values while moving upward within the Dundee interval.

Rogers City Limestone Slice Images

Rogers City Top-down Slicing

Top-down slicing of the Rogers City Limestone is shown in Figure 26. This unit is thinner than the Dundee Limestone and consequently contains less slice images. The Bell Shale influences the higher gamma ray response near the top of the Rogers City Limestone. The first appearance of this influence is located in the eastern part of the basin, south of Saginaw Bay, in slice 10 and perhaps as early as slice 16. Progressing toward the top of the Rogers City (slices 10 to 2 respectively), the green region advances north and westward. As the slicing continues downward (slices 31 to 70) toward those sediments deposited earliest in Rogers City time, the gamma ray values become increasingly lower (6-15 APIU). As the contour area decreases, a consistent northeast southwest trend remains in the northern part of the basin. The top-down slices for the Rogers City interval illustrate a low natural radioactive depositional environment and the possible westward transportation of increasingly siliciclastic-rich sediments during late Rogers City sedimentation.

Rogers City Bottom-up Slicing

Representative bottom-up slicing results for the Rogers City Limestone are shown in Figure 27. Slice 1 occurs at the Rogers City-Dundee contact and subsequent slices progress toward the top of the Rogers City, similar to chronological sediment deposition.

The thickest Rogers City interval is 125 ft. If both the top and bottom boundaries for the Rogers City Limestone are time surfaces, then the top-down and bottom-up results should be identical, assuming that the thickness remains constant. Results from top-down and bottom-up slicing of the Rogers City exhibit similarities where the slices meet in the center of the thicker Roger City units. This equivalence suggests that the bounding surfaces for the Rogers City represent approximate time surfaces.

The majority of gamma ray values for the bottom-up slicing are between 9-15 APIU. The most prominent feature illustrated by the slicing is a low gamma ray trend, extending from northeast to southwest through the center of the contoured region in every slice. This follows the same trend as seen in the top-down slicing. From these combined results, the Rogers City Limestone appears to have been deposited in a relatively unchanging environment due to the small range of gamma ray values. A deviation from this uniformity occurred as more naturally radioactive material associated with Bell Shale sediments began being introduced into the basin.

Discussion

The Dundee-Rogers City interval (Figure 22) was sliced using a color contour scale consistent with the Traverse Group study (Figure 28) to allow for their comparison. There is a marked contrast between these slice images due to variations in the gamma ray amplitudes. The Traverse Group amplitudes range between 0-150 APIU whereas the Dundee-Rogers City interval has a narrower range, 0-30 APIU. Although the contour interval for slicing can be reduced, such that a narrow range appears broader, there is a fundamental difference between these data distributions. For gamma ray values between 0-150 APIU, the end members infer a lithology change, whereas the end members for a limited range (e.g. 0-30 APIU) describe small natural radioactivity fluctuations in a more uniform lithology. Consequently, patterns observed within the Dundee-Rogers City slices are not attributed to major changes in lithology from carbonates to clastics as was shown in the Traverse Group study. The resultant patterns from changes in gamma ray amplitudes within the Dundee-Rogers City interval also do not illustrate the presence of delta features as were previously observed in the Traverse Group results. This indicates that sedimentation within the basin during Dundee-Rogers City deposition came from a non-fluvial source.

The base of the Traverse Group shares a slicing surface with the top of the Dundee-Rogers City interval. This relationship can be used to test the results from this study. The last slice image for the Traverse Group should correspond to the first Dundee-Rogers City slice. Figure 29B, from the Traverse Group slicing, illustrates the extent of the Bell Shale with the yellow-red-brown contours. The slicing images were created using proportional slicing, which averages the gamma ray values based on the thinnest interval to eliminate having wells “drop out” (Wylie, 2002). Thus, the blue contours indicate where the Bell Shale has pinched out and overlying Traverse Group carbonate is present. Five feet above the top of the “Dundee” is used (Figure 29A) to account for slight differences in the surface pick between the studies. The correlation between the slices images (Figure 29) implies that the WLT results are comparable to the Traverse Group results.

In addition to comparison with the Travers Group results, the slice images from this study are correlated to previously published interpretations of the Dundee depositional environment. A subtle similarity exists between the depositional environment proposed by both Gardner (1974) and Taylor (2001) and the top-down slicing for the Dundee Limestone. The location of the shell banks (Gardner, 1974) and inner shelf region (Taylor, 2001) appears as a low gamma ray trend running north-south through the center of the basin in slices 15-45 and to a lesser extent through slice 75 (Figure 24). These same slices illustrate a consistently higher naturally radioactive region in the southeast, described as a shallow marine environment (Gardner, 1974; Taylor, 2001). Figure 30 superimposes Taylor’s (2001) map onto slice 19 from the top-down Dundee Limestone results. This figure suggests that beyond Taylor’s study region, the low natural radioactive trend appears to expand in the northern part of the basin. The occurrence of low naturally radioactive sediments could be attributed to reworking of carbonate material through wave action, decreasing the overall siliciclastic concentration that would typically cause higher gamma ray reading such as is present in the southeastern part of the basin. As the slices move down toward the base of the Dundee the low gamma ray trend disappears. This may be due to either a change in the depositional environment, supported by the lack of a north-south trend in the bottom-up slicing (Figure 25), or the result of decreased accuracy as the slicing progresses further from the bounding surface.

The bottom-up slicing results from the Kawkawlin Bentonite also indicate another subtle trend similar to Gardner's (1974) description of the depositional environment near the end of Detroit River Group deposition. The presence of a persistent low natural radioactive region in the northwestern region of the basin directly correlates with a deep saline sea associated with upper Detroit River halite sediments. This suggests a possible relationship between evaporites and carbonates that can be observed regionally using the gamma ray log curve.

Regional analysis of the limestone and dolomite within the Dundee-Rogers City interval using lithology data from the Aangstrom Precision Corporation indicates that the carbonates have equivalent average gamma ray values. Figure 8 illustrated that in some wells the dolomite produced higher gamma ray values than limestone, and additional well control and wells log curves are needed to separate these lithologies on a regional scale. Further analysis of the Dundee-Rogers City interval could also identify additional correlative surfaces, as the internal gamma ray character within the limestone units is not uniform. Slicing between these surfaces would improve the interpretation of natural radioactive sediment distribution during Dundee and Rogers City deposition.

Conclusions

The WLT tomography technique was successfully applied to the Rogers City and Dundee Limestone in the Michigan Basin. The primary result from the suite of gamma ray log curves sliced over the Lower Peninsula of Michigan indicated a period of low natural radioactive carbonate deposition during Dundee-Rogers City time. This is in sharp contrast with the previous work on the Traverse Group by Wylie (2002) and Wylie and Huntoon (2003) that identified heterogeneous gamma ray distributions including expansion and contraction of muddy deltas in the eastern Michigan Basin at several periods in Traverse Group deposition. No comparable delta building activity is apparent in the gamma ray data for the Dundee and Rogers City Limestones.

A subtle north-south gamma ray trend within the Dundee interval was found to correlate with previous interpretations of Dundee facies tracts by Gardner (1974) and Taylor (2001). These results indicated that lower gamma ray amplitudes characterized the central shelf region during Dundee deposition. There was also a subtle correlation between the low gamma ray amplitudes stratigraphically above the Kawkawlin Bentonite and the presence of a deep saline sea. Additional analysis of internal Dundee-Rogers City log curve correlations would better define relative depositional rates and distributions within the basin and create more accurate paleogeographic trends using the WLT technique.

Future Work

There are three areas of improvement suggested for future slicing of the Dundee and Rogers City Limestones that can also be applied to additional formations. These areas include picking slicing surfaces, normalizing log curves and slicing additional curves. In regard to this study, the contact between the Rogers City and Dundee Limestones was picked using a previously published Rogers City isopach map (Cohee and Underwood, 1945) because the pick was indistinguishable using only wireline log curves. The Kawkawlin Bentonite was also picked using only the gamma ray log curve and was often difficult or impossible to differentiate from adjacent high amplitudes. Similarly, the base of the Dundee could not be separated from the Detroit River in the southeastern region of the basin where the lithologies and subsequent gamma ray log values are equivalent. In order to improve top picks, the wireline data could be coupled with physical samples such as cores. Observing sections of core and relating their characteristics to responses on wireline curves would identify more accurate contacts to be used as boundaries for slicing.

Normalizing log curve data was addressed but performing individual well normalization in addition to identifying and adjusting all factors causing skewed log amplitudes were beyond the scope of this study. The overall normalization corrections could be minimal but currently remain unknown as most workers do not describe performing a normalization process for Rogers City and Dundee well log curves in the Michigan Basin. Normalization is important in that it could have a dramatic impact on WLT results because trends within the Dundee-Rogers City were separated by as few as

3 APIU, indicating that even a minimal correction could alter the shape or even the presence of a trend.

In a publication on the identification of depositional environments using gamma ray logs, Rider (1990) stated that too many complications and variations exist to base interpretations solely on one log curve. This is evident in slicing the Dundee and Rogers City Limestones as the gamma ray curve does not identify all lithofacies changes. Lilienthal (1978) stated that porosity zones could be traced in the Dundee-Rogers City interval across the basin using the neutron log. Applying WLT to the neutron curve could highlight important porosity trends. The density log was useful for identifying anhydrite and slicing this curve would improve delineation of Reed City deposition. Furthermore, if lithology or facies data could be assigned values and input into the WLT slicing program, the resulting trends would improve both the Rogers City and Dundee depositional environment models.

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Figures

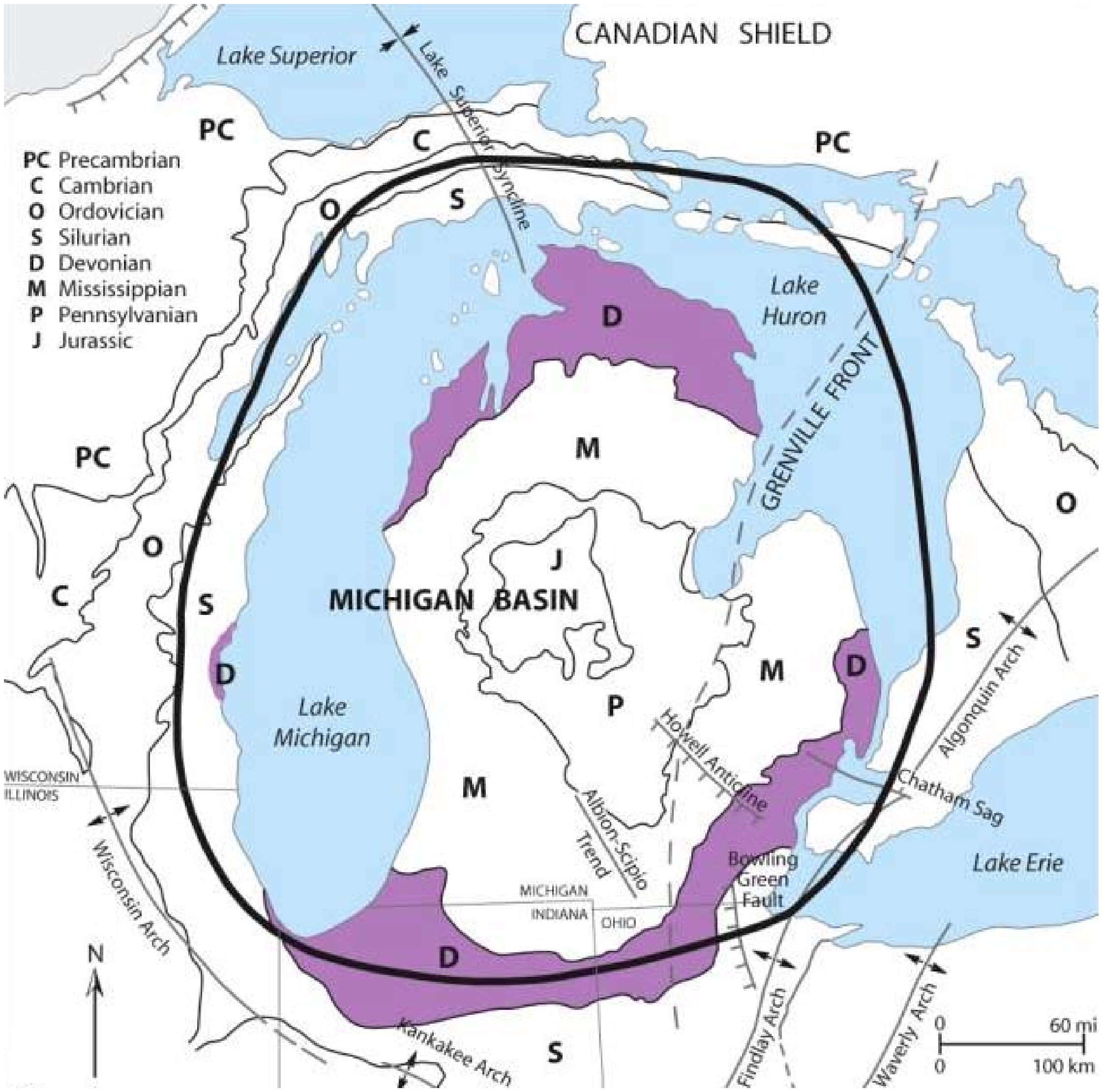


Figure 1. Location of the Michigan Basin outlined in black. The dark purple region highlights the Devonian bedrock geology (from Wylie and Huntoon, 2003).

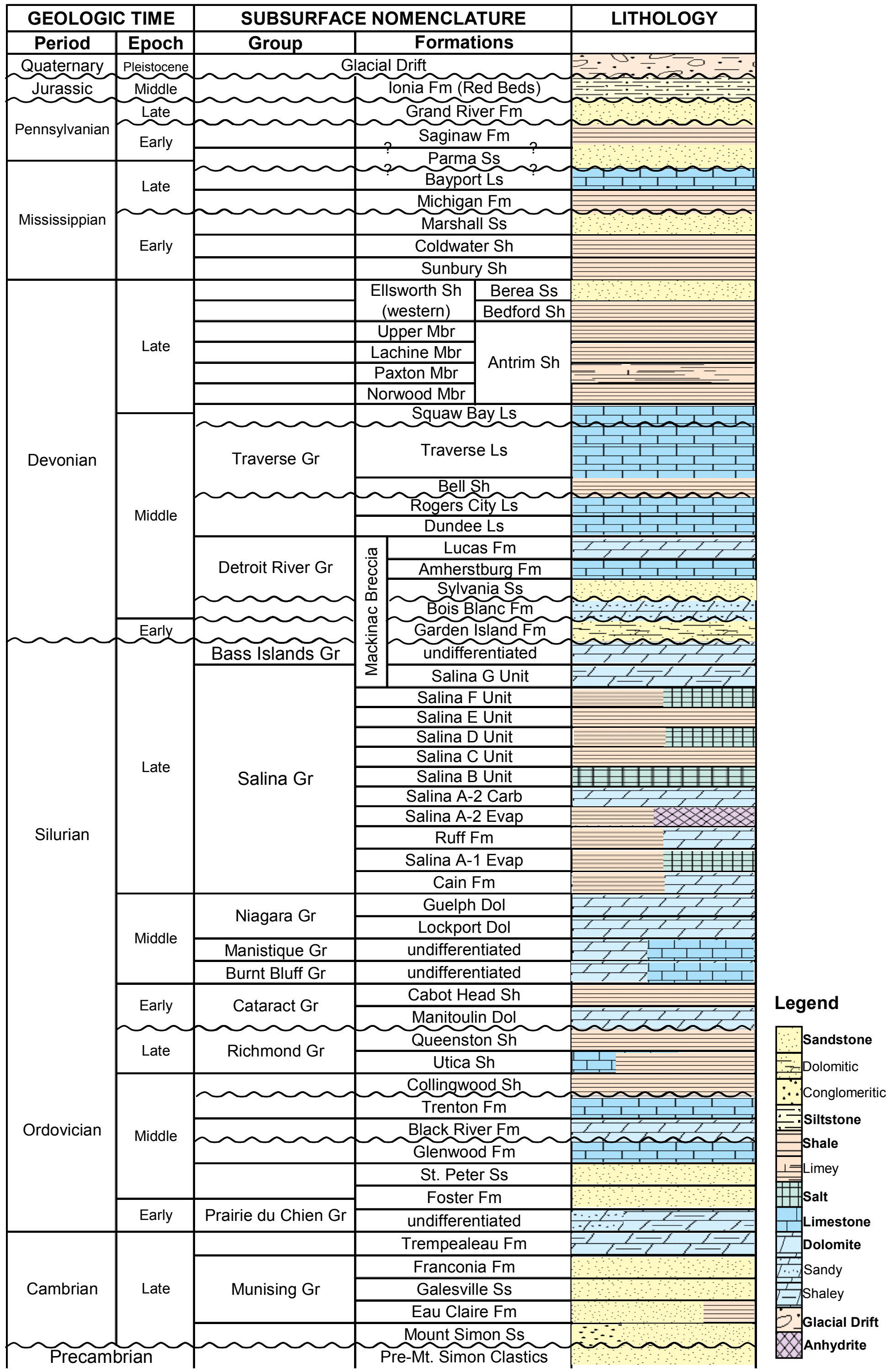


Figure 2. Stratigraphic column for the Michigan Basin, modified from the Michigan Department of Environmental Quality, Geological Survey Division and the Michigan Basin Geological Society (2000), accessed at <http://www.deq.state.mi.us/documents/deq-gsd-info-geology-Stratigraphic.pdf> on Jan. 15, 2004.

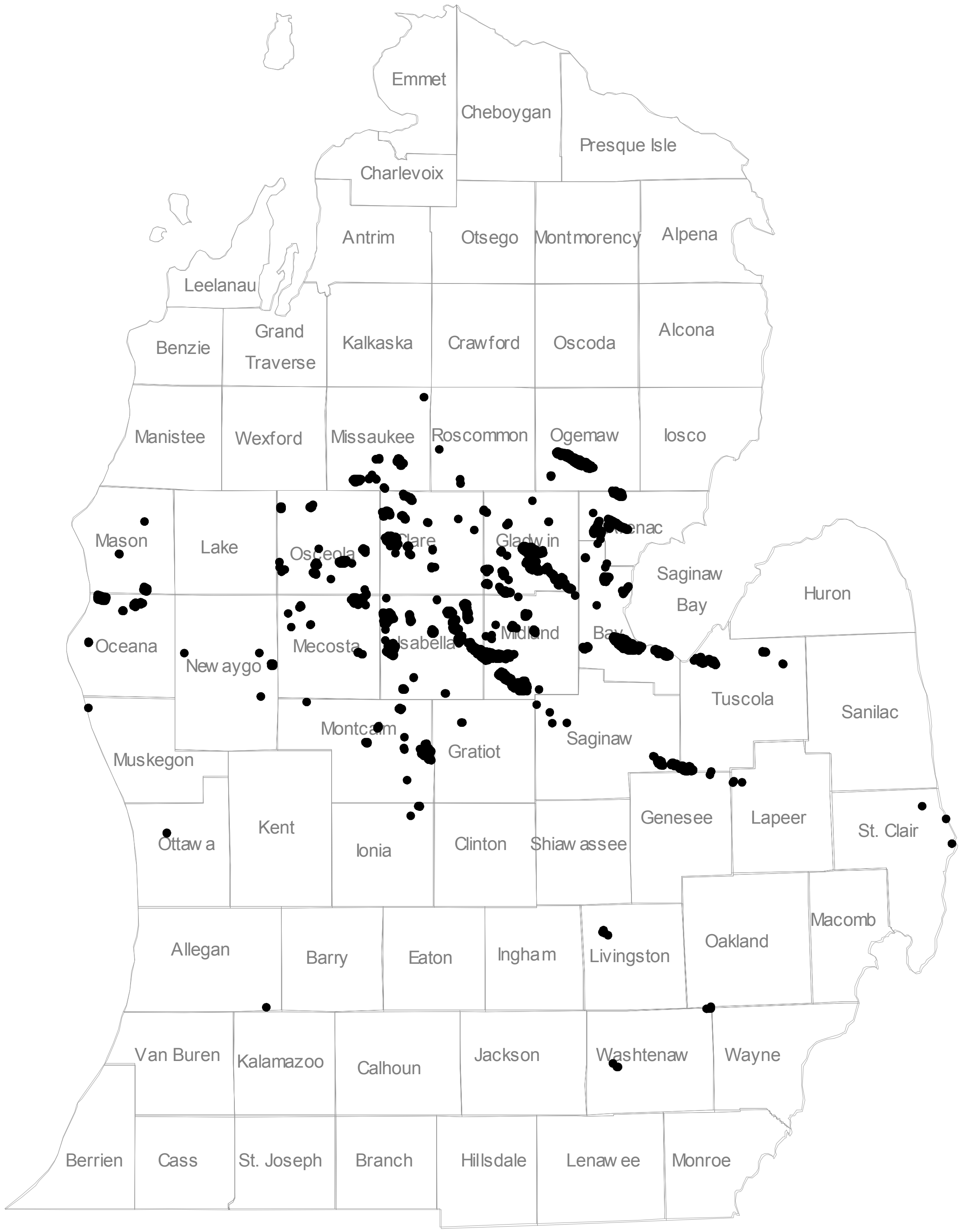


Figure 3. Location map for 2003 Dundee-Rogers City producing wells (black dots) from the Michigan Department of Natural Resources (MDNR) production database. County names are also shown for reference within the paper.

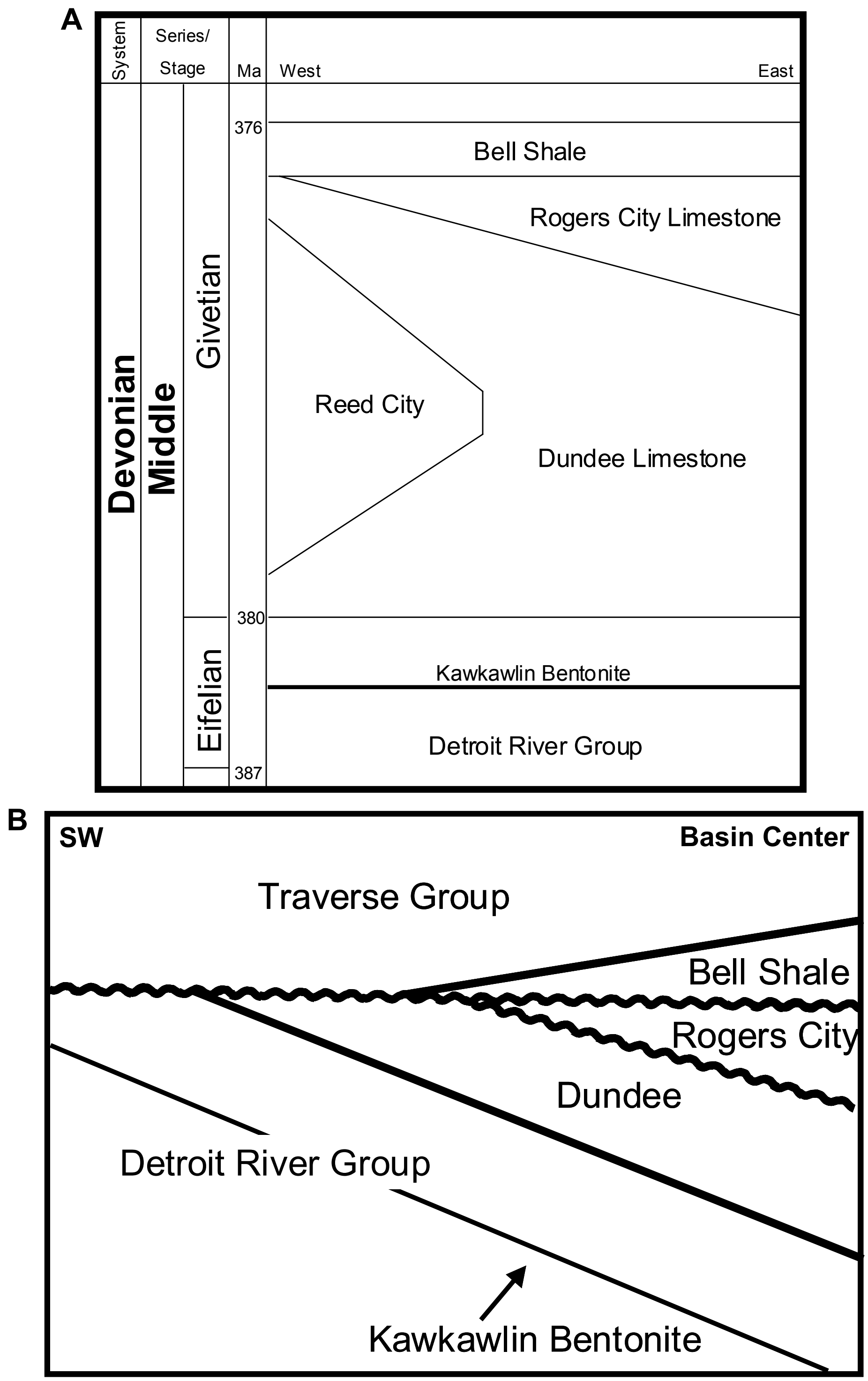


Figure 4. (A) Stratigraphy diagram for the Dundee-Rogers City and surrounding Middle Devonian units from west to east across the central Lower Peninsula of Michigan (modified from Catacosinos et al., 1991). (B) Cross-sectional stratigraphy schematic from southwest toward the center of the basin, illustrating that the Bell Shale, Rogers City and Dundee intervals are all absent in portions of southwestern Michigan. Note that the vertical scale is exaggerated.

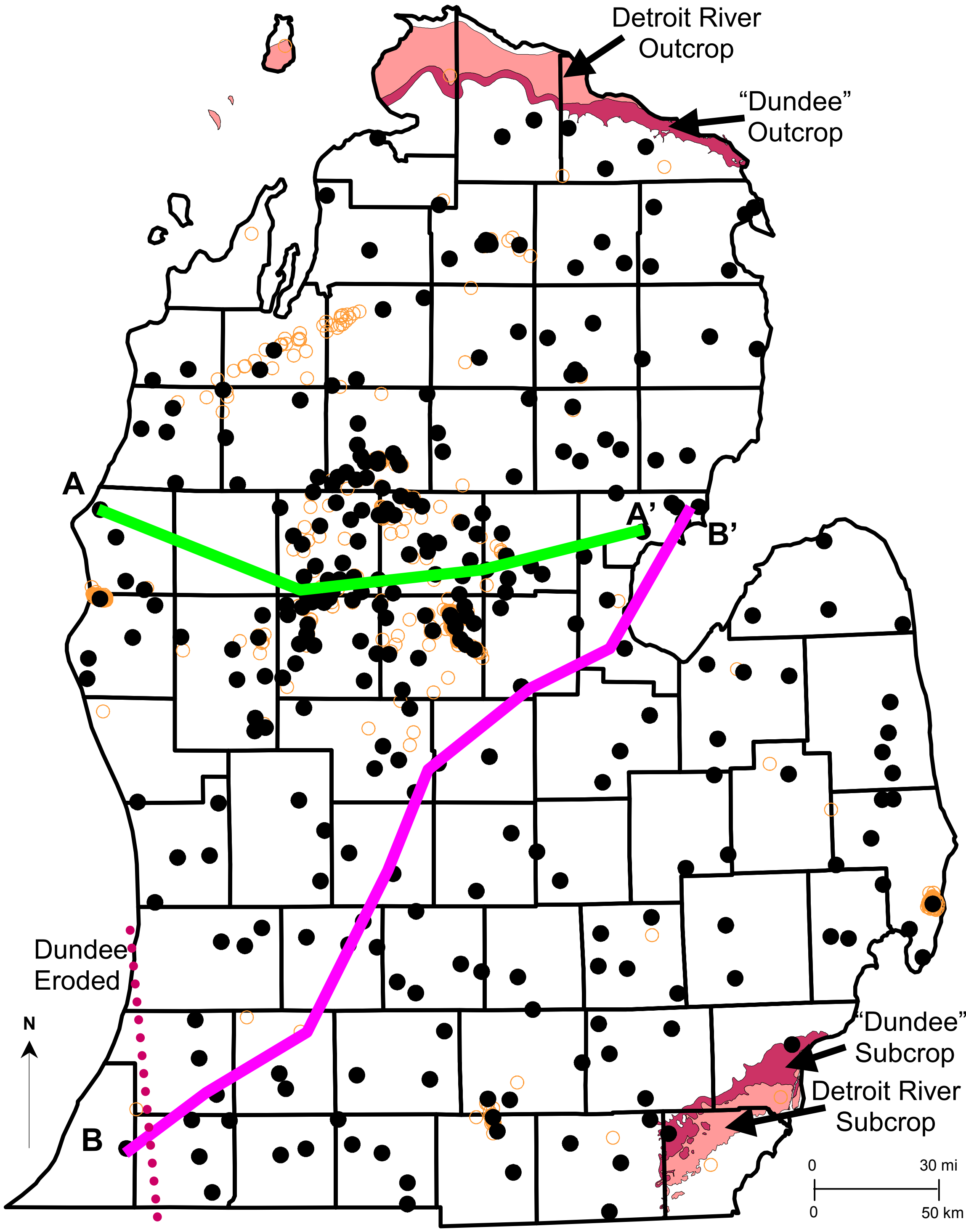


Figure 5. Outcrop and subcrop locations for the Detroit River Group and the combined Dundee-Rogers City ("Dundee") unit. A dotted line in the southwest region illustrates the absence of the Dundee Limestone due to erosion. Black closed circles represent wells used in the WLT slicing program and orange open circles locate the wells discarded before slicing. Cross-section lines are also shown for subsequent figures.

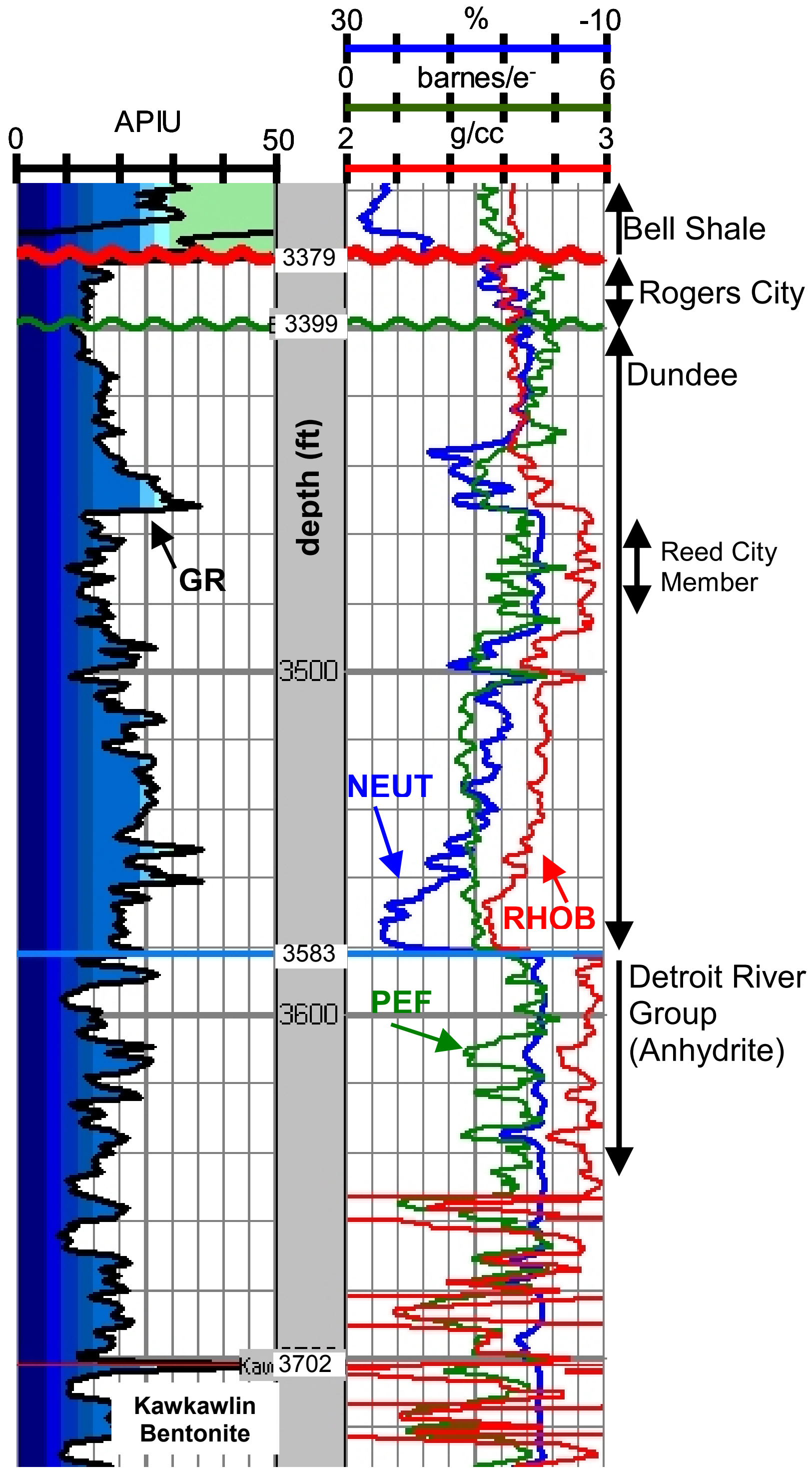


Figure 6. Example digital well log, from the Alber #1-23 well, permit 40215 located in Mecosta County, Michigan. The gamma ray (GR) log curve is located on the left track of the well log with a color-filled amplitude. On the right track are the density (RHOB) log curve (red), neutron (blue) and photoelectric effect (green). The top picks are labeled on the depth scale in the center track. The Reed City is labeled but has no top pick because it is only a Member of the Dundee and is not present throughout the entire basin.

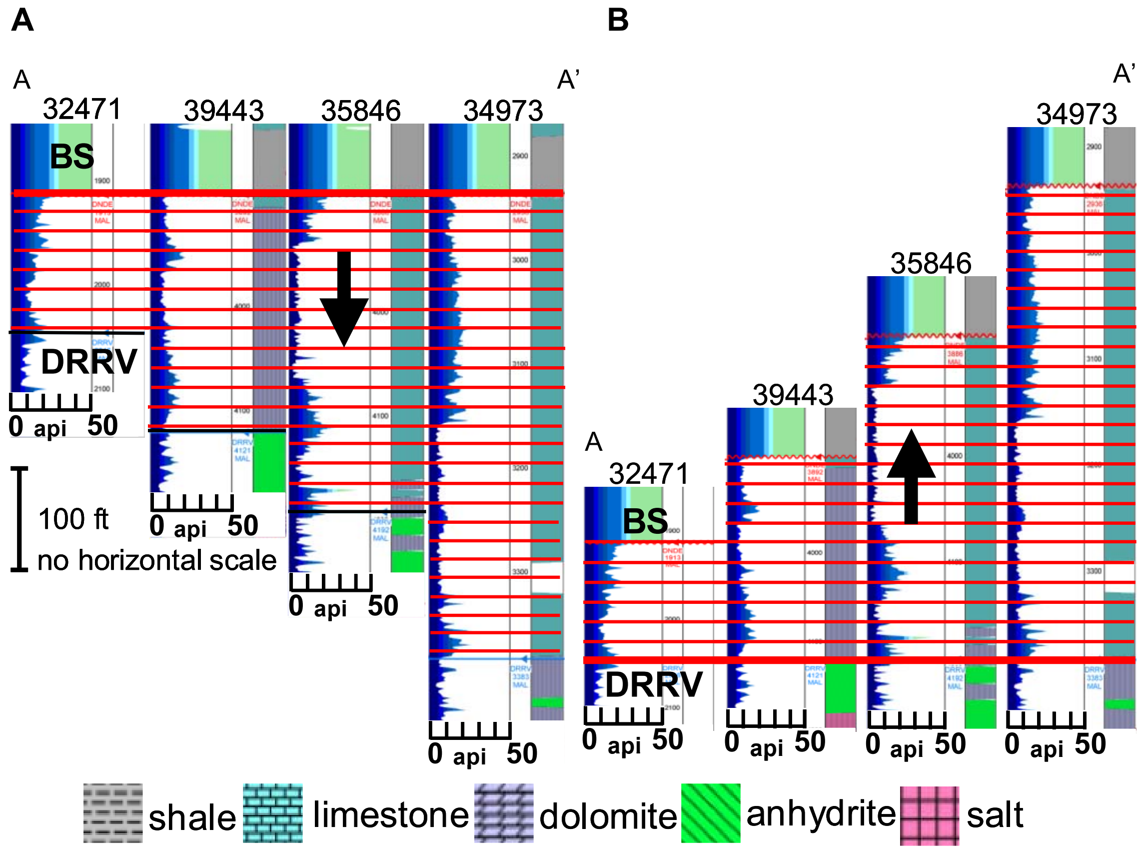


Figure 7. Illustration of the well log tomography method on the Dundee-Rogers City interval located between the Bell Shale (BS) and Detroit River Group (DRRV). Cross-section line, A-A', (Figure 5) includes four representative wells used to illustrate the slicing method. These wells from left to right, west to east across the Lower Peninsula of Michigan are: Mason County/ Carnagel Oil Associates #3-30/ permit 32471; Osceola County/ Thompson #1-27/ permit 39443; Gladwin County/ Dull #3-6/ permit 35846; Arenac County/ Hagley #1-21/ permit 34973. The gamma ray is shown on the left track of the log and the lithology is shown on the right with the lithology legend located below the figures. (A) Example of top-down slicing. The common datum point is the top of the Dundee-Rogers city interval. Slices are shown as solid red lines approximately every 20 ft. The westernmost well with the thinnest Dundee interval has the fewest slices. (B) Example of bottom-up slicing. Opposite of (A) with the common datum point at the base of the Dundee-Rogers City interval. Slices are also shown as solid red lines approximately every 20 ft.

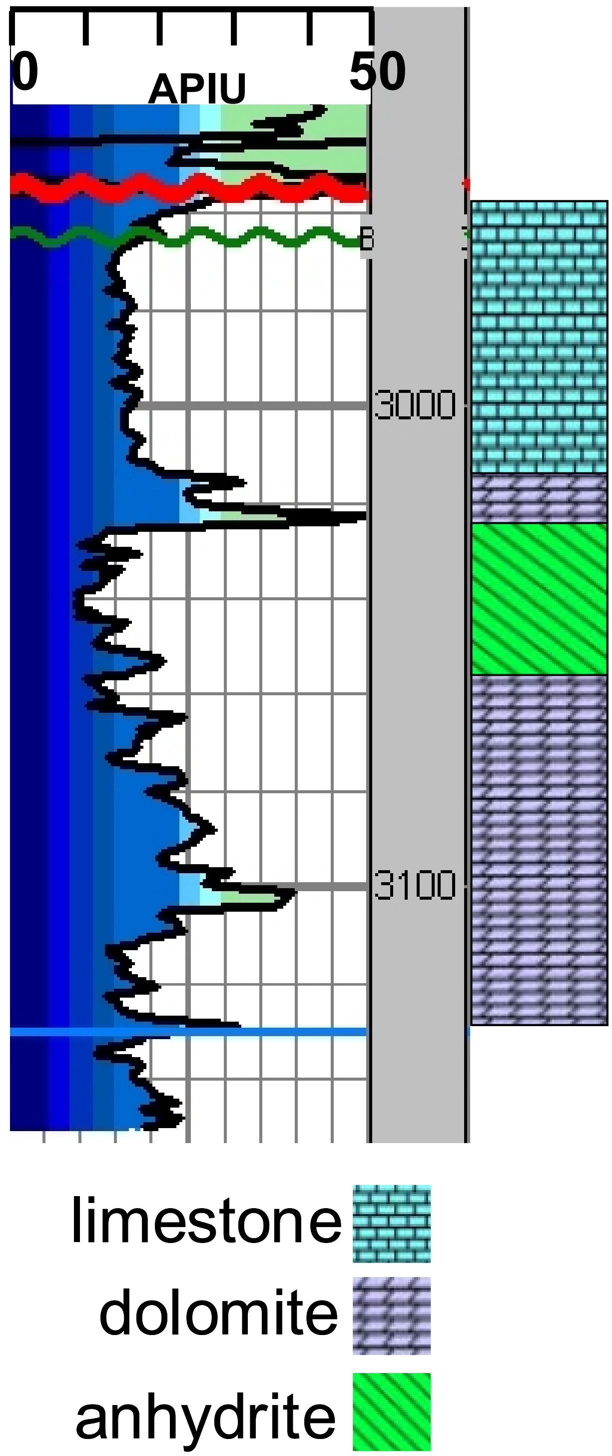


Figure 8. Gamma ray log curve of the Dundee and Rogers City interval for the Croton #1-30 well, permit 41892 located in Newaygo County. The lithology as described by Gardner (1974) from core in a nearby well is shown to the right of the log curve and illustrates the gamma ray amplitudes for the different lithologies.

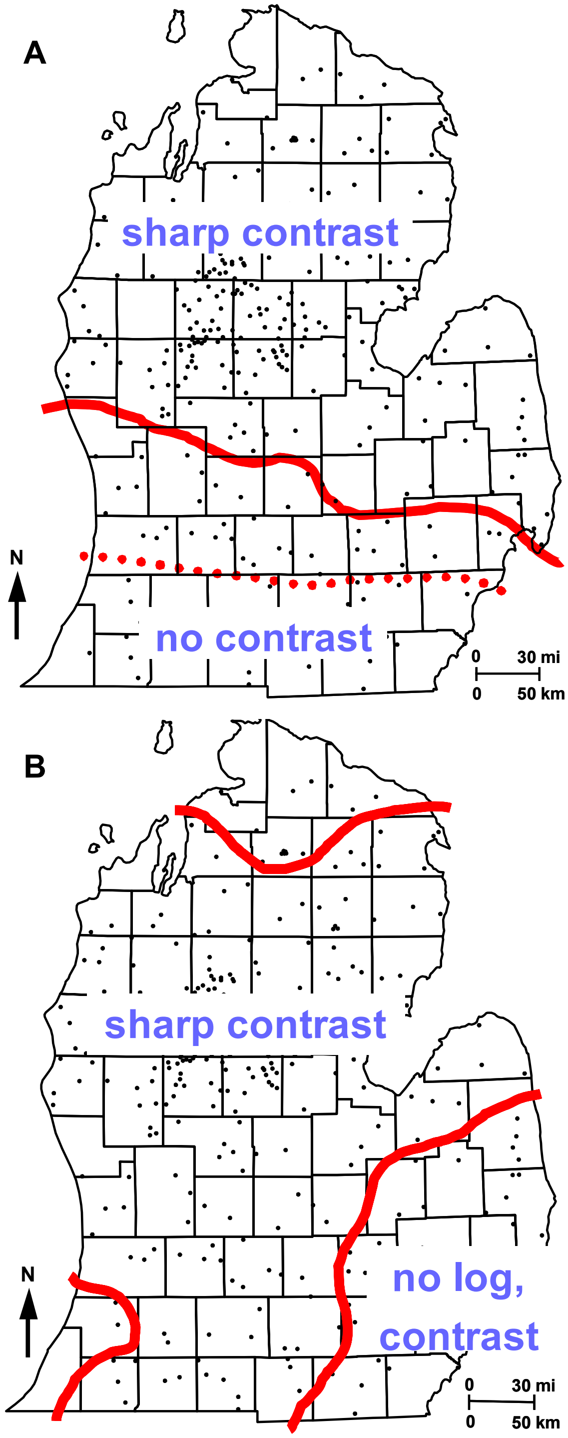


Figure 9. (A) Map showing where the Bell Shale-"Dundee" contact is easy (sharp contrast) and difficult (no contrast, absence of Bell Shale) to pick using the gamma ray log curve. The wells within the region between the solid and dotted red lines indicate a moderately difficult pick due to the thinning of the Bell Shale but a contrast between the "Dundee" and the overlying Traverse Group. (B) Map showing where the density log is present, identified by a sharp contrast between the "Dundee" and the first anhydrite within the Detroit River Group. In the southeast, the lithology changes and the "Dundee"-Detroit River anhydrite contact cannot be picked with confidence using only well log curves.

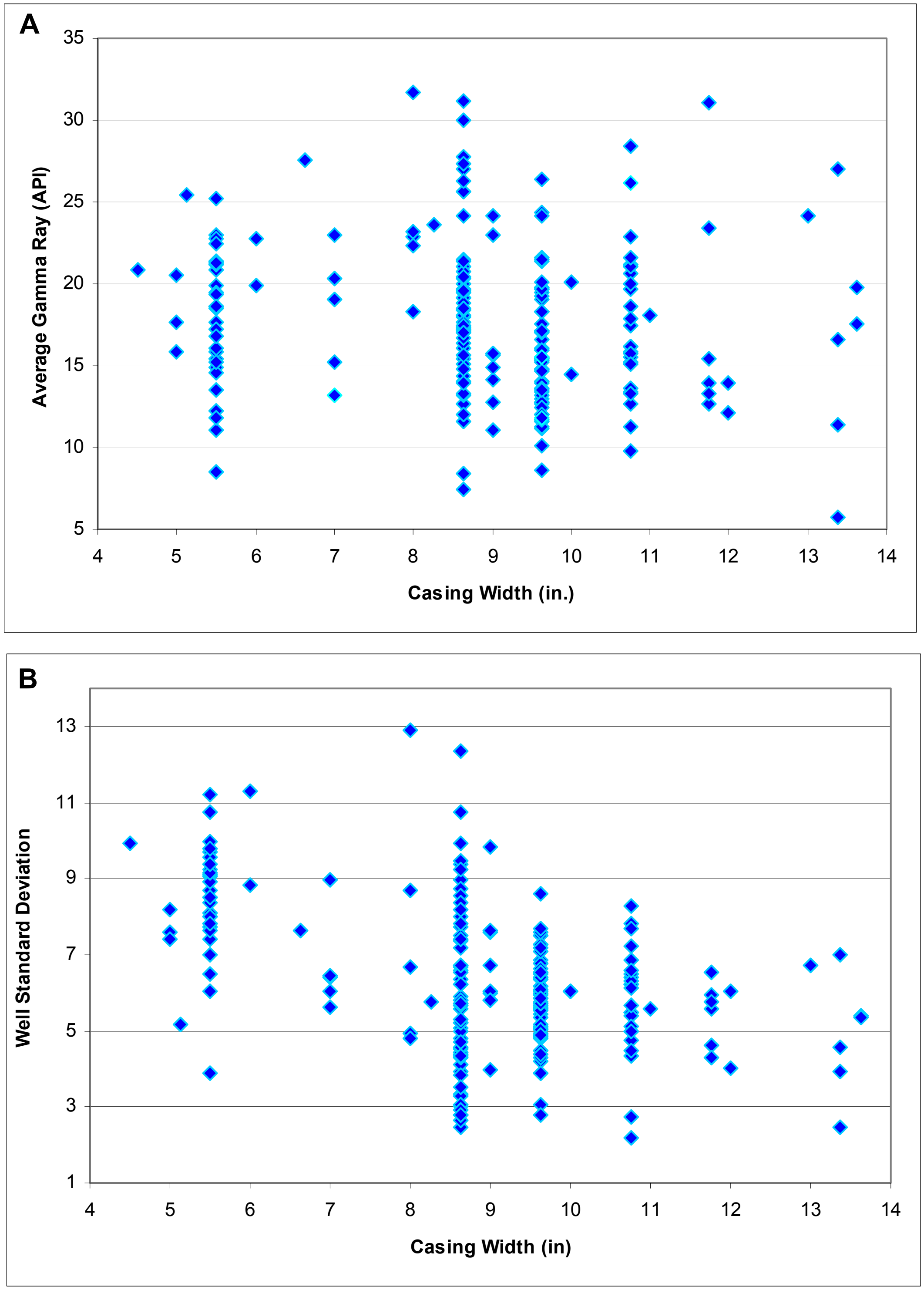


Figure 10. Cross-plot used to determine if a borehole correction was necessary. (A) Casing width (a proxy for borehole diameter) versus the average gamma ray value for the Dundee-Rogers City interval in 217 wells. (B) Casing width versus the standard deviation for the Dundee-Rogers City interval in 217 wells.

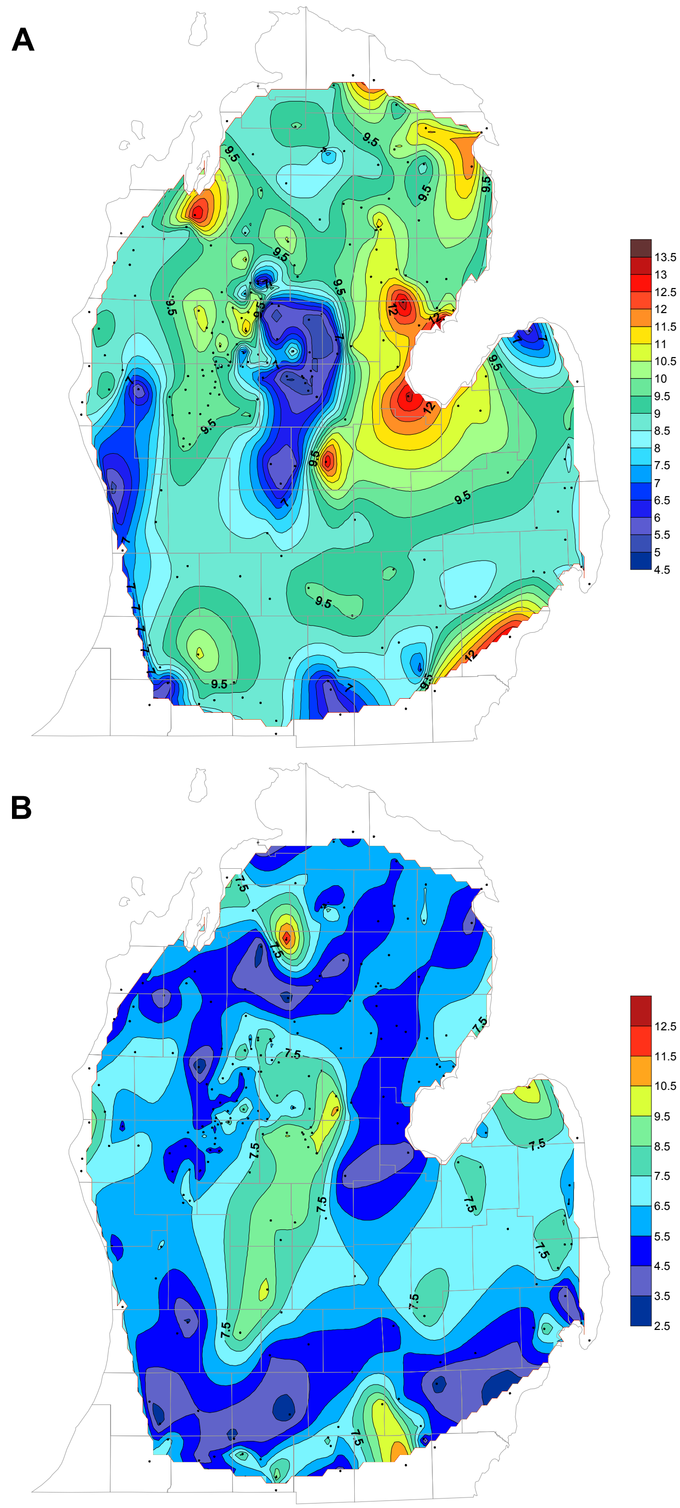


Figure 11. Contour maps illustrating the distribution of (A) casing diameter size (in) and (B) standard deviation (APIU) for the Dundee-Rogers City interval in 217 wells.

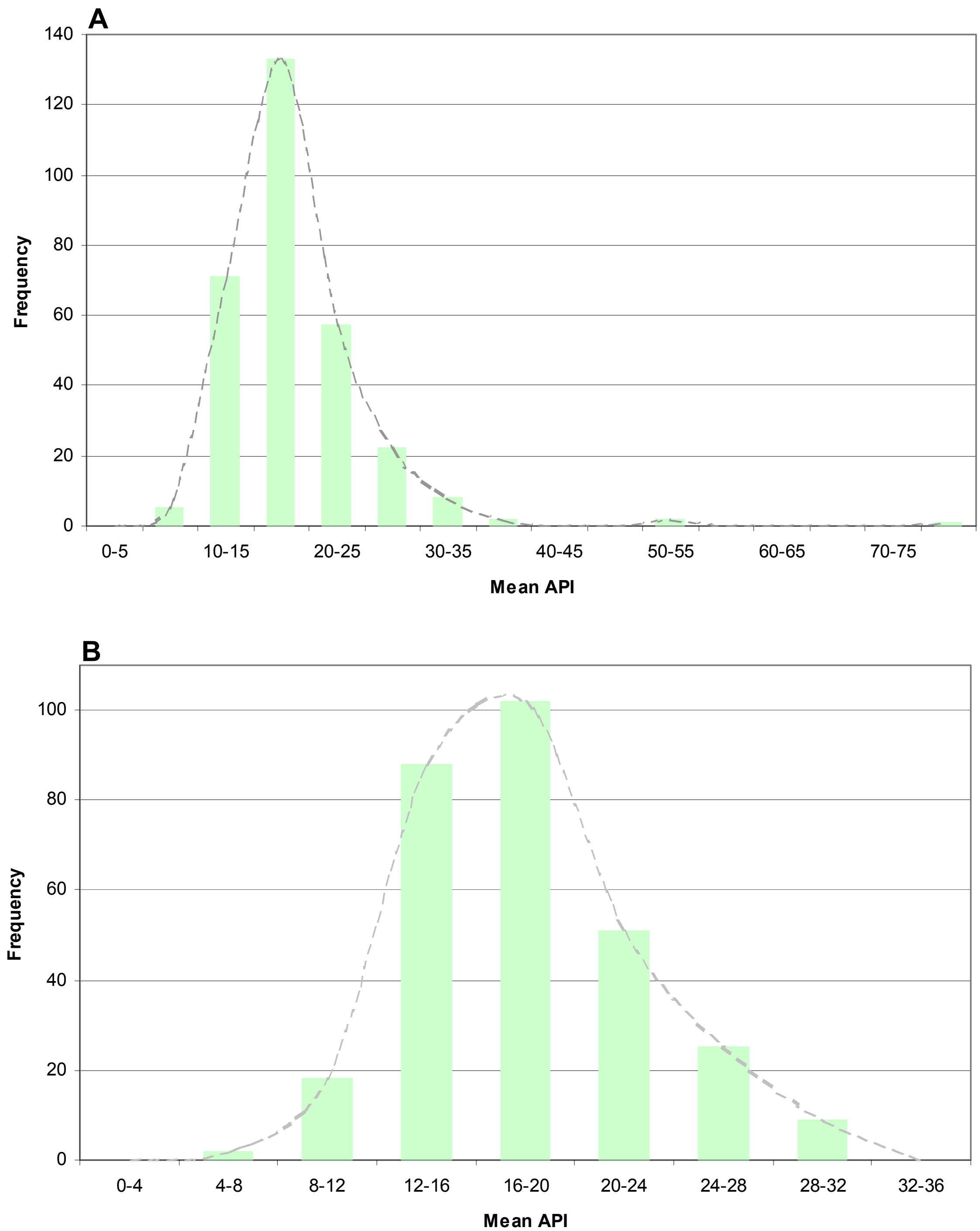


Figure 12. Frequency histogram of the average gamma ray value for (A) 302 sliced wells and (B) 295 sliced wells after those wells having a standard deviation greater than two were excluded. The bars represent the number of wells for each average gamma ray value range. The dotted curve illustrates the smoothed distribution.

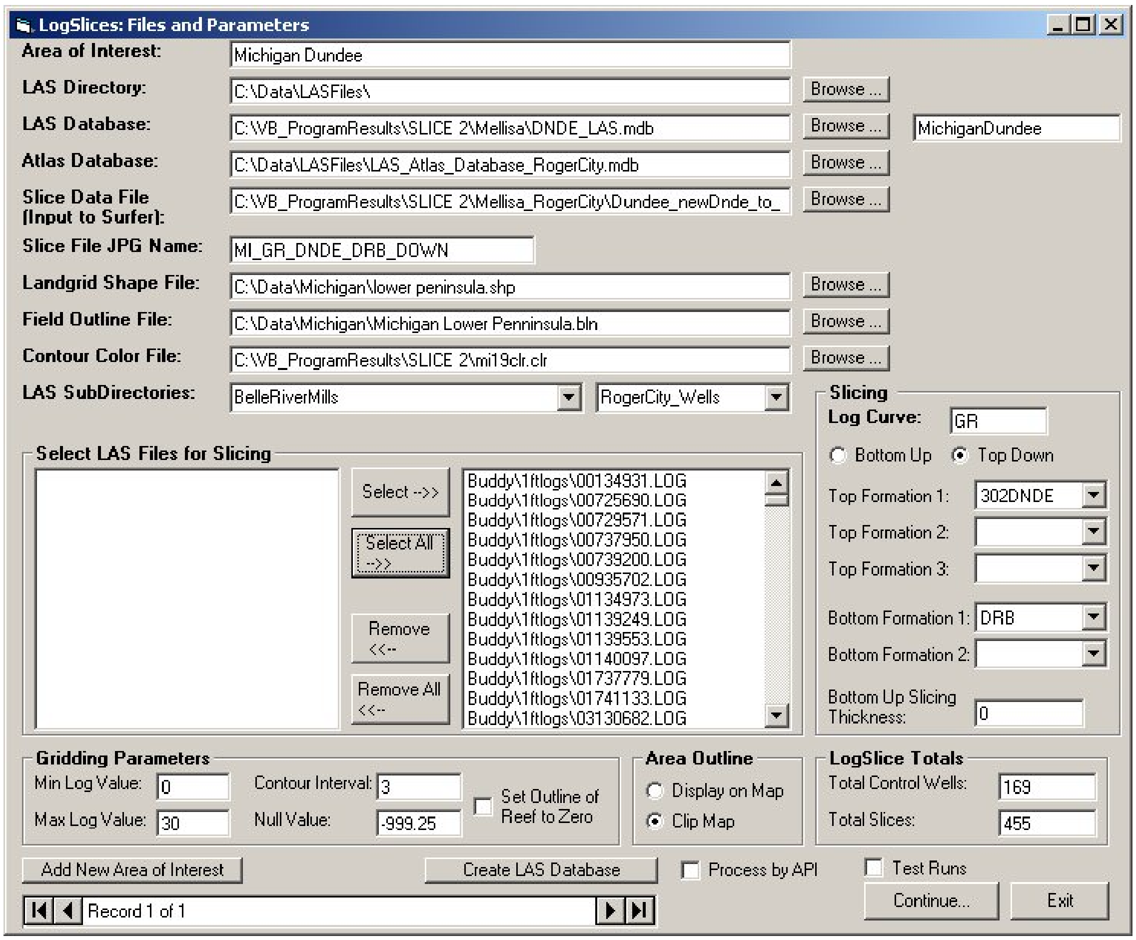


Figure 13. Screen capture of the Slice 2 Files and Parameters form. With this form, the user identifies slicing parameters such as the locations of all the necessary databases, outline of the sliced region, the curve used for slicing, slicing method (either top-down or bottom-up), the LAS files needed, surfer color contour scale, contour interval and minimum and maximum values.

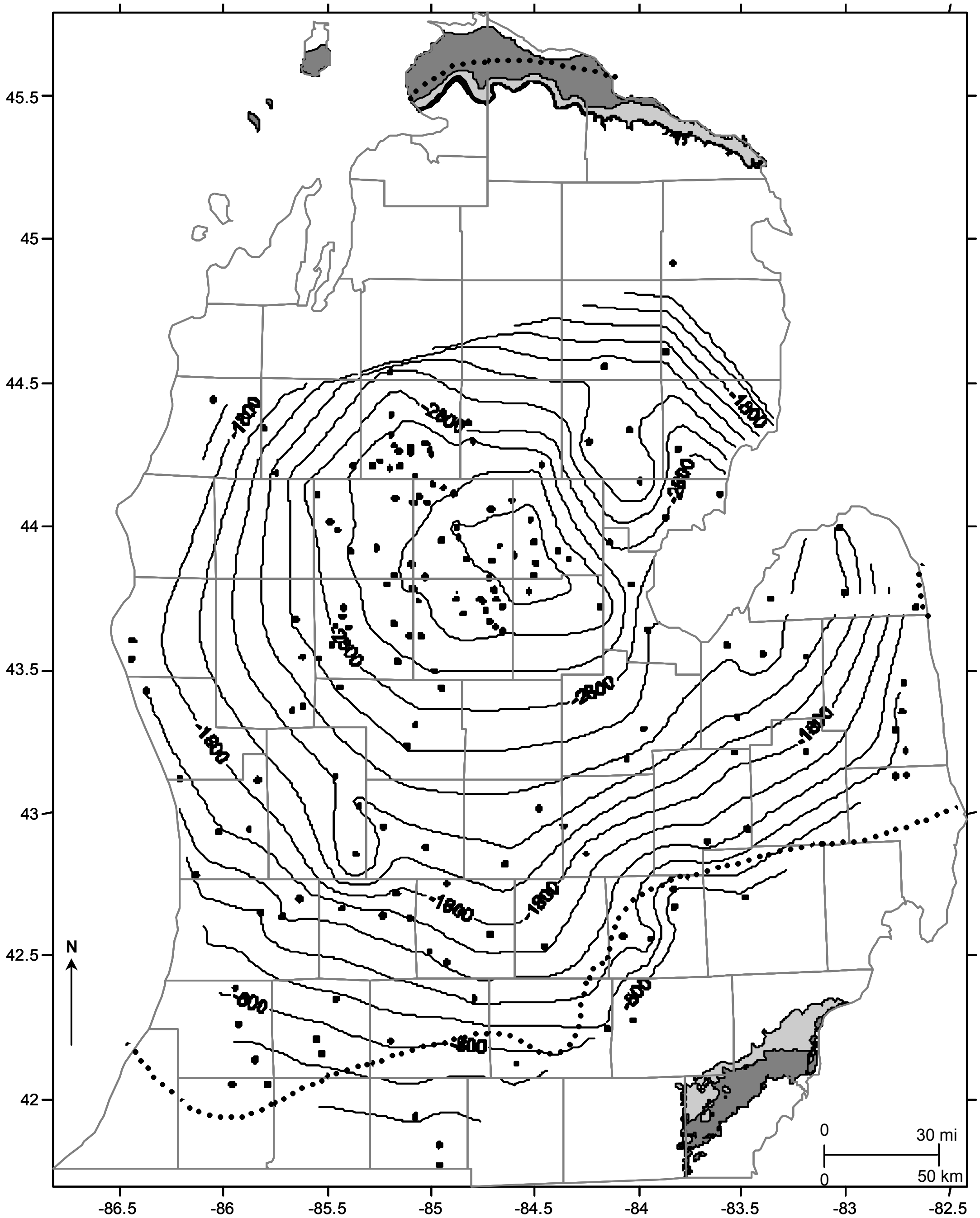


Figure 14. Structure contour map of the Kawkawlin Bentonite pick. The dotted line traces the truncation of the ash bed as defined by Baltrusaitis (1974). The black dots represent the 172 wells used in the study that had a bentonite pick on the gamma ray log curve.

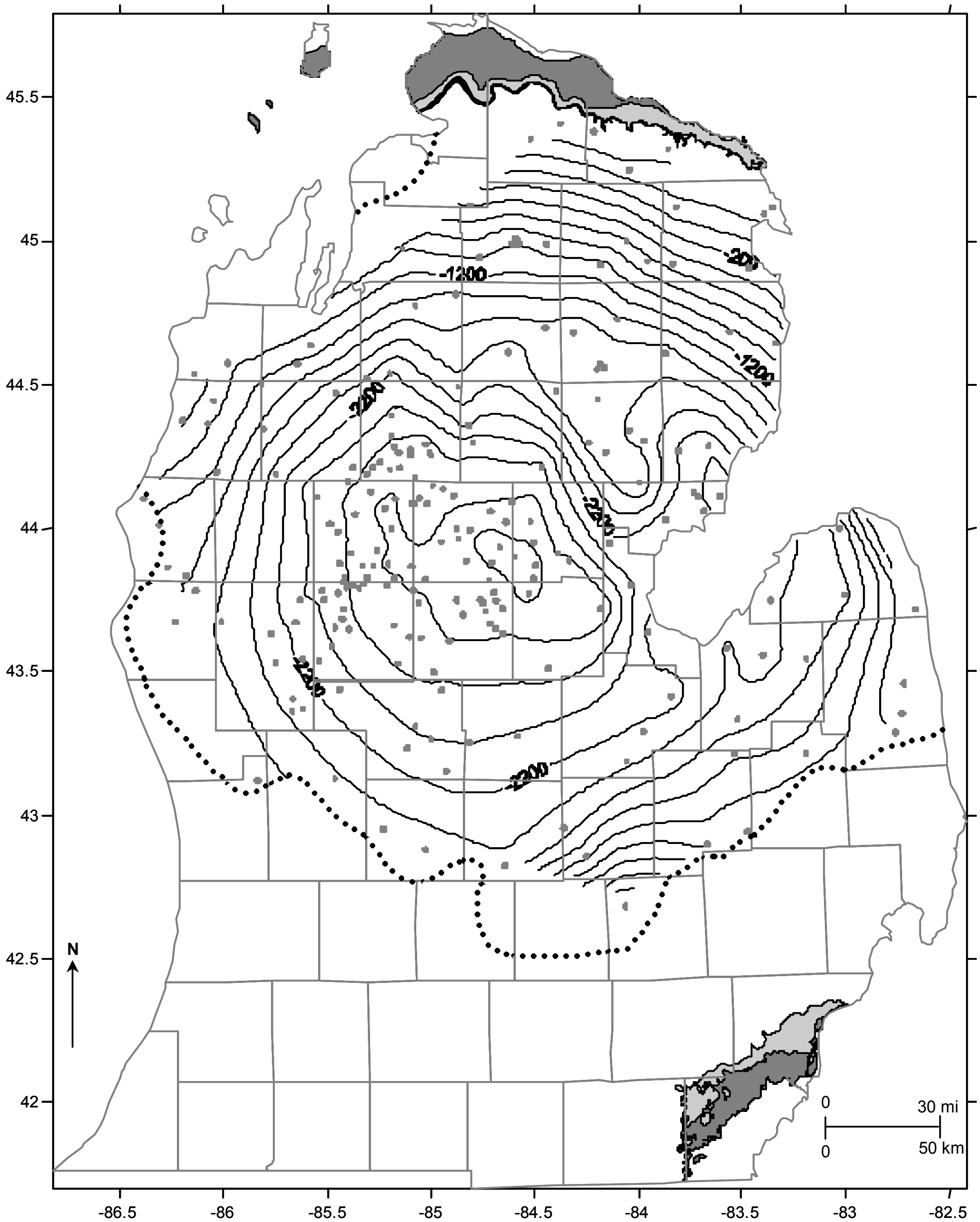


Figure 15. Top of the Rogers City structure contour map. Contour interval is 200 ft. The dotted line (from Cohee and Underwood, 1945) traces the zero-outline of the Rogers City Limestone.

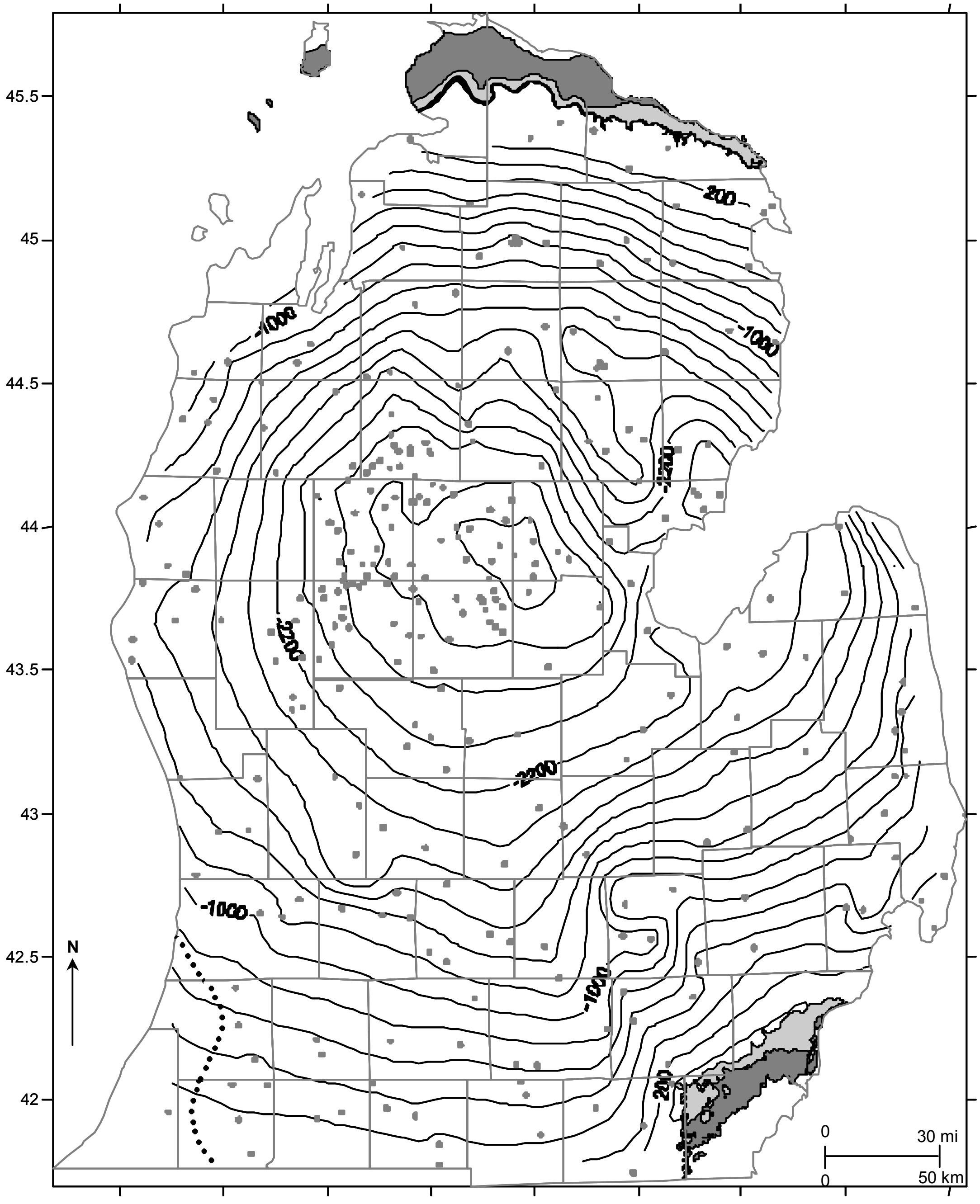


Figure 16. Top of the Dundee Limestone structure contour map. Contour interval is 200 feet. The dotted line (from Cohee and Underwood, 1945) in the southwestern counties indicates the edge of the subsurface Dundee Limestone.

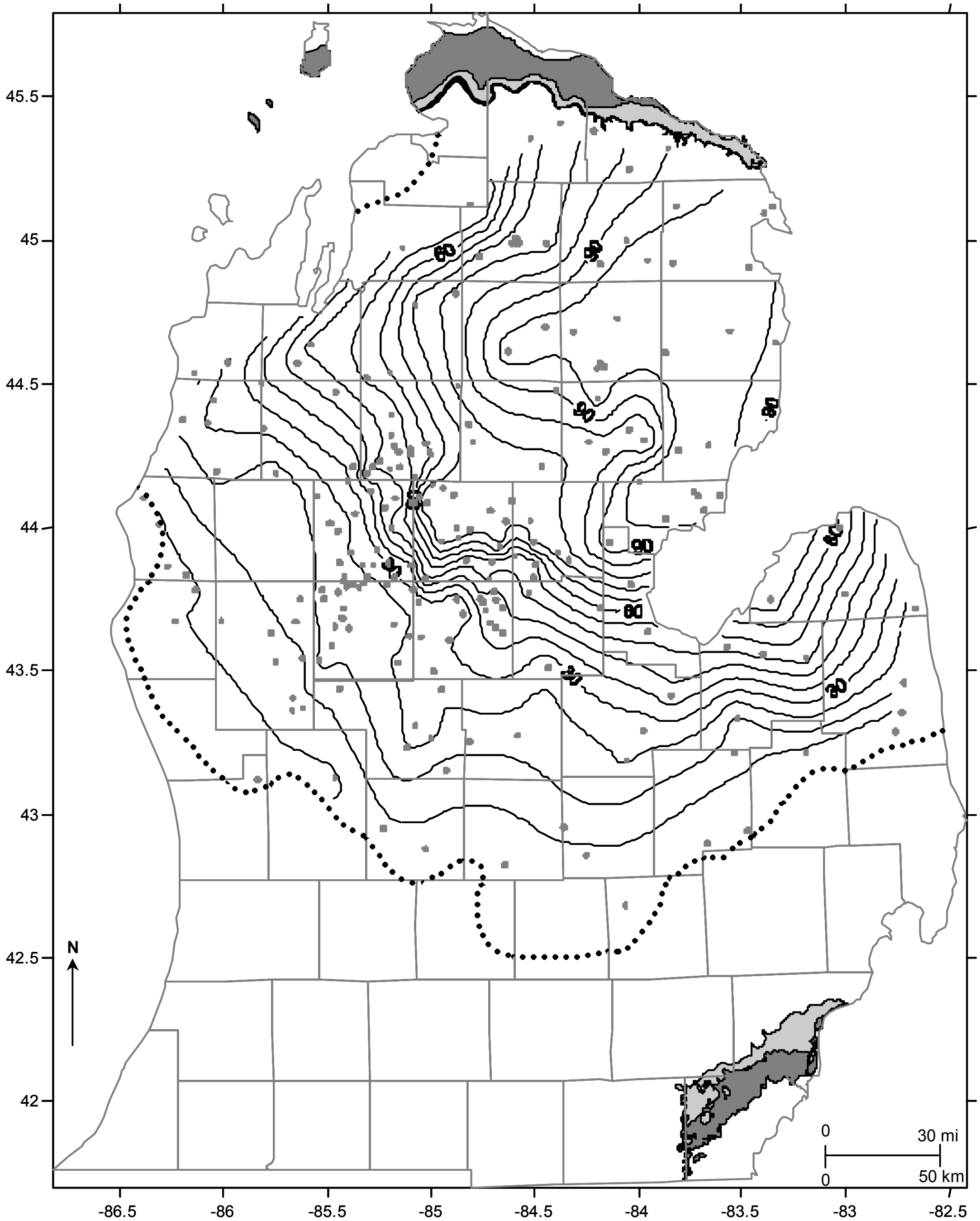


Figure 17. Isopach of the Rogers City Limestone. Contour interval is 6 ft. Zero-outline (from Cohee and Underwood, 1945) of the Rogers City is shown as a black dotted line.

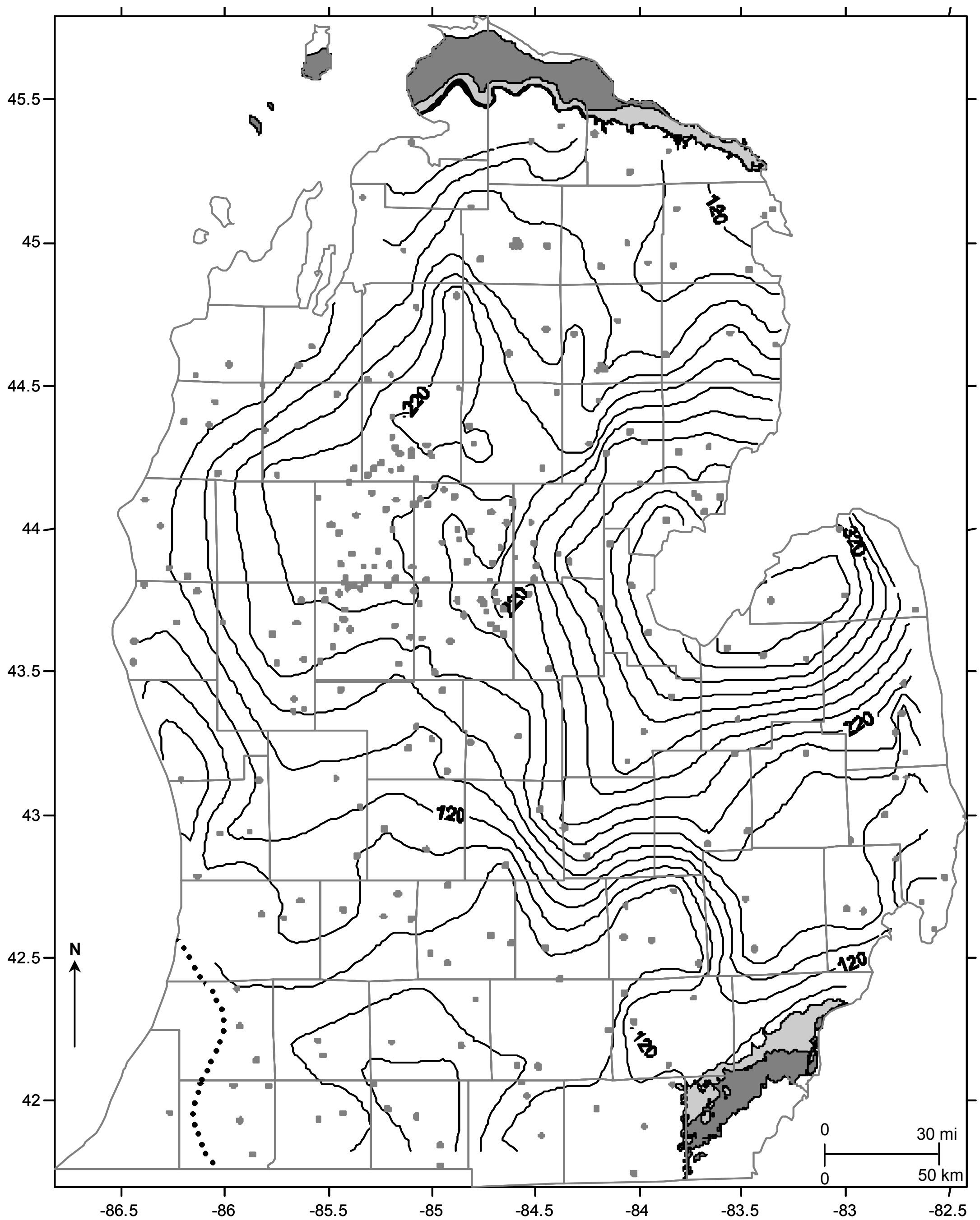


Figure 18. Isopach of the Dundee Limestone. Contour interval is 20 ft. The dotted line (from Cohee and Underwood, 1945) in the southwestern counties indicates the edge of the subsurface Dundee Limestone.

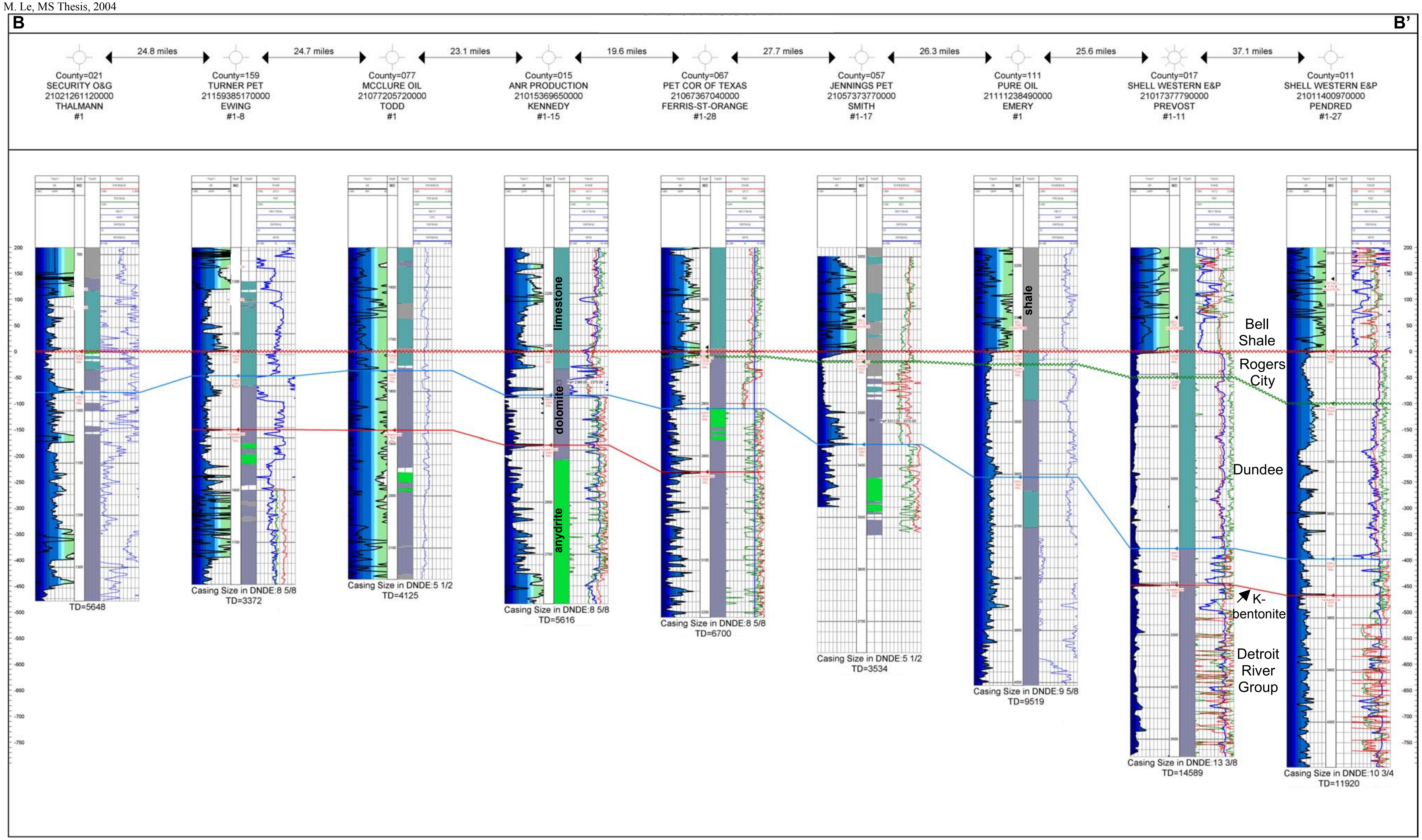


Figure 19. SW to NE cross-section from Berrien County to Saginaw Bay shown as B-B' on Figure 5. The gamma ray log curve (0-40 apiu) is shown on the right track and has a color-coded amplitude. The center track illustrates lithology data from mud logs in the Aangstrom Precision Corp database. The right track illustrates the red bulk density curve (2-3 g/cc), the green photoelectric effect curve (0-6 barnes/e-) and blue neutron porosity curves (NEUT: 0-1000 napi; SNP: ¯15-45 %; NPHI: 30-¯10 %).

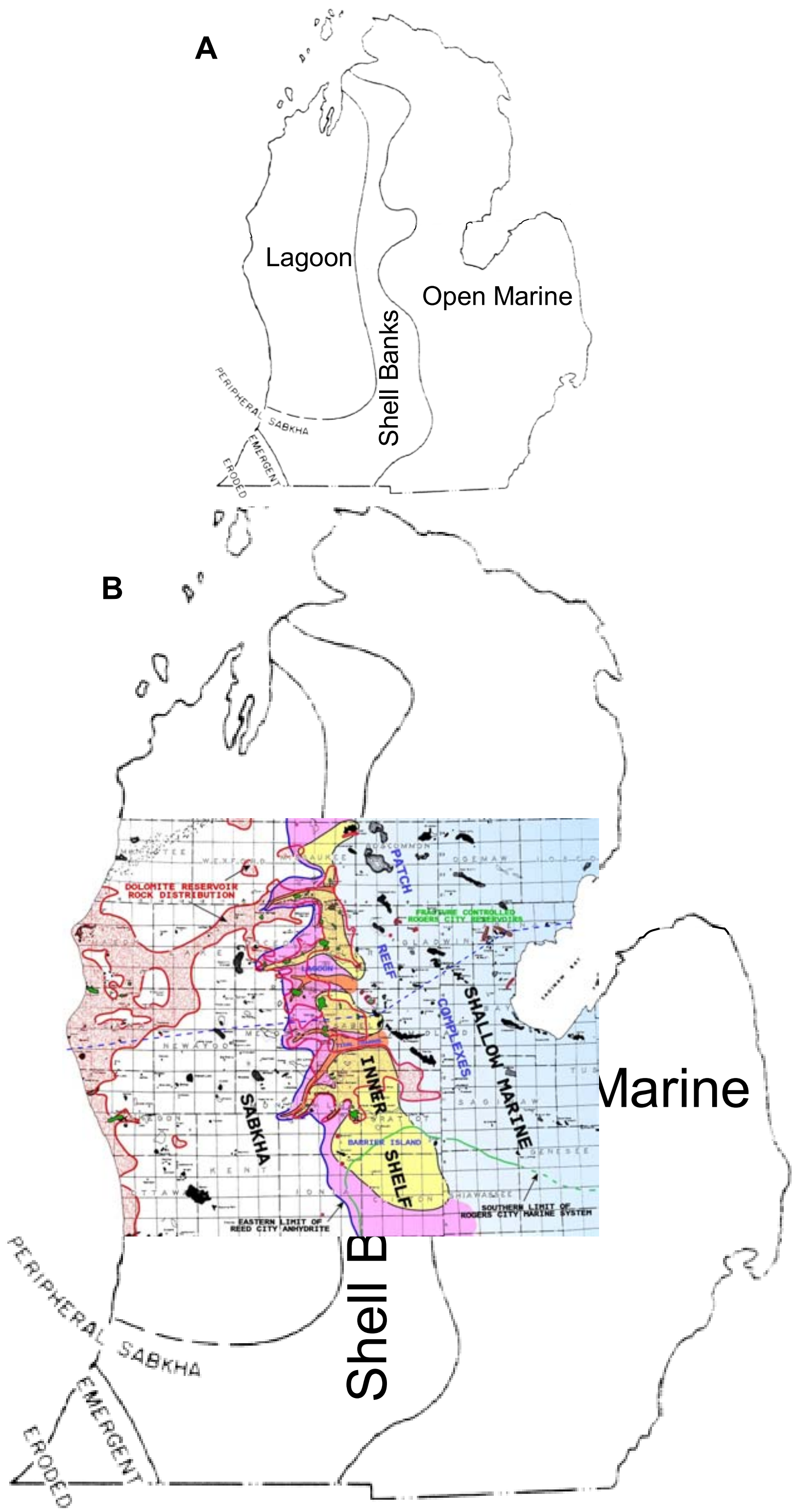
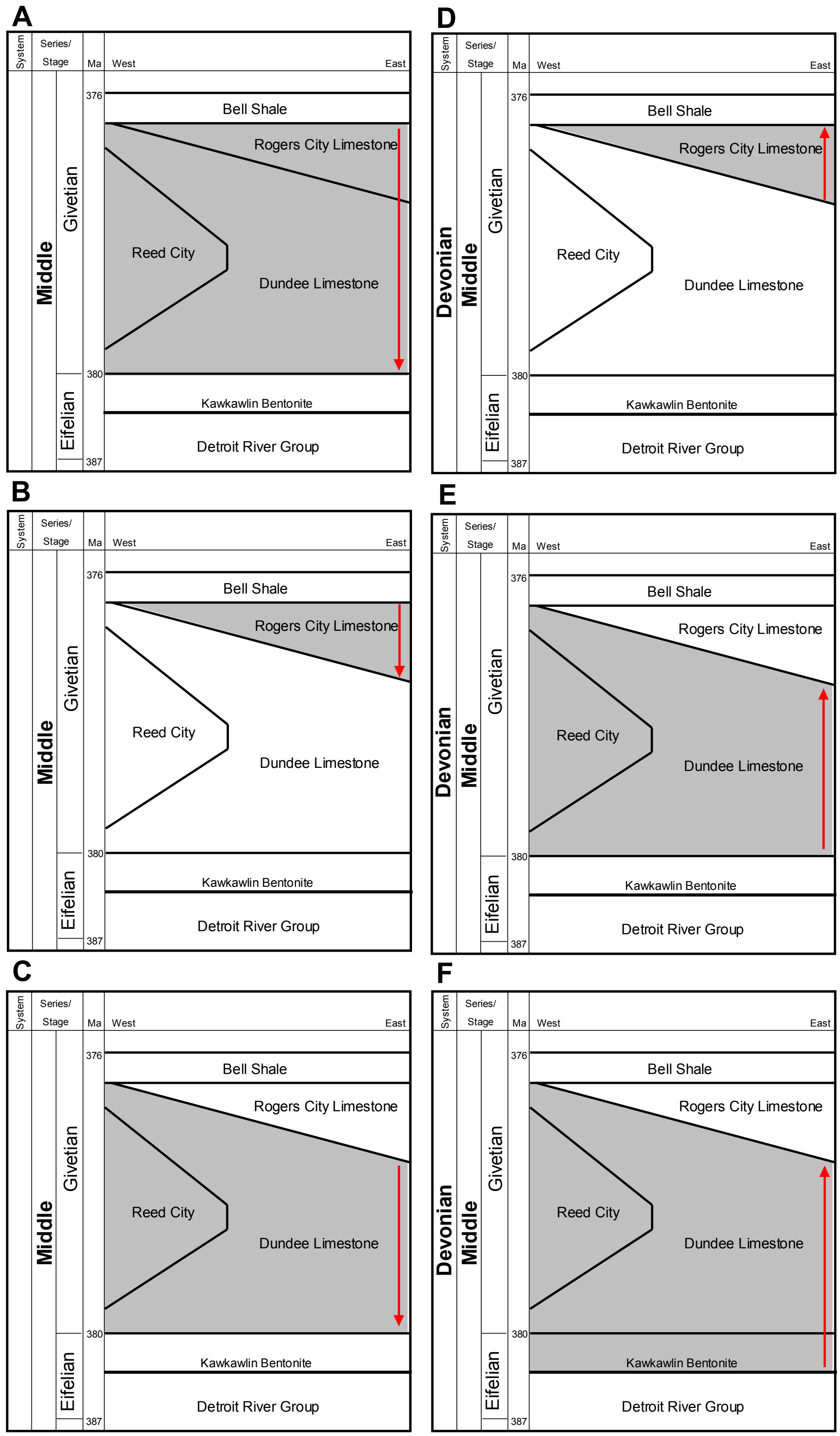


Figure 20. (A) Gardner's (1974) Dundee depositional environment model. (B) Taylor's (2001) interpretation of the Dundee depositional environment superimposed onto the Gardner model to illustrate their similarity.

Figure 21. Diagrams illustrating the sliced intervals (shaded) and direction of slicing (arrow) presented in the results section. (A) Top-down slicing of the "Dundee" Limestone (B) top-down slicing of the Rogers City Limestone, (C) top-down slicing of the Dundee Limestone, (D) bottom-up slicing of the Rogers City Limestone, (E) bottom-up slicing of the Dundee Limestone and (F) bottom-up slicing from the Kawkawlin Bentonite layer.


A
System
Series/ Stage
Ma
West
East
Middle
Givetian
Eifelian
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380
387
Bell Shale
Rogers City Limestone
Reed City
Dundee Limestone
Kawkawlin Bentonite
Detroit River Group
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Eifelian
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380
387
Bell Shale
Rogers City Limestone
Reed City
Dundee Limestone
Kawkawlin Bentonite
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Bell Shale
Rogers City Limestone
Reed City
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Bell Shale
Rogers City Limestone
Reed City
Dundee Limestone
Kawkawlin Bentonite
Detroit River Group

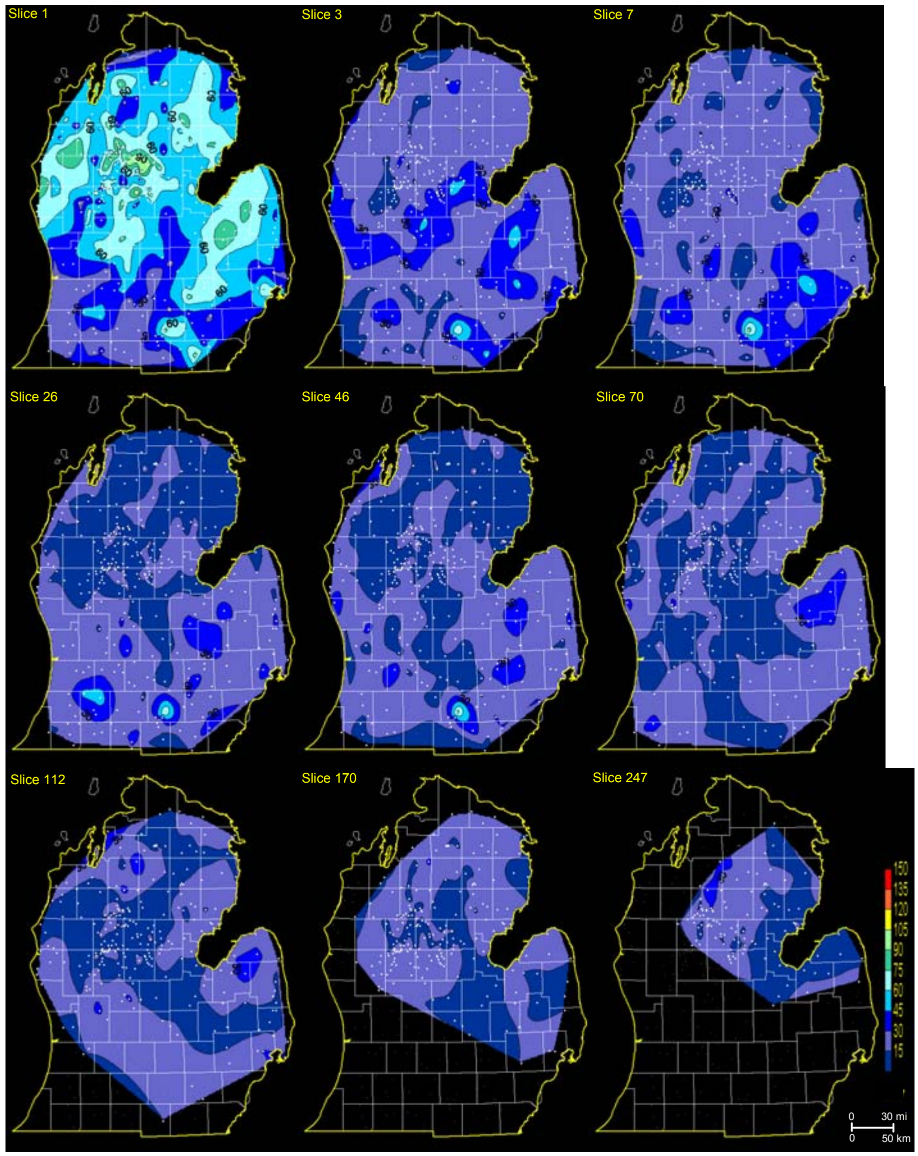


Figure 22. Representative top-down slices for the "Dundee" interval. Slice numbers correspond to the depth (ft) beneath the Bell Shale-"Dundee contact. The contour interval is 15 APIU and the white dots represent the wells used for contouring.

Figure 23. Representative bottom-up slices from the Kawkawlin Bentonite layer toward the top of the Dundee Limestone. Slice numbers correspond to the depth (ft) above this bentonite. The contour interval is 3 APIU and the white dots represent the wells used for contouring. Note that the black color within the contoured area for Slices 1 and 3 is a product of the gridding algorithm and lies within the 27-30 APIU range.

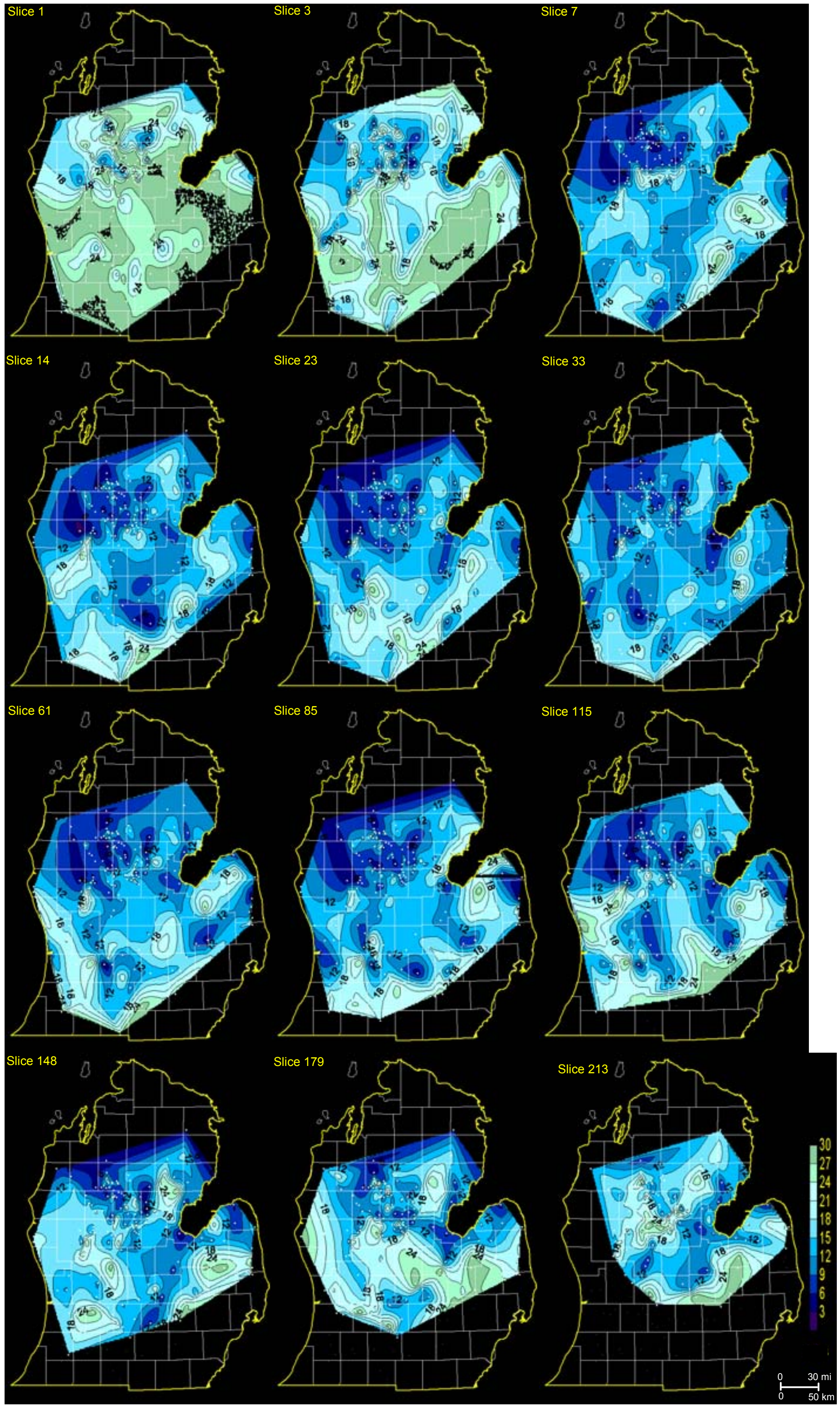

Slice 1
Slice 3
Slice 7
Slice 14
Slice 23
Slice 33
Slice 61
Slice 85
Slice 115
Slice 148
Slice 179
Slice 213
30
27
24
21
18
15
12
9
6
3
0 30 mi
0 50 km

Figure 24. Representative top-down slices for the Dundee Limestone. Slice numbers correspond to the depth (ft) beneath the Dundee Limestone top pick. The contour interval is 3 APIU and the white dots represent the wells used for contouring. Note that the black color within the contoured area for Slices 1 and 3 is a product of the gridding algorithm and lies within the 27-30 APIU range.

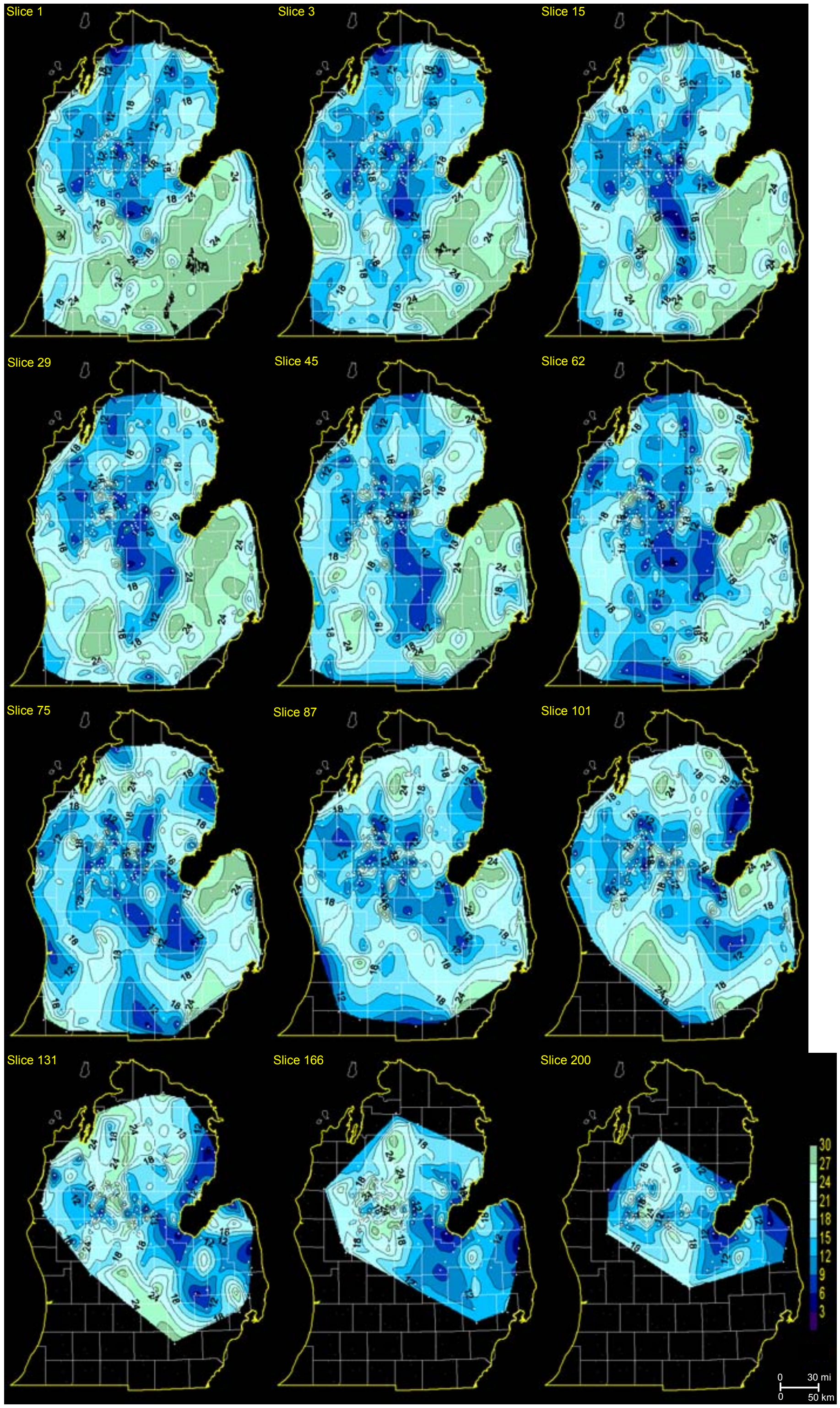
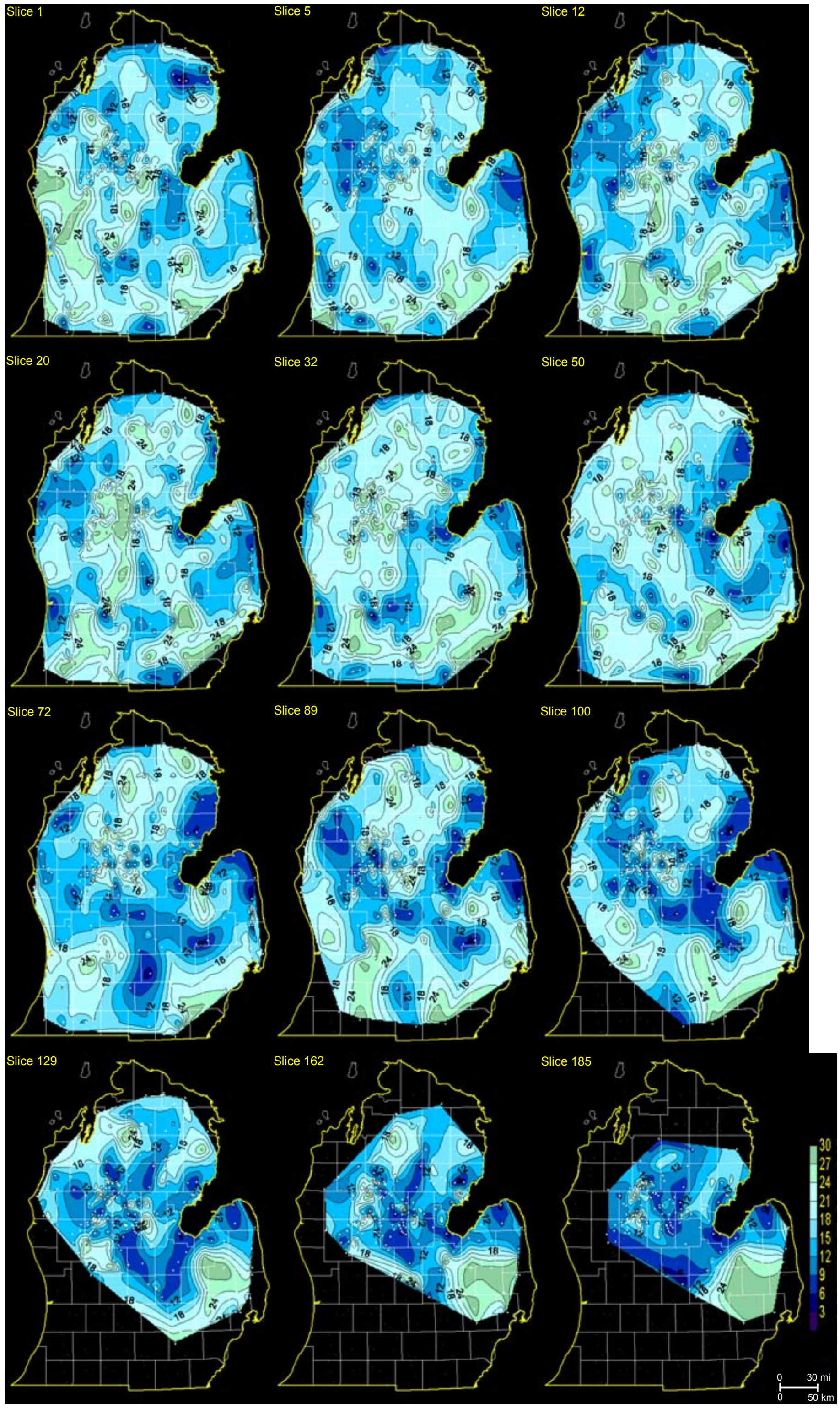

Slice 1
Slice 3
Slice 15
Slice 29
Slice 45
Slice 62
Slice 75
Slice 87
Slice 101
Slice 131
Slice 166
Slice 200
30
27
24
21
18
15
12
9
6
3
0 30 mi
0 50 km

Figure 25. Representative bottom-up slices for the Dundee Limestone. Slice numbers correspond to the depth (ft) above the Detroit River Group top pick. The contour interval is 3 APIU and the white dots represent the wells used for contouring.


Slice 1
Slice 5
Slice 12
Slice 20
Slice 32
Slice 50
Slice 72
Slice 89
Slice 100
Slice 129
Slice 162
Slice 185
30
27
24
21
18
15
12
9
6
3
0 30 mi
0 50 km

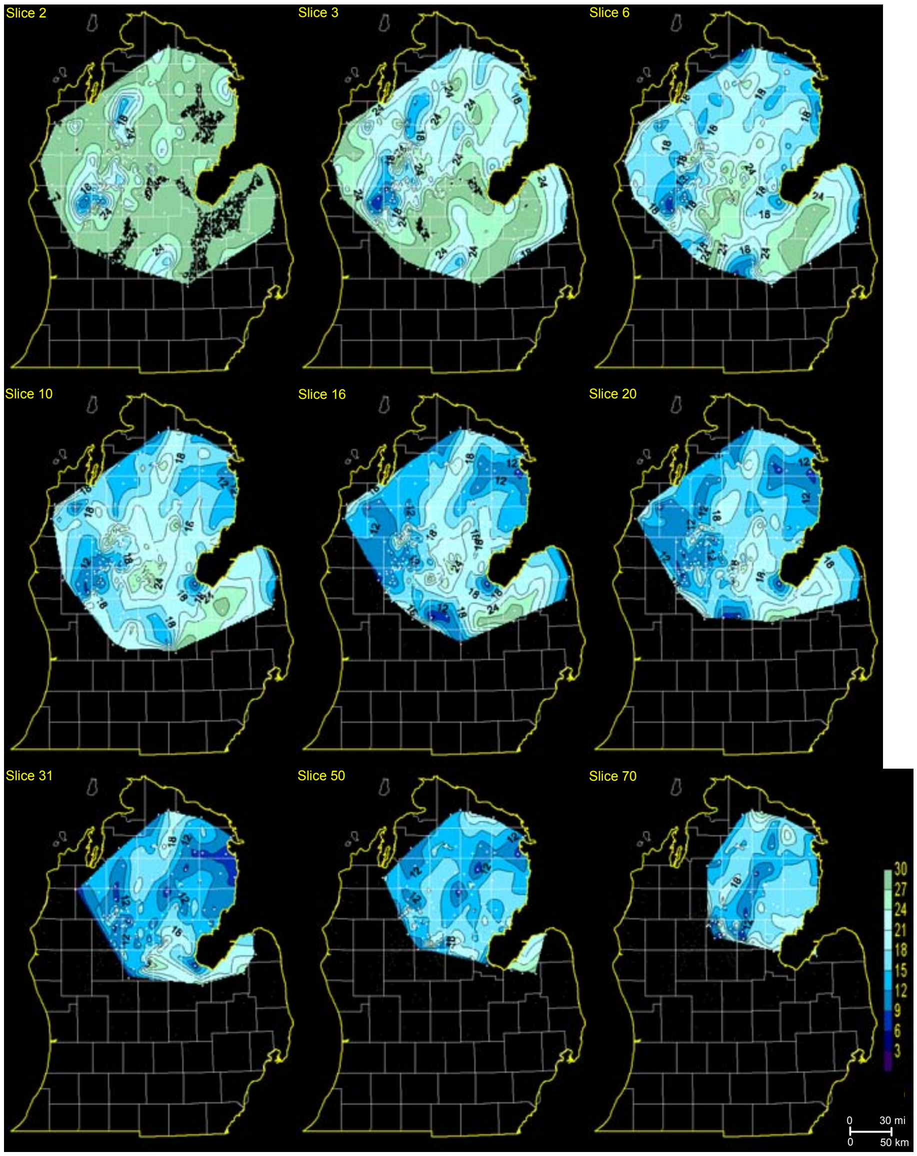


Figure 26. Representative top-down slices for the Rogers City Limestone. Slice numbers correspond to the depth (ft) beneath the Bell Shale-Rogers City Limestone contact. The contour interval is 3 APIU and the white dots represent the wells used for contouring. Note that the black color within the contoured area for Slices 2 and 3 is a product of the gridding algorithm and lies within the 27-30 APIU range.

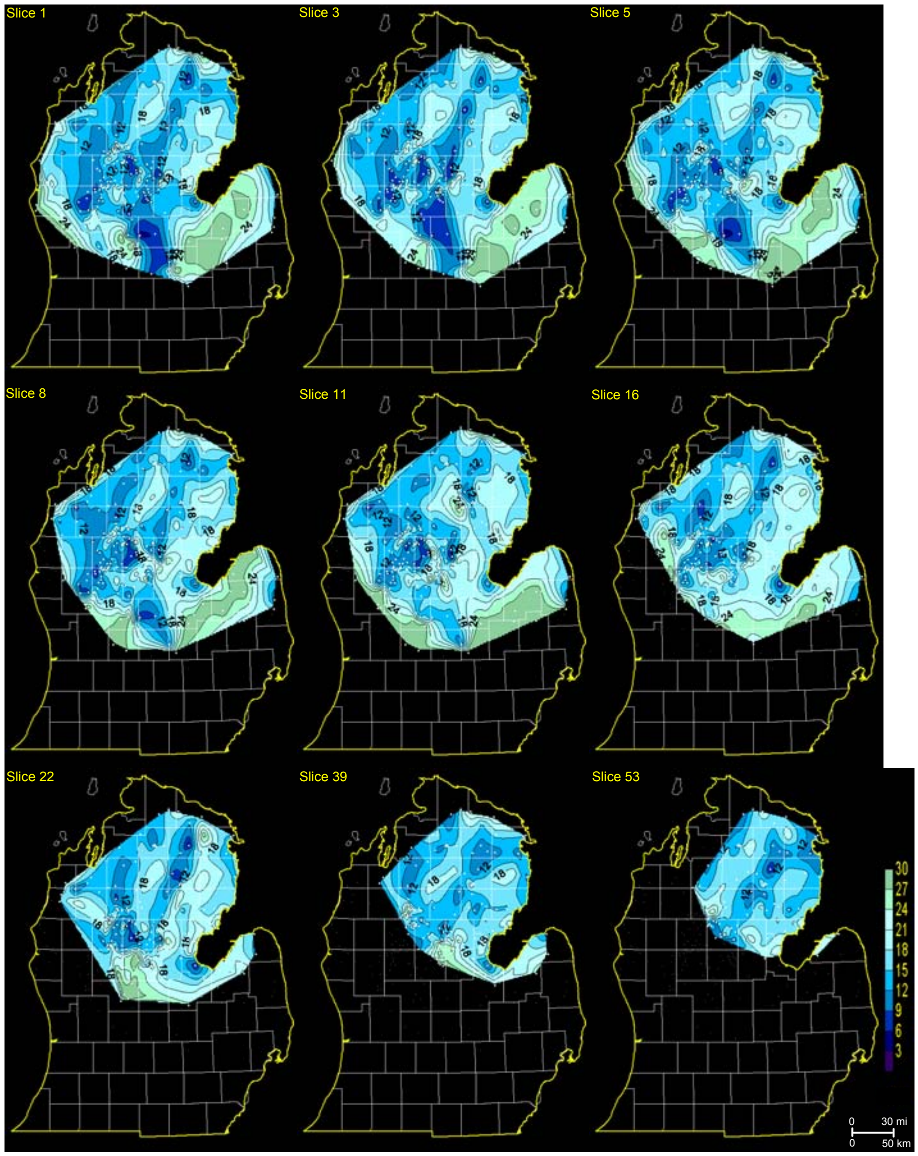


Figure 27. Representative bottom-up slices for the Rogers City Limestone. Slice numbers correspond to the depth (ft) above the Rogers City-Dundee contact. The contour interval is 3 APIU and the white dots represent the wells used for contouring.

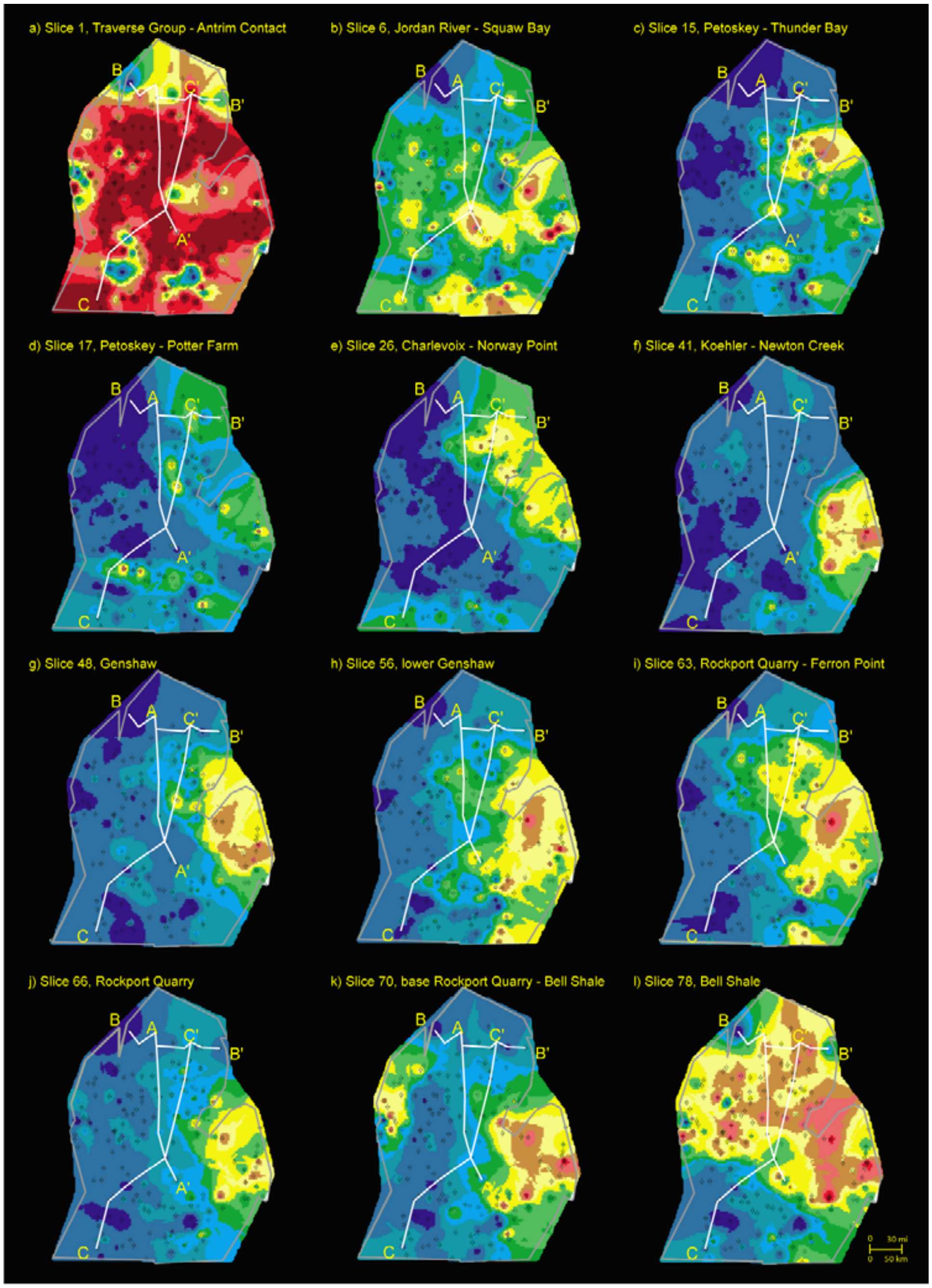


Figure 28. Twelve representative proportional slice images of the Traverse Group. The color contour scale is as follows: blue- less than 40 APIU, green and yellow- 40 to 80 APIU, brown and red- 80 to 150 APIU. The blue contours infer carbonate lithology, green-yellow contours infer mixed carbonate and shale (e.g. argillaceous limestone), and the brown-red contours infer shale or claystone (taken from Wylie, 2002).

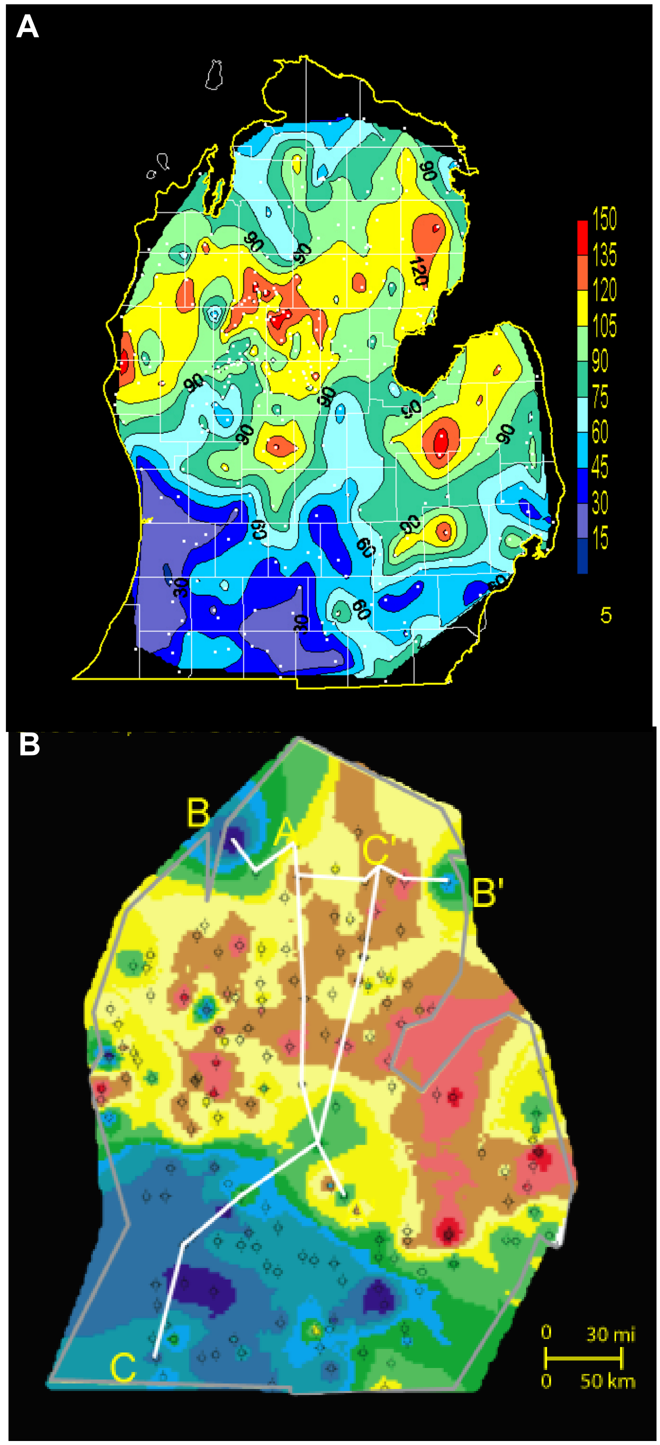


Figure 29. Comparison of the Bell Shale using the WLT and LCAS methods. (A) WLT slice image for 5 ft above the base of the Bell Shale. (B) LCAS proportional slice image at the base of the Bell Shale (taken from Wylie, 2002). Note that the color contour scale refers only to the WLT slice (A).

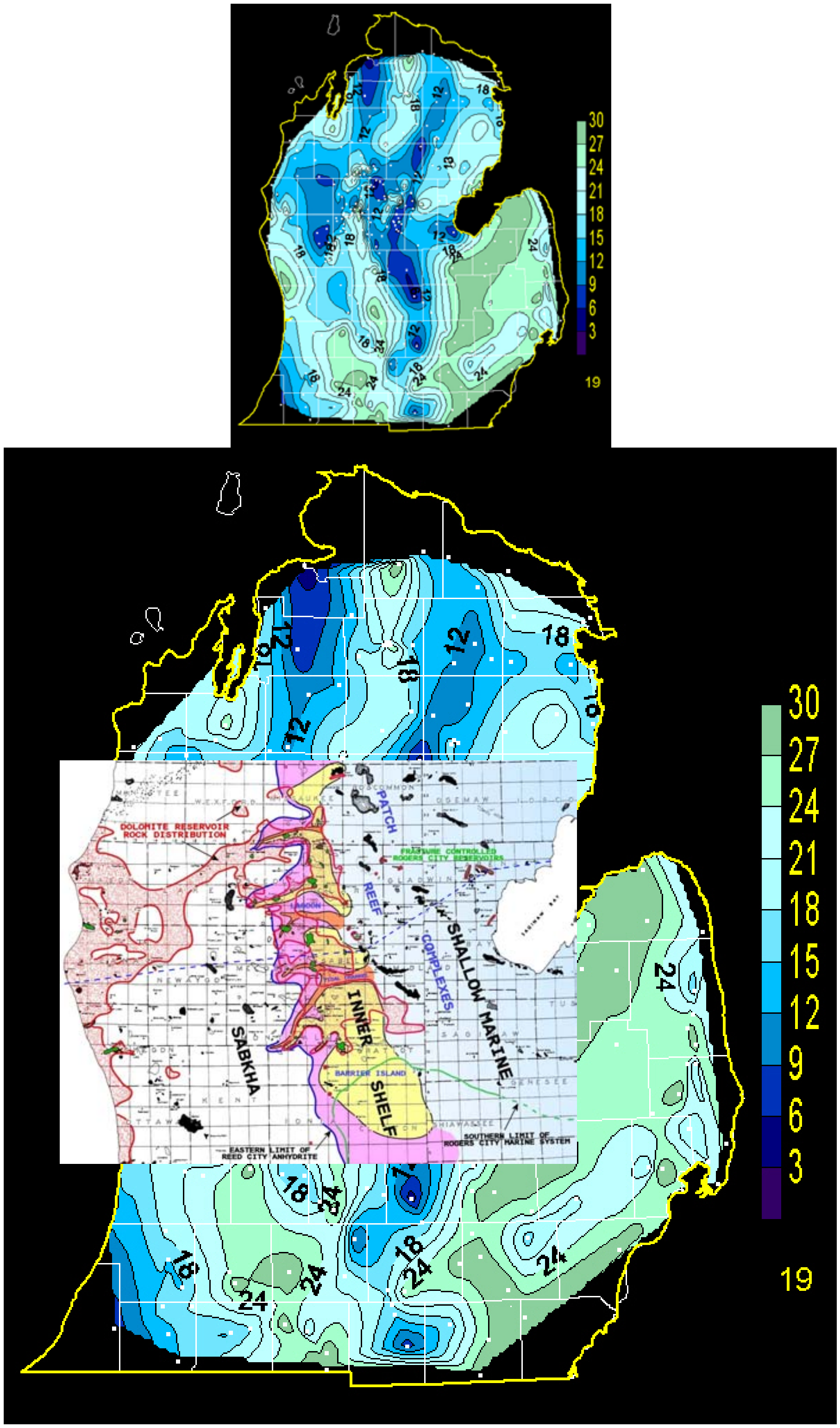


Figure 30. (A) Slice 19 from the top-down Dundee Limestone results. (B) Taylor's (2001) depositional model for the upper Dundee superimposed onto slice 19 illustrating the similarity between the shelf trend in Taylor's model and the low gamma ray trend from the slicing results.

Appendix A: Digital Log Information

Description of the columns:

Permit- well permit number

Name- county name

Top picks,

RGRC- Rogers City, *DNDE*- Dundee, *DRRV*- Detroit River, *DRB*- Bentonite

Well Location,

Latitude, *Longitude*, *Twn*- township, *Rng*- range, *Sec*- section number

KB- kelly bushing

TD- total depth

(*) No TD available, used LAS file "stop depth" as proxy

Type- well type

D- dry hole, O- oil or oil/gas, G-gas, GC-gas condensate, GS- gas storage

BD-brine disposal well, WI-water injection well, OI-other injection well,

Obs-observation well.

Omit- provides reasons for excluding wells

1- well in a group or field was not chosen to be the "representative" well

2- no digitial gamma ray data for the Dundee- Rogers City interval

3- duplicate or triplicate well

4- digitizing error

5- outlier

6- other

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
23208	Alcona	1596	1691	1856		44.64125	-83.33780	26N	9E	22	733	2610	D	1
24102	Alcona	1912	2012	2201		44.68279	-83.55712	26N	7E	2	877	2987	D	1
34931	Alcona	2692	2792	2947	3132	44.60795	-83.87002	26N	5E	31	987	10402	D	1
32648	Allegan		2045	2159	2234	42.69800	-85.63505	4N	11W	29	772	4721	D	1
32870	Allegan		1993	2106	2181	42.63780	-85.71407	3N	12W	22	739	4400	D	2
34060	Allegan		1892	1950	2078	42.65174	-85.82360	3N	13W	15	882	3200	D	1
25690	Alpena	305	405	501		45.11610	-83.35227	31N	9E	5	684	6380	D	1
29513	Alpena	384	484	580		45.09336	-83.39298	31N	8E	12	669	3900	D	1
29571	Alpena	616	711	845		45.11750	-83.81702	32N	5E	34	756	5971	D	3
37950	Alpena	1050	1150	1285		44.90526	-83.46694	29N	8E	16	785	7120	D	1
39200	Alpena	1409	1509	1634	1843	44.91831	-83.83193	29N	5E	9	887	8500	G	1
22639	Antrim		1220	1368		45.15630	-85.33428	32N	8W	19	878	5778	D	1
35702	Antrim	1746	1796	1936		44.97258	-85.13593	30N	7W	27	731	7322	D	2
34973	Arenac	2936	3036	3383	3450	44.02771	-83.86957	19N	5E	21	629	11425	D	1
39249	Arenac	2434	2534	2808	2940	44.15724	-83.99120	20N	4E	4	826	12100	G	1
39553	Arenac	2969	3094	3379		44.11051	-83.70986	20N	6E	26	621	12087	G	1
40097	Arenac	3289	3389	3687	3757	44.11156	-83.60755	20N	7E	27	630	11920	D	1
40763	Arenac	2918	3043	3322		44.12363	-83.73261	20N	6E	22	630	11850	O	1
42858	Arenac	2937	3037	3326		44.06008	-83.68134	19N	7E	7	621	15514	O	3
23572	Barry		2444	2539	2643	42.72033	-85.16498	4N	7W	20	882	5711*	D	1
24504	Barry		2071	2181	2263	42.66664	-85.42845	3N	10W	12	776	5004*	D	1
36965	Barry		2311	2395	2490	42.64149	-85.23349	3N	8W	15	945	5616	D	1
39719	Barry		2336	2425	2531	42.63317	-85.10111	3N	7W	23	927	5530	D	1
37779	Bay	2756	2806	3134	3204	43.63587	-83.95252	14N	4E	11	621	14589	GC	1
39976	Bay					43.79479	-83.98120	16N	4E	15	633	12500	G	
40516	Bay	3065	3140	3465	3544	43.79823	-84.03292	16N	4E	7	644	12430	GC	1
41133	Bay	3043	3138	3436	3556	43.94507	-84.14046	18N	3E	20	782	12770	G	6
29711	Benzie	1578	1593	1725		44.53619	-86.14207	25N	15W	29	707	4328	D	1
31855	Benzie	1977	2002	2128		44.57281	-85.97692	25N	14W	11	812	3250*	D	3
37007	Benzie					44.53944	-85.84039	25N	13W	26	903	5670	D	
26112	Berrien		886	965		41.95775	-86.26294	6S	17W	10	804	5648	D	1
29779	Branch		1334	1369		42.05506	-85.28130	5S	8W	7	890	5432	D	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
33019	Branch		1120	1149	1187	41.77103	-84.96022	8S	6W	13	1019	4633	D	1
37569	Branch		1238	1269		41.97126	-85.21600	6S	8W	3	911	5248*	D	1
38045	Branch		1289	1319	1383	41.94235	-85.07792	6S	7W	13	944	5378	D	1
38169	Branch		1135	1163	1216	41.84277	-84.95950	7S	6W	24	1011	3473	D	2
22352	Calhoun		1658	1702	1786	42.20369	-85.19459	3S	8W	13	952	4739	D	
34619	Calhoun		1657	1699	1740	42.18952	-84.85558	3S	5W	33	982	4315	D	2
34783	Calhoun		2016	2126	2196	42.35149	-84.78869	1S	4W	28	939	3400*	D	1
34763	Cass		1176	1258	1313	42.05323	-85.96071	5S	14W	8	885	4000	D	2
35459	Cass		881	966		41.81015	-85.86569	7S	13W	31	897	3800	D	1
35553	Cass		1062	1146		41.93047	-85.92542	6S	14W	22	890	3238	D	1
37536	Cass		1248	1338	1391	42.05131	-85.78565	5S	13W	11	895	3900	D	3
23435	Charlevoix					45.65858	-85.52788	38N	10W	27	678	5383	D	2
29079	Charlevoix		641	717		45.34931	-85.09757	34N	7W	13	743	5022	D	3
34824	Charlevoix					45.14005	-84.79456	32N	4W	27	1145	8900	D	
36260	Charlevoix	1586	1626	1804		45.12470	-84.81299	32N	4W	33	1195	8030	D	1
30682	Cheboygan	221	296	364		45.40920	-84.37300	35N	1W	24	801	5753	D	1
35060	Cheboygan	397	467	600		45.35375	-84.52022	34N	2W	11	813	5940	D	2
22435	Clare					44.11176	-84.80796	20N	4W	21	1219	5456	D	1
25847	Clare					44.14222	-84.92978	20N	5W	8	1118	3819	D	1
26649	Clare					44.02090	-85.03729	19N	6W	21	1055	4000	D	1
27451	Clare					44.09006	-85.07905	20N	6W	30	1146	5155	O	1
27530	Clare					44.08620	-85.07924	20N	6W	31	1129	5057	O	1
27575	Clare					44.09305	-85.07933	20N	6W	30	1154	5213	O	1
29087	Clare					44.06211	-84.72463	19N	3W	6	1133	5265	O	1
29136	Clare					44.02824	-84.98524	19N	6W	24	1135	4056	D	1
30563	Clare					44.00947	-84.62026	19N	3W	25	944	5250	D	1
30745	Clare					44.13869	-84.93985	20N	5W	8	1117	5153	O	1
31186	Clare					44.09967	-85.06427	20N	6W	29	1133	5122	O	1
31596	Clare					44.09700	-85.06949	20N	6W	30	1144	5150	O	1
31654	Clare					44.14632	-84.98755	20N	6W	12	1151	5207	O	2
31697	Clare					44.09393	-85.07028	20N	6W	30	1145	5120	WI	4
31698	Clare					44.09719	-85.06445	20N	6W	29	1135	5119	WI	2

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
32227	Clare					44.09717	-85.06026	20N	6W	29	1144	5150	O	2
32296	Clare					44.10072	-85.06007	20N	6W	29	1149	5181	WI	2
32297	Clare					44.10059	-85.07003	20N	6W	30	1144	5150	WI	2
32372	Clare					44.10079	-85.07418	20N	6W	30	1152	5176	O	2
32384	Clare					44.09733	-85.05449	20N	6W	29	1122	5148	WI	2
32385	Clare					44.09726	-85.07423	20N	6W	30	1156	5183	WI	2
32392	Clare					44.09670	-85.07918	20N	6W	30	1160	5180	O	2
32393	Clare					44.09670	-85.08452	20N	6W	30	1156	5170	O	2
32396	Clare					44.10054	-85.05449	20N	6W	29	1129	5170	O	2
32398	Clare					44.09385	-85.05950	20N	6W	29	1123	5134	WI	2
32461	Clare					44.07210	-84.97083	19N	6W	1	1107	5190	D	2
32477	Clare					44.09319	-85.06481	20N	6W	29	1135	5140	O	2
32546	Clare	3983	4033	4227	4442	43.87926	-84.70439	17N	3W	8	940	5315	D	1
32858	Clare					43.94164	-84.93598	18N	5W	20	1144	5340	O	2
32880	Clare					44.08624	-85.06961	20N	6W	31	1119	5115	WI	2
32890	Clare					44.08653	-85.07436	20N	6W	31	1137	5132	O	2
32897	Clare					44.08663	-85.05465	20N	6W	32	1101	5161	D	2
32902	Clare					44.09333	-85.07420	20N	6W	30	1114	5150	O	2
32930	Clare	4143	4218	4430	4637	43.96126	-84.86586	18N	5W	12	1237	5560	D	3
32966	Clare					44.08600	-85.06504	20N	6W	32	1132	5150	O	2
32971	Clare					44.08319	-85.06466	20N	6W	32	1107	5115	WI	2
32991	Clare					44.09060	-85.06114	20N	6W	29	1118	5132	O	2
32992	Clare					44.08256	-85.06965	20N	6W	31	1136	5141	O	2
33004	Clare					44.08278	-85.06025	20N	6W	32	1096	5100	G	2
33011	Clare	3738	3813	4004	4220	44.08343	-85.07440	20N	6W	31	1132	5125	WI	2
33097	Clare					43.88554	-84.83747	17N	4W	7	993	5250	D	2
33467	Clare					44.08970	-85.07420	20N	6W	30	1142	5137	WI	2
33492	Clare					44.09643	-85.06569	20N	6W	29	1149	4082	BD	2
33508	Clare	3773	3848	4054	4279	44.14768	-84.99169	20N	6W	2	1128	5251	O	1
33526	Clare	3971	4046	4244	4467	43.95167	-84.95145	18N	5W	18	1129	5320	O	1
33609	Clare					44.08960	-85.08450	20N	6W	30	1137	5155	WI	2
33633	Clare					44.08258	-85.07924	20N	6W	31	1140	5140	O	2

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
33680	Clare					44.09751	-85.07990	20N	6W	30	1158	10260	G	2
33723	Clare					44.10393	-85.06439	20N	6W	20	1145	5175	WI	2
34326	Clare	4194	4269	4482	4692	43.99644	-84.87657	19N	5W	35	1239	5600	D	1
34330	Clare	3933	4008	4205	4433	44.05852	-84.70893	19N	3W	7	1092	5335	BD	1
34331	Clare					44.06538	-84.71941	19N	3W	6	1162	5373	O	2
34370	Clare					44.10435	-85.05952	20N	6W	20	1151	5170	O	2
34493	Clare	3810	3885	4087	4296	44.10411	-85.05435	20N	6W	20	1116	5145	D	1
34611	Clare	3920	3970	4179	4386	43.88485	-84.82961	17N	4W	7	1004	11864	D	2
34662	Clare					44.14230	-84.94995	20N	5W	7	1106	5190	O	2
34698	Clare					44.14572	-84.96603	20N	5W	7	1137	5200	O	
34706	Clare					44.14237	-84.96520	20N	5W	7	1127	5190	O	
34710	Clare	4198	4273	4466		43.99021	-84.81420	19N	4W	32	1194	4538	D	1
34790	Clare	4003	4053	4234	4415	43.82184	-85.02634	17N	6W	34	1121	13022	D	1
34790	Clare					43.82184	-85.02634	17N	6W	34	1121	13022	D	
34790	Clare					43.82184	-85.02634	17N	6W	34	1121	13022	D	
35649	Clare					44.07550	-84.89575	20N	5W	34	1138	5365	D	
35652	Clare					44.13152	-84.94519	20N	5W	17	1104	5180	D	
35690	Clare					43.86300	-85.08488	17N	6W	18	1059	5155	O	
35762	Clare	3768	3843	4036	4262	44.13443	-84.93985	20N	5W	8	1109	5205	O	1
35781	Clare					44.11060	-85.07683	20N	6W	19	1166	11563	D	
35781	Clare					44.11060	-85.07683	20N	6W	19	1166	11563	D	
35963	Clare	3811	3886	4080	4303	44.08940	-84.61060	20N	3W	36	997	5215	WI	1
36333	Clare					44.10831	-85.06442	20N	6W	20	1131	5131	O	
36565	Clare					44.07896	-85.06969	20N	6W	31	1117	5121	WI	
36751	Clare					44.08287	-85.04465	20N	6W	33	1095	5190	O	
37423	Clare					44.08664	-85.04216	20N	6W	33	1092	3875	BD	
37480	Clare					44.07507	-85.07032	20N	6W	31	1112	5125	O	
37659	Clare					43.86625	-84.83679	17N	4W	18	943	5200	D	
37709	Clare					44.07234	-85.03481	19N	6W	4	1077	5143	D	
37719	Clare					44.07133	-85.07432	19N	6W	6	1105	3165	O	
38434	Clare	3748	3798	4002	4198	43.81767	-84.71900	17N	3W	31	836	4985	D	1
38568	Clare	4053	4128	4307	4534	43.93163	-84.66824	18N	3W	21	869	5200	D	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
38760	Clare	3823	3898	4085	4303	44.11313	-84.89254	20N	5W	22	1111	5216	D	2
38982	Clare	3765	3840	4036	4248	44.08326	-85.02030	20N	6W	34	1083	5155	D	1
39007	Clare					44.09030	-85.06203	20N	6W	29	1137	5140	WI	
39127	Clare					44.07871	-85.07471	20N	6W	31	1123	5110	O	
39132	Clare					44.07988	-85.07922	20N	6W	31	1132	5145	WI	
39155	Clare					43.93895	-84.87146	18N	5W	23	1159	4200	D	
39165	Clare	3794	3869	4063		44.02042	-84.63777	19N	3W	23	950	4137	D	1
40577	Clare					44.12333	-84.95552	20N	5W	18	1125	11880	G	
40987	Clare					44.07681	-85.08002	20N	6W	31	1120	11540	G	
40993	Clare					44.14185	-84.98266	20N	6W	12	1167	12300	G	
41464	Clare					44.14881	-84.97326	20N	6W	1	1138	12997	G	
41826	Clare					44.11229	-85.08222	20N	6W	19	1167	11560	G	
41826	Clare					44.11229	-85.08222	20N	6W	19	1167	11560	G	
22348	Clinton	2783	2788	2862	2998	42.82157	-84.64042	5N	3W	14	834	5178	D	
27811	Clinton		2808	3015	3071	43.01606	-84.47844	7N	1W	6	770	7781	D	3
28862	Crawford	3145	3245	3441		44.61242	-84.62675	26N	3W	36	1242	8300	D	1
35587	Crawford					44.59664	-84.69215	25N	3W	5	1277	10447	O	
41307	Crawford	2780	2880	3044		44.69907	-84.44543	27N	1W	28	1145	10760	G	2
43116	Crawford					44.84607	-84.66506	28N	3W	3	1367	2396	G	
28163	Eaton		2159	2224	2337	42.47940	-84.92133	1N	5W	17	883	5174	D	1
29117	Eaton		2390	2443		42.55114	-84.61575	2N	3W	24	869	6922	D	1
33604	Eaton		2202	2273	2376	42.51667	-85.00749	2N	6W	34	958	5341	D	1
36319	Eaton		2477	2547	2675	42.57687	-84.71253	2N	3W	7	923	6051	D	1
41423	Eaton		2601	2694	2816	42.75361	-84.91988	4N	5W	8	881	6770	D	1
28212	Emmet					45.55899	-84.76258	37N	4W	35	714	3945	D	1
23948	Genesee	2115	2120	2318	2337	42.89878	-83.66838	6N	7E	29	850	5537	D	1
24028	Genesee	2148	2153	2334	2337	42.94361	-83.47196	6N	8E	12	915	5424	D	1
24079	Genesee	2459	2474	2691	2713	43.21128	-83.53653	9N	8E	4	837	8525	D	4
20493	Gladwin					43.96563	-84.52658	18N	2W	10	845	5066	O	1
20714	Gladwin					43.97983	-84.54638	18N	2W	4	850	5678	D	2
24030	Gladwin					43.84835	-84.59209	17N	2W	19	756	5093	D	1
34805	Gladwin	3845	3895	4134	4327	43.87061	-84.49291	17N	2W	13	740	5135	O	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
35090	Gladwin	3598	3673	3966	4098	43.88525	-84.33464	17N	1E	15	735	15859	D	1
35846	Gladwin	3886	3936	4192	4384	43.89994	-84.59358	17N	2W	6	778	5175	D	1
37774	Gladwin	3798	3848	4070	4260	43.82445	-84.50479	17N	2W	36	748	5075	D	3
38836	Gladwin	3521	3596	3859	4016	43.91283	-84.38746	18N	1W	35	747	12246	D	1
39396	Gladwin	3732	3807	4044	4261	43.94729	-84.50141	18N	2W	13	773	5088	O	1
39724	Gladwin	3842	3917	4151	4380	44.02225	-84.52102	19N	2W	23	865	5283	D	1
39772	Gladwin					43.96006	-84.52642	18N	2W	10	859	12700	D	
39772	Gladwin					43.96006	-84.52642	18N	2W	10	859	12700	D	
42226	Gladwin					43.95053	-84.51438	18N	2W	14	813	12350	G	
29703	Grand Traverse					44.58248	-85.71683	25N	12W	11	1102	6015	D	1
30656	Grand Traverse					44.73262	-85.33713	27N	9W	13	995	6598	D	1
31637	Grand Traverse					44.65625	-85.54394	26N	10W	17	843	6113	O	5
31836	Grand Traverse					44.54269	-85.42537	25N	9W	20	1073	7550	D	5
32109	Grand Traverse					44.65432	-85.54807	26N	10W	17	916	6045	D	2
32248	Grand Traverse					44.63890	-85.61821	26N	11W	22	916	5958	G	2
32341	Grand Traverse					44.69415	-85.45847	27N	10W	36	953	6347	D	2
32537	Grand Traverse					44.61921	-85.48713	26N	10W	26	947	6675	D	2
32619	Grand Traverse					44.63367	-85.43059	26N	9W	20	931	6780	G	2
32874	Grand Traverse					44.58374	-85.71332	25N	12W	12	1104	6192	G	2
33384	Grand Traverse					44.65560	-85.54812	26N	10W	17	914	6060	D	2
34132	Grand Traverse	2564	2609	2751		44.57136	-85.64389	25N	11W	9	1101	6469*	D	2
34132	Grand Traverse					44.57136	-85.64389	25N	11W	9	1101	0	D	2
34292	Grand Traverse	2168	2218	2350		44.63675	-85.57964	26N	11W	24	915	11020	D	1
34292	Grand Traverse					44.63675	-85.57964	26N	11W	24	915	11020	D	2
35638	Grand Traverse					44.65874	-85.52173	26N	10W	9	825	6500	O	
36364	Grand Traverse					44.67583	-85.52848	26N	10W	4	857	6010	D	
37345	Grand Traverse					44.67284	-85.46775	26N	10W	1	936	6550	D	
37557	Grand Traverse					44.57654	-85.58699	25N	11W	12	1091	6593	D	
37800	Grand Traverse					44.60114	-85.66773	26N	11W	32	1109	6090	D	
37964	Grand Traverse					44.56795	-85.76569	25N	12W	16	1137	6100	D	
38763	Grand Traverse					44.67262	-85.45829	26N	10W	1	900	6615	D	
38839	Grand Traverse					44.71970	-85.35076	27N	9W	24	940	7140	D	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
39047	Grand Traverse					44.67571	-85.46102	26N	10W	1	900	6551	D	
29739	Gratiot	3138	3158	3319		43.27301	-84.57954	10N	2W	8	762	17466	D	1
37377	Gratiot	3182	3202	3360		43.25027	-84.81571	10N	4W	17	774	3537	O	1
36596	Hillsdale		1399	1519		41.87741	-84.46888	7S	1W	7	1122	4047	O	1
37886	Hillsdale					42.03494	-84.55759	5S	2W	17	1156	4343	D	
38358	Hillsdale		1609	1678		42.01550	-84.54280	5S	2W	21	1166	4360	O	1
38521	Hillsdale					42.00814	-84.56242	5S	2W	29	1192	4400	D	
38809	Hillsdale					42.07015	-84.56732	5S	2W	5	1087	4370	D	
38879	Hillsdale		1639	1702		42.06233	-84.56262	5S	2W	5	1090	4360	D	1
38904	Hillsdale					42.06604	-84.57614	5S	2W	6	1129	4400	D	
39030	Hillsdale					42.07005	-84.56867	5S	2W	5	1087	4415	D	
40414	Hillsdale					42.06252	-84.64076	5S	3W	3	1107	5917	O	
41359	Hillsdale					42.04817	-84.55767	5S	2W	8	1137	4370	D	
42345	Hillsdale					42.05620	-84.57114	5S	2W	8	1140	4380	D	
42346	Hillsdale					42.03729	-84.55883	5S	2W	17	1156	4350	O	
42829	Hillsdale					42.02825	-84.55167	5S	2W	21	1141	4380	O	
43862	Hillsdale					42.04095	-84.57079	5S	2W	17	1172	4470	O	
44285	Hillsdale					42.04554	-84.56624	5S	2W	8	1153	4350	O	
44319	Hillsdale					42.05883	-84.56869	5S	2W	5	1141	4299	O	
44503	Hillsdale					42.04264	-84.55503	5S	2W	16	1143	4360	D	
45242	Hillsdale					42.05615	-84.56848	5S	2W	8	1131	4358	D	
24789	Huron	2621	2666	3036	3013	43.76668	-83.00609	16N	12E	36	763	7260	D	1
29191	Huron	1683	1703	1963	1960	43.71690	-82.66180	15N	15E	26	711	2320	O	3
33550	Huron	2397	2457	2810	2808	43.99671	-83.02677	18N	12E	12	644	3400	D	1
39544	Huron	2687	2757	3131	3132	43.74653	-83.35815	15N	9E	1	651	11290	D	1
28607	Ingham		2400	2485	2574	42.53314	-84.44778	2N	1W	29	939	7866	D	4
29672	Ingham		2324	2389		42.42392	-84.37833	1N	1W	36	977	6300	D	1
26990	Ionia	2720	2730	2830	2940	42.94959	-85.23059	7N	8W	35	820	6313	D	1
36704	Ionia	2700	2710	2810	2931	42.87989	-85.02622	6N	6W	28	822	6700	D	1
39530	Iosco	3098	3198	3472		44.28342	-83.66049	22N	6E	24	740	11244	D	1
40267	Iosco	3009	3109	3385	3498	44.26797	-83.80821	22N	5E	27	776	11807	G	1
21117	Isabella					43.66555	-85.07580	15N	6W	30	1040	3825	D	1

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22826	Isabella					43.67836	-85.00405	15N	6W	23	941	3770	D	1
27193	Isabella					43.79783	-85.07991	16N	6W	7	1078	4117	D	1
27405	Isabella					43.73061	-84.74671	16N	4W	36	785	4838	O	1
27775	Isabella					43.72700	-84.74641	15N	4W	1	782	4810	O	1
30404	Isabella					43.48855	-84.83860	13N	4W	30	874	3750	D	1
30746	Isabella					43.53747	-84.77136	13N	4W	10	855	3891	D	1
32562	Isabella					43.80273	-84.77076	16N	4W	3	877	4020	D	2
33262	Isabella					43.73060	-84.75170	16N	4W	35	795	4840	O	2
34097	Isabella	3571	3601	3784	3923	43.49630	-84.98342	13N	6W	24	903	5287*	D	1
34166	Isabella					43.64823	-84.85986	15N	5W	36	833	0	D	2
34481	Isabella					43.62620	-85.03594	14N	6W	4	960	3672	D	2
34572	Isabella	3663	3703	3931	4115	43.77653	-84.69444	16N	3W	17	799	4886	O	1
34960	Isabella					43.72625	-84.75118	15N	4W	2	793	4843	O	
35091	Isabella	3723	3763	3975	4147	43.74731	-84.76140	16N	4W	26	822	4900	O	1
35206	Isabella					43.67060	-84.72436	15N	3W	19	759	4820	G	
35303	Isabella					43.72654	-84.74607	15N	4W	1	786	4830	BD	
35380	Isabella					43.72321	-84.74668	15N	4W	1	791	4845	O	
35425	Isabella					43.72607	-84.75612	15N	4W	2	798	4846	O	
35475	Isabella					43.73068	-84.72161	16N	3W	31	783	5240	D	
35540	Isabella					43.63620	-84.64437	14N	3W	2	736	4670	O	
35546	Isabella					43.73428	-84.73680	16N	4W	36	796	4856	O	
35586	Isabella					43.65988	-84.72536	15N	3W	30	753	4745	G	
35601	Isabella					43.75922	-84.75698	16N	4W	23	804	4010	O	
35607	Isabella					43.75961	-84.74180	16N	4W	24	804	4970	D	
35622	Isabella					43.66331	-84.72427	15N	3W	30	756	4742	G	
35637	Isabella	3633	3673	3889	4087	43.66700	-84.71430	15N	3W	30	756	4775	O	1
35651	Isabella					43.76281	-84.75669	16N	4W	23	803	4956	D	
35654	Isabella					43.75565	-84.75117	16N	4W	26	823	4870	O	
35711	Isabella	3639	3679	3873	4049	43.64877	-84.68927	15N	3W	32	745	4740	D	1
35744	Isabella					43.71565	-84.75166	15N	4W	2	791	4829	O	
35757	Isabella					43.71188	-84.75166	15N	4W	11	792	4840	O	
35808	Isabella					43.75193	-84.76161	16N	4W	26	824	4950	O	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
35831	Isabella					43.72301	-84.75661	15N	4W	2	797	4850	O	
35944	Isabella					43.76281	-84.76161	16N	4W	23	827	4910	BD	
35986	Isabella					43.71940	-84.75165	15N	4W	2	791	4825	O	
35987	Isabella					43.70851	-84.74668	15N	4W	12	786	4836	O	
35991	Isabella					43.75979	-84.68052	16N	3W	21	772	4900	D	
36005	Isabella					43.71180	-84.74669	15N	4W	12	787	4835	O	
36040	Isabella					43.71571	-84.74669	15N	4W	1	789	4840	O	
36047	Isabella					43.66727	-84.71930	15N	3W	30	756	4760	O	
36049	Isabella					43.62133	-84.63002	14N	3W	11	725	4672	O	
36073	Isabella					43.71194	-84.73677	15N	4W	12	785	4859	O	
36142	Isabella					43.70825	-84.75165	15N	4W	11	785	4838	O	
36146	Isabella					43.70823	-84.75630	15N	4W	11	780	4835	O	
36147	Isabella					43.71163	-84.75547	15N	4W	11	785	4830	O	
36151	Isabella					43.62538	-84.63438	14N	3W	11	721	4685	O	
36168	Isabella					43.74153	-84.68089	16N	3W	33	771	4548	O	
36181	Isabella					43.70145	-84.73184	15N	4W	12	775	4833	O	
36202	Isabella					43.69723	-84.75165	15N	4W	14	773	4830	D	
36204	Isabella					43.63619	-84.66458	14N	3W	3	741	4695	O	
36262	Isabella	3816	3841	4017	4200	43.61628	-85.04563	14N	6W	9	1100	4930	D	1
36264	Isabella					43.71208	-84.74176	15N	4W	12	784	4840	O	
36270	Isabella					43.71960	-84.74668	15N	4W	1	790	4840	O	
36271	Isabella					43.71580	-84.74179	15N	4W	1	787	4841	O	
36281	Isabella					43.70110	-84.78153	15N	4W	10	787	4660	D	
36282	Isabella					43.74959	-84.86242	16N	5W	25	887	5160	D	
36366	Isabella					43.63625	-84.63939	14N	3W	2	734	4690	O	
36367	Isabella					43.62133	-84.63437	14N	3W	11	728	4690	O	
36387	Isabella					43.63620	-84.65440	14N	3W	3	739	4680	O	
36390	Isabella					43.71235	-84.73183	15N	4W	12	783	4875	O	
36437	Isabella					43.70467	-84.75167	15N	4W	11	785	4835	O	
36449	Isabella					43.72020	-84.75626	15N	4W	2	795	4880	O	
36491	Isabella					43.71960	-84.73679	15N	4W	1	789	4850	O	
36520	Isabella					43.76260	-84.76659	16N	4W	23	822	3785	O	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
36524	Isabella	3810	3835	4032	4226	43.69544	-84.84188	15N	4W	18	878	5000	G	2
36545	Isabella					43.71554	-84.75623	15N	4W	2	793	4886	O	
36548	Isabella					43.73387	-84.74662	16N	4W	36	795	4846	O	
36549	Isabella					43.70494	-84.74172	15N	4W	12	781	4840	O	
36550	Isabella					43.70494	-84.74667	15N	4W	12	785	5125	O	
36551	Isabella					43.70853	-84.74174	15N	4W	12	785	4840	O	
36556	Isabella					43.74868	-84.76599	16N	4W	26	817	4875	O	
36607	Isabella					43.71960	-84.74176	15N	4W	1	794	4841	O	
36638	Isabella					43.74510	-84.75638	16N	4W	26	816	4873	O	
36646	Isabella					43.74262	-84.87223	16N	5W	26	924	5145	G	
36675	Isabella					43.63260	-84.64480	14N	3W	2	738	4675	O	
36696	Isabella					43.73421	-84.75161	16N	4W	35	798	4850	O	
36697	Isabella					43.72330	-84.74174	15N	4W	1	790	4845	O	
36762	Isabella	3678	3718	3924	4093	43.73781	-84.75149	16N	4W	35	795	4860	O	1
36783	Isabella					43.73059	-84.75650	16N	4W	35	805	4830	O	
36784	Isabella					43.73813	-84.68621	16N	3W	33	770	4835	O	
36797	Isabella					43.74506	-84.76622	16N	4W	26	810	4600	O	
36805	Isabella					43.75937	-84.77156	16N	4W	22	840	3795	O	
36806	Isabella					43.68821	-84.83127	15N	4W	18	853	4992	G	
36807	Isabella					43.71590	-84.73679	15N	4W	1	783	4830	O	
36826	Isabella					43.73788	-84.74591	16N	4W	36	796	4850	O	
36839	Isabella					43.74154	-84.68556	16N	3W	33	769	4821	O	
36894	Isabella					43.76600	-84.79170	16N	4W	21	884	3865	D	
36900	Isabella					43.74120	-84.75644	16N	4W	35	802	4849	O	
36928	Isabella					43.73421	-84.75650	16N	4W	35	807	4860	O	
36935	Isabella					43.74125	-84.68084	16N	3W	33	770	5243	BD	
36936	Isabella					43.67422	-84.72472	15N	3W	19	756	4755	G	
36944	Isabella					43.66692	-84.72959	15N	4W	25	759	4754	BD	
36951	Isabella	3913	3943	4154	4332	43.78172	-85.08731	16N	6W	18	1092	5160	D	3
37036	Isabella					43.73790	-84.74174	16N	4W	36	794	4840	O	
37038	Isabella					43.73393	-84.74174	16N	4W	36	795	4845	O	
37075	Isabella					43.73808	-84.69125	16N	3W	32	770	4845	O	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
37077	Isabella					43.73057	-84.76149	16N	4W	35	806	4880	O	
37078	Isabella					43.73421	-84.76148	16N	4W	35	807	4865	O	
37114	Isabella					43.74592	-84.86722	16N	5W	25	905	5150	G	
37133	Isabella	3934	3959	4163	4353	43.74625	-84.87729	16N	5W	26	939	5160	D	1
37147	Isabella					43.74533	-84.69132	16N	3W	29	774	4850	O	
37148	Isabella	3651	3691	3911	4091	43.74534	-84.68579	16N	3W	28	763	4845	O	2
37158	Isabella					43.70824	-84.76157	15N	4W	11	778	4830	D	
37169	Isabella					43.71024	-84.85220	15N	5W	12	843	5029	D	
37170	Isabella	3671	3711	3923	4091	43.70828	-84.73677	15N	4W	12	782	4885	O	1
37179	Isabella					43.70124	-84.74175	15N	4W	12	774	4825	O	
37209	Isabella					43.74149	-84.75141	16N	4W	35	798	4860	O	
37222	Isabella					43.76247	-84.77163	16N	4W	22	827	3834	BD	
37242	Isabella	3684	3724	3957	4140	43.71981	-84.65113	15N	3W	3	761	4900	D	1
37243	Isabella					43.64926	-85.01507	15N	6W	34	943	3700	D	
37290	Isabella					43.73509	-84.68619	16N	3W	33	766	4840	D	
37350	Isabella					43.62121	-84.61930	14N	3W	12	717	4670	O	
37380	Isabella					43.73452	-84.67617	16N	3W	33	761	4823	D	
37462	Isabella					43.73791	-84.73192	16N	4W	36	788	4830	O	
37482	Isabella					43.74151	-84.74176	16N	4W	36	794	4901	O	
37591	Isabella					43.65945	-84.72920	15N	4W	25	752	4760	D	
37672	Isabella	3716	3741	3940	4124	43.73860	-85.06017	16N	6W	32	998	5010	D	1
37724	Isabella					43.75935	-84.77601	16N	4W	22	847	3810	O	
37744	Isabella					43.67469	-84.72993	15N	4W	24	763	4765	G	
37820	Isabella					43.69171	-84.85235	15N	5W	13	854	4971	O	
37909	Isabella	3670	3700	3888		43.60371	-84.90895	14N	5W	16	880	3930	D	1
38007	Isabella					43.73782	-84.75650	16N	4W	35	809	4900	O	
38037	Isabella					43.73279	-84.95032	16N	5W	31	950	4958	O	
38144	Isabella					43.64309	-84.65927	15N	3W	34	740	4675	D	
38512	Isabella					43.63232	-84.63939	14N	3W	2	737	4670	O	
38537	Isabella					43.67422	-84.71965	15N	3W	19	753	4755	O	
39059	Isabella					43.75901	-84.76623	16N	4W	23	830	3800	BD	
39806	Isabella					43.75538	-84.76641	16N	4W	26	820	3798	D	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
40039	Isabella	3529	3569	3772	3939	43.63230	-84.64942	14N	3W	3	738	4650	G	1
40292	Isabella					43.64733	-84.72481	15N	3W	31	780	10955	D	
40292	Isabella					43.64733	-84.72481	15N	3W	31	780	10955	D	
40823	Isabella					43.62179	-85.05070	14N	6W	8	1155	10306	D	
40823	Isabella					43.62179	-85.05070	14N	6W	8	1155	10306	D	
41254	Isabella					43.60414	-84.61214	14N	3W	13	744	10900	D	
42540	Isabella					43.69388	-84.73744	15N	4W	13	781	11010	D	
54950	Isabella					43.75560	-84.74607	16N	04W	25	800	3763	D	
22275	Jackson					42.17914	-84.45066	3S	1W	29	997	6038	D	2
35153	Jackson		1918	1981	2046	42.24587	-84.14951	3S	2E	1	1041	5202	D	2
36384	Jackson		1698	1763		42.12073	-84.48516	4S	2W	13	1057	4598	O	1
37237	Jackson					42.10869	-84.59496	4S	3W	24	1138	4700	D	
38927	Jackson					42.08065	-84.57768	4S	2W	31	1071	4400	O	
38927	Jackson					42.08065	-84.57768	4S	2W	31	1071	4400	O	
39014	Jackson		1744	1799	1810	42.12406	-84.58667	4S	2W	18	1127	4550	D	1
39014	Jackson					42.12406	-84.58667	4S	2W	18	1127	4550	D	
39273	Jackson					42.10696	-84.58643	4S	2W	19	1134	4600	D	
39273	Jackson					42.10696	-84.58643	4S	2W	19	1134	4600	D	
43040	Jackson					42.09299	-84.56221	4S	2W	29	1090	5025	D	
43040	Jackson					42.09299	-84.56221	4S	2W	29	1090	5025	D	
20572	Kalamazoo					42.34982	-85.45585	1S	10W	27	916	4125	D	2
23035	Kalamazoo					42.39777	-85.70501	1S	12W	10	789	3860	D	1
27508	Kalamazoo		1408	1444	1528	42.15817	-85.52424	3S	10W	31	874	3660	D	1
99989_077	Kalamazoo		1452	1508	1576	42.20914	-85.55411	03S	11W	14	886	5588*	OI	
29096	Kalkaska					44.76725	-85.18255	27N	7W	5	1058	6688	O	1
29209	Kalkaska					44.75677	-85.23966	27N	8W	11	1033	6765	O	2
29304	Kalkaska					44.71218	-85.28484	27N	8W	28	1010	6815	O	1
29474	Kalkaska					44.69949	-85.33438	27N	8W	30	937	7224	GC	1
29657	Kalkaska					44.74642	-85.22872	27N	8W	12	1029	6759	BD	1
29794	Kalkaska					44.73553	-85.24467	27N	8W	14	1027	6790	BD	1
30473	Kalkaska					44.72065	-85.31048	27N	8W	20	984	6750	O	1
30495	Kalkaska					44.76025	-85.20938	27N	7W	6	962	6550	D	2

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
31983	Kalkaska					44.74560	-85.26994	27N	8W	10	1010	7743	O	1
33596	Kalkaska	3335	3395	3588	3808	44.53893	-85.19657	25N	7W	30	1091	10107	D	1
33944	Kalkaska	2636	2711	2877		44.77372	-85.07295	28N	6W	31	1186	6945	G	1
33944	Kalkaska					44.77372	-85.07295	28N	6W	31	1186	6945	GS	2
34208	Kalkaska					44.51408	-85.27242	25N	8W	34	1018	2895	G	2
34613	Kalkaska	2745	2825	3073		44.81292	-84.88298	28N	5W	23	1315	9221	D	1
36703	Kalkaska					44.75474	-85.26054	27N	8W	10	952	6587	D	
36937	Kalkaska					44.72404	-85.26068	27N	8W	22	1028	6853	O	
36947	Kalkaska					44.72198	-85.27236	27N	8W	22	989	6800	D	
37414	Kalkaska					44.75235	-85.26840	27N	8W	10	965	6640	D	
44882	Kalkaska	3087	3142	3329		44.51854	-85.30970	25N	8W	32	1081	10475	GC	2
26946	Kent		2784	2906	3011	43.02479	-85.34450	7N	9W	2	944	6598	D	1
27296	Kent	2917	2922	3055	3153	43.12661	-85.46343	9N	10W	35		7814	BD	3
00156BD	Kent		2431	2530	2628	42.85551	-85.36301	5N	9W	3	857	6393	D	1
34116	Lapeer					43.24880	-83.27914	10N	10E	34	801	0	O	2
37408	Lapeer					43.09512	-82.99440	8N	12E	25	813	7057	D	
41590	Lapeer	2329	2339	2522	2542	43.21440	-83.19150	9N	11E	9	805	8670	D	1
22627	Leelanau					45.02820	-85.68315	30N	11W	6	925	5750	D	2
28168	Lenawee		1320	1408		41.97464	-84.20445	6S	2E	4	1008	4075	D	2
28531	Lenawee		603	684		41.74535	-84.02288	8S	3E	26	746	3146	D	3
31792	Lenawee		390	396		42.05428	-83.83422	5S	5E	9	772	3800	D	1
34689	Lenawee					41.99368	-84.00643	5S	3E	36	853	4220	D	
38576	Lenawee		861	966		41.90936	-83.96994	6S	4E	32	852	3690	D	1
25868	Livingston		2139	2200	2295	42.56152	-83.94038	2N	4E	14	939	7205	D	3
26999	Livingston		1050	1117		42.47806	-83.70638	1N	6E	14	936	5560	D	1
27986	Livingston					42.67363	-83.82514	3N	5E	11	980	7589	D	1
36447	Livingston		2048	2116	2197	42.56985	-84.07438	2N	3E	10	924	4600	D	2
37893	Livingston		1527	1592	1748	42.73344	-83.82823	4N	5E	23	935	7548	D	2
40438	Livingston	1238	1243	1314		42.67933	-84.06337	3N	3E	2	940	7450	G	1
33737	Macomb		1186	1325		42.84378	-82.75331	5N	14E	24	739	5400	D	2
36238	Macomb		1187	1372		42.66266	-82.91387	3N	13E	22	618	4571	D	1
39859	Macomb		805	976		42.66930	-82.99601	3N	12E	23	641	5027	D	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
30125	Manistee					44.47894	-85.89184	24N	13W	16	869	5635	D	1
30502	Manistee	1836	1861	1986	2199	44.44261	-86.04772	24N	14W	31	748	6360	D	1
34277	Manistee	1945	1970	2107		44.36233	-86.07643	23N	15W	25	764	6631	D	1
35882	Manistee	2177	2197	2366		44.19115	-86.03582	21N	14W	29	756	7400	D	1
36588	Manistee					44.46253	-86.02620	24N	14W	20	789	6265	D	
37174	Manistee	1735	1755	1874		44.37362	-86.19537	23N	16W	25	761	6288	D	1
15692	Mason					43.82567	-86.40455	17N	18W	36	595	2083	D	1
18905	Mason					43.83340	-86.17481	17N	16W	25	725	7249	O	1
21123	Mason					43.83899	-86.16720	17N	16W	25	720	2337	OI	1
21722	Mason					43.84214	-86.42462	17N	18W	26	616	2088	D	1
29503	Mason	2273	2278	2419		43.86210	-86.26686	17N	16W	18	718	6000	D	1
32471	Mason	1913	1918	2046		44.10186	-86.38542	20N	17W	30	668	5480	D	1
39984	Mason	2175	2180	2312		44.00937	-86.31203	19N	17W	26	679	7485	D	1
40773	Mason	2271	2276	2424		43.83304	-86.18087	17N	16W	26	725	7200	D	1
25790	Mecosta					43.72218	-85.41685	15N	9W	5	947	3569	D	1
35259	Mecosta	3859	3884	4083	4238	43.61832	-85.10234	14N	7W	12	1103	10175	D	1
35259	Mecosta					43.61832	-85.10234	14N	7W	12	1103	10175	D	
35426	Mecosta	3902	3927	4134	4290	43.79834	-85.21474	16N	8W	12	1152	5100	GC	1
36067	Mecosta	3969	3989	4198		43.80564	-85.32189	16N	8W	6	1192	8386	D	1
36067	Mecosta					43.80564	-85.32189	16N	8W	6	1192	8386	D	
36187	Mecosta					43.79102	-85.31133	16N	8W	7	1214	8380	D	
36283	Mecosta					43.79796	-85.34081	16N	9W	12	1167	8215	D	
36396	Mecosta					43.79025	-85.21474	16N	8W	12	1130	5100	D	
36455	Mecosta	3707	3727	3941		43.79805	-85.37634	16N	9W	10	1059	7975	D	2
36455	Mecosta					43.79805	-85.37634	16N	9W	10	1059	7975	D	
36864	Mecosta	3882	3902	4118		43.79003	-85.34641	16N	9W	11	1154	8121	D	1
36864	Mecosta					43.79003	-85.34641	16N	9W	11	1154	8121	D	
36890	Mecosta					43.77655	-85.30730	16N	8W	18	1158	8264	D	
36890	Mecosta					43.77655	-85.30730	16N	8W	18	1158	8264	D	
37188	Mecosta					43.80761	-85.34541	16N	9W	2	1114	8085	D	
37188	Mecosta					43.80761	-85.34541	16N	9W	2	1114	8085	D	
37723	Mecosta	3787	3807	3996	4156	43.66044	-85.17749	15N	7W	29	1044	5006	D	3

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
39713	Mecosta	3250	3270	3450	3566	43.53748	-85.53870	13N	10W	8	944	8145	G	1
39727	Mecosta					43.50662	-85.51820	13N	10W	21	963	8225	D	
40215	Mecosta	3379	3399	3582	3702	43.58517	-85.47877	14N	10W	23	991	8760	G	3
40242	Mecosta					43.77926	-85.46422	16N	10W	14	1084	9484	G	
40242	Mecosta					43.77926	-85.46422	16N	10W	14	1084	9484	G	
40477	Mecosta	3517	3537	3745		43.81168	-85.42501	16N	9W	6	1024	9733	D	1
40477	Mecosta					43.81168	-85.42501	16N	9W	6	1024	9733	D	
40543	Mecosta	3614	3634	3821	3999	43.64578	-85.39360	15N	9W	33	1059	9313	D	6
40682	Mecosta	3544	3564	3770		43.79140	-85.40383	16N	9W	8	979	9820	D	1
40869	Mecosta					43.64547	-85.42760	15N	9W	4	1059	10080	G	
41010	Mecosta	3456	3476	3676		43.74891	-85.51469	16N	10W	28	1034	9325	D	1
41010	Mecosta					43.74891	-85.51469	16N	10W	28	1034	9325	D	
41116	Mecosta	3484	3504	3696	3854	43.68368	-85.42729	15N	9W	19	1005	9268	G	1
41116	Mecosta					43.68368	-85.42729	15N	9W	19	1005	9268	G	
41137	Mecosta					43.67512	-85.42131	15N	9W	20	1064	9305	G	
41137	Mecosta					43.67512	-85.42131	15N	9W	20	1064	9305	G	
41267	Mecosta	3834	3859	4021	4167	43.52705	-85.16070	13N	7W	9	1213	9610	D	1
41267	Mecosta					43.52705	-85.16070	13N	7W	9	1213	9610	D	
41440	Mecosta	3440	3460	3663		43.78123	-85.52195	16N	10W	16	1002	9325	G	1
41440	Mecosta					43.78123	-85.52195	16N	10W	16	1002	9325	G	
42068	Mecosta					43.73453	-85.41011	16N	9W	32	1025	9417	D	
42314	Mecosta					43.76826	-85.44467	16N	10W	24	1135	8439	G	
42553	Mecosta	3504	3524	3727	3893	43.71597	-85.42243	15N	9W	5	1022	9392	D	1
42553	Mecosta					43.71597	-85.42243	15N	9W	5	1022	9392	D	
42685	Mecosta					43.73182	-85.40591	16N	9W	32	1025	9703	GC	
42817	Mecosta	3413	3433	3627	3789	43.65093	-85.46112	15N	10W	36	947	8960	G	2
42907	Mecosta	3510	3530	3734		43.77446	-85.44750	16N	10W	13	1069	9510	D	1
42907	Mecosta					43.77446	-85.44750	16N	10W	13	1069	9510	D	
43106	Mecosta					43.68905	-85.42069	15N	9W	17	1010	7320	D	
23849	Midland	3365	3390	3606		43.50800	-84.43211	13N	1W	21	695	9514*	D	1
30378	Midland	3649	3709	3989	4051	43.71877	-84.17845	15N	2E	12	676	5264	D	3
37150	Midland	3791	3841	4050	4234	43.77185	-84.52784	16N	2W	15	735	5050	D	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
20389	Missaukee					44.26330	-85.00981	22N	6W	35	1186	5223	D	2
24501	Missaukee					44.26350	-85.09163	22N	6W	31	1207	5642	D	1
27105	Missaukee					44.25216	-84.99458	22N	6W	35	1170	5228	D	1
31479	Missaukee					44.26795	-85.08786	22N	6W	30	1197	5215	WI	1
31967	Missaukee					44.26074	-85.08773	22N	6W	31	1207	5261	O	1
32017	Missaukee					44.26812	-85.09791	22N	7W	25	1207	5200	WI	2
32092	Missaukee					44.26423	-85.08269	22N	6W	31	1198	5220	O	5
32132	Missaukee					44.26433	-85.08774	22N	6W	31	1208	5233	O	2
32138	Missaukee					44.26072	-85.09292	22N	6W	31	1209	5265	O	2
32139	Missaukee					44.26451	-85.09798	22N	7W	36	1207	5232	O	2
32163	Missaukee					44.26443	-85.09289	22N	6W	31	1210	5215	WI	2
32174	Missaukee					44.27173	-85.10311	22N	7W	25	1209	5245	WI	2
32175	Missaukee					44.26816	-85.10311	22N	7W	25	1213	5307	O	2
32181	Missaukee	3986	4036	4241	4482	44.22732	-85.24349	21N	8W	11	1241	5330	D	1
32189	Missaukee					44.25712	-85.08769	22N	6W	31	1209	5500	O	2
32221	Missaukee					44.26745	-85.09288	22N	6W	30	1199	5210	O	2
32223	Missaukee					44.26104	-85.09798	22N	7W	36	1210	5215	WI	2
32233	Missaukee	3851	3906	4110	4312	44.27173	-85.09796	22N	7W	25	1203	5218	O	2
32351	Missaukee					44.27017	-85.09285	22N	6W	30	1200	5250	WI	2
32421	Missaukee					44.26457	-85.10310	22N	7W	36	1210	5256	WI	2
32422	Missaukee					44.26104	-85.10310	22N	7W	36	1215	5226	O	2
32584	Missaukee					44.26821	-85.10762	22N	7W	25	1203	5264	O	2
32636	Missaukee					44.27043	-85.10609	22N	7W	25	1208	5211	O	2
32642	Missaukee					44.26782	-85.09169	22N	6W	30	1193	4155	O	2
32659	Missaukee					44.25294	-85.01535	22N	6W	34	1192	5260	D	2
32673	Missaukee					44.27172	-85.11334	22N	7W	25	1212	5213	BD	2
32697	Missaukee					44.26463	-85.10814	22N	7W	36	1209	3486	O	2
32715	Missaukee					44.26995	-85.10815	22N	7W	25	1205	3870	O	2
33016	Missaukee					44.25204	-84.98455	22N	6W	36	1165	3811	BD	2
33046	Missaukee					44.26995	-85.10777	22N	7W	25	1203	3495	O	2
33413	Missaukee	3862	3917	4126	4335	44.25744	-85.09799	22N	7W	36	1204	5225	O	2
33758	Missaukee	3976	4026	4236	4426	44.28144	-85.17628	22N	7W	20	1251	5320	D	2

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
33760	Missaukee	3825	3885	4125	4355	44.26319	-85.00469	22N	6W	35	1190	5280	O	1
33819	Missaukee					44.25712	-85.09295	22N	6W	31	1208	5225	O	2
34000	Missaukee					44.25744	-85.10310	22N	7W	36	1197	5230	WI	2
34005	Missaukee					44.26103	-85.10814	22N	7W	36	1211	5230	WI	2
34078	Missaukee					44.49063	-85.08097	24N	6W	7	1289	9300	D	2
34293	Missaukee					44.25744	-85.10814	22N	7W	36	1198	5225	O	2
34357	Missaukee					44.26270	-85.07707	22N	6W	31	1205	0	D	2
34376	Missaukee					44.27762	-85.09120	22N	6W	30	1232	14713	D	2
34459	Missaukee	3992	4052	4284	4500	44.29041	-85.02561	22N	6W	22	1277	5380	D	1
34511	Missaukee	3930	3980	4201	4409	44.26195	-85.15658	22N	7W	33	1210	10812	D	1
34606	Missaukee	3866	3926	4128	4352	44.25184	-84.99678	22N	6W	35	1177	10970	D	1
34606	Missaukee					44.25184	-84.99678	22N	6W	35	1177	10970	D	
34981	Missaukee					44.25381	-85.09298	22N	6W	31	1211	4417	O	
36173	Missaukee					44.18481	-85.30207	21N	8W	29	1446	11650	O	
36173	Missaukee					44.18481	-85.30207	21N	8W	29	1446	11650	O	
36325	Missaukee					44.17743	-85.07876	21N	6W	31	1193	5077	D	
36778	Missaukee	4024	4074	4270		44.18530	-85.30841	21N	8W	29	1398	5400	D	2
36940	Missaukee	4006	4056	4292	4491	44.20222	-85.19768	21N	7W	19	1298	5380	O	1
37137	Missaukee					44.19828	-85.19750	21N	7W	19	1252	5340	O	
37298	Missaukee	4000	4050	4258	4499	44.21097	-85.28337	21N	8W	16	1344	5334	D	2
38462	Missaukee					44.25743	-85.11323	22N	7W	36	1206	5238	D	
38506	Missaukee					44.20008	-85.31372	21N	8W	20	1461	5500	D	
39578	Missaukee	3792	3842	4047	4232	44.31902	-85.19246	22N	7W	8	1254	5219	D	1
39725	Missaukee	3688	3738	3962	4145	44.39126	-85.18978	23N	7W	17	1219	11650	D	1
40314	Missaukee	3180	3260	3501		44.49009	-84.86880	24N	5W	12	1328	11756	O	1
40605	Missaukee					44.19807	-85.19155	21N	7W	20	1251	11980	D	
41179	Missaukee	3942	3997	4202	4409	44.17366	-85.07611	21N	6W	31	1219	12030	GC	1
41179	Missaukee					44.17366	-85.07611	21N	6W	31	1219	12030	GC	
41717	Missaukee					44.18114	-85.08386	21N	6W	30	1189	11745	G	
41830	Missaukee	3955	4005	4240	4447	44.20910	-85.15002	21N	7W	15	1234	11970	G	1
42691	Missaukee					44.20942	-85.15782	21N	7W	16	1246	10920	D	
43617	Missaukee					44.17249	-85.23750	21N	8W	35	1385	11700	D	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
35948	Monroe					41.90265	-83.55255	7S	7E	1	646	3506	D	
37906	Monroe		66	171		42.00728	-83.74864	5S	6E	32	690	3273	D	1
24011	Montcalm					43.35485	-84.93167	11N	5W	8	965	3496	D	2
30027	Montcalm	3202	3227	3365	3496	43.23288	-85.11194	10N	7W	26	875	4173	D	1
30107	Montcalm	3453	3478	3653	3803	43.43437	-84.94908	12N	5W	18	905	4736	D	1
30147	Montcalm	3386	3411	3551	3691	43.30777	-85.07321	11N	6W	30	965	4494	D	1
33611	Montcalm	3083	3098	3245		43.15287	-84.92448	9N	5W	20	794	3275	D	1
37674	Montcalm					43.45969	-84.99249	12N	6W	2	998	4645	O	
37799	Montcalm					43.36747	-85.14046	11N	7W	3	949	3505	D	
39483	Montcalm					43.31138	-84.94873	11N	5W	30	878	3343	O	
39779	Montcalm	3237	3252	3420	3558	43.43700	-85.44029	12N	9W	18	927	8420	D	1
39779	Montcalm					43.43700	-85.44029	12N	9W	18	927	8420	D	
41480	Montcalm	3251	3276	3407		43.26139	-85.00030	10N	6W	15	850	3435	D	1
34648	Montmorency	2295	2390	2543		44.91434	-84.18036	29N	2E	10	1216	8455	D	2
40601	Montmorency	1536	1631	1782		44.99981	-84.05682	30N	3E	15	929	894	G	1
41036	Montmorency	1477	1577	1706		44.92937	-83.95456	29N	4E	4	820	8300	D	1
18666	Muskegon					43.42468	-86.37202	12N	17W	20	666	4858	D	1
23010	Muskegon		2035	2080	2179	43.12057	-86.21192	9N	16W	33	620	3636	D	1
26662	Newaygo	2646	2656	2817		43.67446	-86.01056	15N	14W	20	829	8215	D	1
26662	Newaygo					43.67446	-86.01056	15N	14W	20	829	8215	D	1
35311	Newaygo	3466	3481	3683		43.74731	-85.63168	16N	11W	28	1078	7954	D	1
36622	Newaygo					43.61961	-85.64392	14N	11W	8	1081	8639	G	
38561	Newaygo	3013	3023	3212		43.53129	-85.75035	13N	12W	9	888	3400	D	1
38567	Newaygo					43.66809	-85.64616	15N	11W	29	1092	8300	G	
39166	Newaygo	3351	3366	3556	3734	43.67247	-85.65116	15N	11W	20	1092	8744	G	1
39443	Newaygo					43.66080	-85.73744	15N	12W	27	935	8300	D	
39675	Newaygo					43.67990	-85.65167	15N	11W	20	1065	8250	D	
39856	Newaygo					43.65824	-85.63140	15N	11W	28	1093	0	GC	
39856	Newaygo					43.65824	-85.63140	15N	11W	28	1093	0	GC	
39914	Newaygo					43.62930	-86.00105	14N	14W	5	850	6980	G	
39916	Newaygo					43.65451	-85.63521	15N	11W	33	1088	9375	G	
39952	Newaygo	3195	3205	3394	3481	43.54272	-85.62049	13N	11W	3	977	8109	D	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
39992	Newaygo	2857	2867	3027	3113	43.35906	-85.66859	11N	11W	7	826	7080	G	1
41628	Newaygo					43.68272	-85.62248	15N	11W	21	1208	9248	GC	
41714	Newaygo					43.38254	-85.62368	12N	11W	33	988	7376	G	
41892	Newaygo	2955	2965	3130		43.40230	-85.66583	12N	11W	30	891	7320	D	3
42856	Newaygo	3073	3083	3246	3333	43.37021	-85.61846	11N	11W	3	989	7200	G	3
44217	Newaygo	3028	3038	3238		43.63229	-85.77187	14N	12W	5	942	7892	D	1
28258	Oakland		1647	1815	1787	42.70661	-83.48281	4N	8E	35	1048	6500	D	4
36303	Oakland		1030	1215		42.52880	-83.43946	2N	8E	36	975	5610	D	1
14081	Oceana					43.81470	-86.39418	16N	17W	6	628	2235	O	3
14084	Oceana					43.81853	-86.39926	16N	18W	1	615	2094	O	2
14141	Oceana					43.81289	-86.38689	16N	17W	6	665	2175	O	2
14143	Oceana					43.81289	-86.39671	16N	17W	6	623	2092	O	2
14256	Oceana					43.80753	-86.38439	16N	17W	6	665	2139	O	1
14258	Oceana					43.80568	-86.39189	16N	17W	6	642	2117	O	1
14268	Oceana					43.81134	-86.39929	16N	18W	1	613	2089	O	1
14272	Oceana					43.80747	-86.39430	16N	17W	6	634	2108	O	1
14273	Oceana					43.80571	-86.38689	16N	17W	6	677	2270	O	1
14274	Oceana					43.81109	-86.39424	16N	17W	6	632	2106	O	3
14338	Oceana					43.80760	-86.39932	16N	18W	1	618	2092	O	1
14341	Oceana					43.80389	-86.38961	16N	17W	7	665	2133	O	2
14342	Oceana					43.80386	-86.39437	16N	17W	7	637	2111	O	3
14372	Oceana					43.80224	-86.38673	16N	17W	7	664	2138	O	4
14399	Oceana					43.81864	-86.41933	16N	18W	2	625	2112	O	5
14411	Oceana					43.80574	-86.38212	16N	17W	6	654	2127	O	1
14412	Oceana					43.80928	-86.39677	16N	17W	6	628	0	O	1
14416	Oceana					43.80392	-86.38461	16N	17W	7	655	2129	O	4
14457	Oceana					43.80213	-86.38216	16N	17W	7	641	2115	O	1
14459	Oceana					43.81864	-86.42113	16N	18W	2	631	2146	D	1
14460	Oceana					43.80565	-86.39683	16N	17W	6	628	2102	O	1
14461	Oceana					43.80928	-86.38208	16N	17W	6	663	2137	O	1
14477	Oceana					43.80395	-86.37964	16N	17W	7	642	2116	O	1
14510	Oceana					43.80756	-86.37960	16N	17W	6	650	2124	O	2

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
14550	Oceana					43.80034	-86.38461	16N	17W	7	644	2117	O	1
14552	Oceana					43.80582	-86.40183	16N	18W	1	614	2085	O	1
14581	Oceana					43.80575	-86.37712	16N	17W	5	641	2115	O	2
14582	Oceana					43.80034	-86.37975	16N	17W	7	645	2119	O	1
14593	Oceana					43.80952	-86.40180	16N	18W	1	605	2079	O	3
14629	Oceana					43.80765	-86.40430	16N	18W	1	606	2080	O	3
14630	Oceana					43.80214	-86.37716	16N	17W	8	613	2087	O	1
14677	Oceana					43.81314	-86.40179	16N	18W	1	609	2085	O	1
14688	Oceana					43.80398	-86.39935	16N	18W	12	623	2097	O	1
14718	Oceana					43.80208	-86.39165	16N	17W	7	645	0	D	1
14730	Oceana					43.80034	-86.38961	16N	17W	7	672	2195	O	1
14801	Oceana					43.81134	-86.40430	16N	18W	1	604	2077	O	1
14825	Oceana					43.80404	-86.40447	16N	18W	12	607	2081	O	1
14876	Oceana					43.80020	-86.37468	16N	17W	8	644	2149	O	1
14888	Oceana					43.80392	-86.37464	16N	17W	8	616	2090	O	1
14948	Oceana					43.80912	-86.37709	16N	17W	5	661	2135	O	1
14983	Oceana					43.80952	-86.40679	16N	18W	1	600	2074	O	1
14984	Oceana					43.80753	-86.37460	16N	17W	5	645	2118	O	1
15000	Oceana					43.79853	-86.38219	16N	17W	7	622	2100	O	1
15001	Oceana					43.80204	-86.39691	16N	17W	7	631	2104	O	2
15006	Oceana					43.80952	-86.41679	16N	18W	1	593	2074	D	1
15010	Oceana					43.80383	-86.36467	16N	17W	8	654	2124	O	1
15011	Oceana					43.81850	-86.41482	16N	18W	1	607	2083	O	1
15030	Oceana					43.80020	-86.36967	16N	17W	8	643	2114	BD	1
15050	Oceana					43.80209	-86.37217	16N	17W	8	650	2120	O	1
15059	Oceana					43.81619	-86.36708	16N	17W	5	664	2144	D	1
15061	Oceana					43.80570	-86.37208	16N	17W	5	645	2117	O	1
15062	Oceana					43.80912	-86.37246	16N	17W	5	649	2122	O	1
15080	Oceana					43.80748	-86.36958	16N	17W	5	649	2119	O	1
15081	Oceana					43.80387	-86.36967	16N	17W	8	650	2124	O	2
15100	Oceana					43.80564	-86.36708	16N	17W	5	645	2114	O	1
15114	Oceana					43.79839	-86.37720	16N	17W	8	623	2093	O	2

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
15115	Oceana					43.80204	-86.36717	16N	17W	8	654	2124	O	2
15146	Oceana					43.79839	-86.37217	16N	17W	8	647	2115	O	1
15147	Oceana					43.80559	-86.36211	16N	17W	5	650	2118	O	1
15159	Oceana					43.80198	-86.36212	16N	17W	8	654	2124	O	1
15160	Oceana					43.79839	-86.36717	16N	17W	8	641	2111	O	1
15175	Oceana					43.81093	-86.37457	16N	17W	5	660	2130	O	1
15208	Oceana					43.80020	-86.36467	16N	17W	8	643	2109	O	1
15239	Oceana					43.80376	-86.35961	16N	17W	8	643	2109	O	1
15249	Oceana					43.81681	-86.41180	16N	18W	1	586	2065	O	1
15302	Oceana					43.80743	-86.36458	16N	17W	5	654	2124	O	1
15303	Oceana					43.81289	-86.38204	16N	17W	6	670	2144	O	1
15304	Oceana					43.80020	-86.35962	16N	17W	8	644	2114	O	1
15326	Oceana					43.79659	-86.36967	16N	17W	8	616	2088	O	1
15356	Oceana					43.80034	-86.39444	16N	17W	7	635	2099	O	1
15378	Oceana					43.79734	-86.36219	16N	17W	8	638	0	D	1
15398	Oceana					43.80552	-86.35711	16N	17W	4	651	2114	O	1
15413	Oceana					43.81109	-86.37957	16N	17W	6	676	2139	O	2
15414	Oceana					43.79659	-86.36467	16N	17W	8	619	2087	O	1
15446	Oceana					43.80912	-86.36708	16N	17W	5	661	2140	O	1
15491	Oceana					43.80737	-86.35960	16N	17W	5	656	2120	O	2
15525	Oceana					43.79659	-86.37472	16N	17W	8	622	2095	O	1
15544	Oceana					43.79806	-86.35712	16N	17W	9	635	0	D	1
15608	Oceana					43.80912	-86.36210	16N	17W	5	653	2121	O	1
15611	Oceana					43.80191	-86.35711	16N	17W	9	652	2125	D	1
15634	Oceana					43.81273	-86.37208	16N	17W	5	659	2138	D	1
15635	Oceana					43.80877	-86.35710	16N	17W	4	659	2131	O	1
16051	Oceana					43.81494	-86.40930	16N	18W	1	591	2065	O	1
16196	Oceana					43.81314	-86.40679	16N	18W	1	598	2075	O	1
16391	Oceana					43.81314	-86.41180	16N	18W	1	590	2062	O	1
17549	Oceana					43.80665	-86.38086	16N	17W	6	651	0	D	2
29168	Oceana					43.80332	-86.37715	16N	17W	8	628	4254	G	1
29588	Oceana		2131	2254		43.80246	-86.38662	16N	17W	7	674	4265	G	3

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
29607	Oceana					43.79795	-86.37171	16N	17W	8	649	4230	D	1
30045	Oceana					43.79766	-86.38171	16N	17W	7	620	4237	D	1
30046	Oceana					43.80943	-86.36660	16N	17W	5	665	4300	G	1
31504	Oceana					43.81030	-86.37065	16N	17W	5	649	4285	D	5
32517	Oceana	2635	2640	2792		43.78080	-86.13099	16N	15W	17	940	6561	D	2
33134	Oceana		2099	2211	2274	43.53448	-86.44577	13N	18W	10	752	7240	D	2
33134	Oceana					43.53448	-86.44577	13N	18W	10	752	7240	D	2
33154	Oceana		2210	2334	2389	43.60269	-86.44004	14N	18W	15	713	5065	O	1
33154	Oceana					43.60269	-86.44004	14N	18W	15	713	5065	O	2
33493	Oceana					43.81007	-86.38018	16N	17W	6	667	4290	BD	2
34479	Oceana					43.80306	-86.38230	16N	17W	7	651	4250	D	2
34490	Oceana					43.80733	-86.37513	16N	17W	5	652	4272	D	2
40121	Oceana	2687	2692	2814		43.67282	-86.23446	15N	16W	21	962	6518	G	1
40121	Oceana					43.67282	-86.23446	15N	16W	21	962	6518	G	
25099	Ogemaw					44.43633	-84.19110	24N	2E	28	1476	12996	D	1
39432	Ogemaw	2766	2841	3104		44.30357	-83.97046	22N	4E	17	902	11538	D	1
39749	Ogemaw	2539	2619	2888		44.26493	-84.15769	22N	2E	26	915	12000	GC	1
40263	Ogemaw	2760	2840	3098	3273	44.33696	-84.04083	23N	3E	35	897	11600	D	1
40372	Ogemaw	2963	3063	3240		44.44652	-84.19308	24N	2E	28	1483	11000	G	1
40546	Ogemaw	2782	2862	3044	3249	44.29657	-84.23553	22N	2E	18	1072	11720	GC	2
34536	Osceola	3709	3739	3991	4176	43.92299	-85.25983	18N	8W	27	1055	4918	O	1
34536	Osceola					43.92299	-85.25983	18N	8W	27	1055	4918	O	2
34558	Osceola	3881	3906	4108		43.82640	-85.30818	17N	8W	31	1117	10858	D	2
35482	Osceola	4011	4061	4257		43.99551	-85.18905	19N	7W	31	1116	11300	D	1
35800	Osceola					43.82741	-85.32228	17N	8W	31	1154	9769	G	
35832	Osceola	3891	3926	4120	4320	43.86690	-85.09448	17N	7W	13	1074	10505	O	1
35977	Osceola					43.84209	-85.31157	17N	8W	30	1116	8371	D	
36068	Osceola					43.82636	-85.32711	17N	9W	36	1125	8200	G	
36110	Osceola					43.82022	-85.33099	17N	9W	36	1201	8366	G	
36186	Osceola					43.82727	-85.35079	17N	9W	35	1215	8309	G	
36426	Osceola					43.83433	-85.28275	17N	8W	28	1123	8440	D	
36426	Osceola					43.83433	-85.28275	17N	8W	28	1123	8440	D	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
36506	Osceola	3757	3782	4003		43.86564	-85.32818	17N	9W	13	1044	8310	BD	1
36506	Osceola					43.86564	-85.32818	17N	9W	13	1044	8310	BD	
36600	Osceola					43.84165	-85.36087	17N	9W	26	1137	8085	D	
36600	Osceola					43.84165	-85.36087	17N	9W	26	1137	8085	D	
36648	Osceola	3551	3571	3779		43.82801	-85.41790	17N	9W	32	1002	7796	D	1
36648	Osceola					43.82801	-85.41790	17N	9W	32	1002	7796	D	
36925	Osceola					43.82022	-85.34092	17N	9W	36	1183	8200	G	
37193	Osceola					44.15447	-85.40430	20N	9W	4	1347	5300	D	
37274	Osceola					43.87461	-85.20378	17N	7W	7	1125	4850	G	
37300	Osceola	3920	3945	4152		43.86709	-85.27497	17N	8W	16	1148	5180	D	1
37317	Osceola					43.83348	-85.34621	17N	9W	26	1140	8095	G	
37655	Osceola					43.86523	-85.26239	17N	8W	15	1157	5170	D	
38005	Osceola					43.88110	-85.20380	17N	7W	7	1098	5070	O	
38076	Osceola					43.87572	-85.19338	17N	7W	7	1085	5050	D	
38201	Osceola	3918	3948	4164		44.16126	-85.39724	20N	9W	4	1353	5310	O	1
38463	Osceola					43.84391	-85.31368	17N	8W	19	1120	8385	D	
38748	Osceola					43.82376	-85.34584	17N	9W	35	1215	8206	G	
39433	Osceola	3892	3917	4121	4297	43.91237	-85.38690	18N	9W	33	1254	10525	D	2
39854	Osceola	3818	3838	4064	4202	44.10851	-85.55086	20N	10W	19	1213	12808*	G	1
40137	Osceola	3721	3741	3955	4120	43.98567	-85.44885	18N	10W	1	1250	10556	G	1
40333	Osceola	3953	3983	4205		43.87503	-85.20880	17N	8W	12	1109	5120	G	1
40556	Osceola	3700	3720	3940	4111	44.01405	-85.48881	19N	10W	27	1228	10550	G	2
40638	Osceola					43.86920	-85.20377	17N	7W	18	1100	5070	G	
40810	Osceola	3998	4043	4247	4460	44.09971	-85.17121	20N	7W	29	1167	11549	D	1
40810	Osceola					44.09971	-85.17121	20N	7W	29	1167	11549	D	
40837	Osceola					43.99795	-85.42006	19N	9W	32	1300	10559	G	
40924	Osceola					43.98470	-85.44046	18N	9W	6	1277	10410	D	
40924	Osceola					43.98470	-85.44046	18N	9W	6	1277	10410	D	
40945	Osceola					43.96275	-85.44190	18N	9W	7	1199	10375	D	
41326	Osceola					43.88063	-85.20879	17N	8W	12	1099	5130	D	
41343	Osceola					43.86949	-85.20865	17N	8W	13	1103	4810	D	
41354	Osceola					44.11050	-85.40956	20N	9W	20	1305	11500	G	

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
41540	Osceola	3728	3748	3962		43.87598	-85.43952	17N	9W	7	1157	10100	D	1
41612	Osceola	4055	4080	4298		44.04734	-85.36573	19N	9W	10	1329	11120	G	1
41777	Osceola	4115	4160	4362		44.06839	-85.22290	19N	8W	1	1236	11540	D	1
41795	Osceola	3764	3814	4021	4232	44.08356	-85.09151	20N	7W	36	1148	11744	G	3
41795	Osceola					44.08356	-85.09151	20N	7W	36	1148	11744	G	
42313	Osceola	4128	4163	4375		44.12524	-85.29071	20N	8W	17	1439	11568	G	1
42421	Osceola					44.01218	-85.36861	19N	9W	27	1428	11105	D	
42421	Osceola					44.01218	-85.36861	19N	9W	27	1428	11105	D	
42596	Osceola	3923	3953	4151	4321	43.82570	-85.17309	17N	7W	32	1137	10894	D	6
42635	Osceola					43.96820	-85.48904	18N	10W	10	1183	10175	D	
42945	Osceola					44.00462	-85.25098	19N	8W	27	1283	11500	D	
42956	Osceola					43.89596	-85.39608	17N	9W	4	1130	10290	D	
43365	Osceola					44.11574	-85.32357	20N	8W	19	1487	11541	D	
44238	Osceola					44.04372	-85.43659	19N	9W	18	1287	10840	G	
34070	Oscoda	2982	3082	3239	3520	44.55701	-84.16123	25N	2E	14	1179	11691	G	1
34494	Oscoda	3077	3177	3337		44.57129	-84.18174	25N	2E	10	1176	11200	D	1
37145	Oscoda	2830	2930	3117		44.67870	-84.30963	26N	1E	3	1062	9671	D	1
40651	Oscoda	2551	2651	2807		44.72759	-84.09876	27N	3E	17	1129	10276	D	1
40891	Oscoda					44.54783	-84.15510	25N	2E	23	1281	11300	G	
41392	Oscoda	2995	3095	3271		44.55379	-84.19753	25N	2E	16	1221	11027	G	2
41462	Oscoda					44.55391	-84.15460	25N	2E	14	1182	10400	G	
25873	Otsego	2400	2475	2615		44.94373	-84.76486	29N	4W	2	1413	8372	D	1
28375	Otsego	2326	2401	2566		44.99153	-84.59010	30N	2W	18	1334	6330	O	1
28463	Otsego	2347	2422	2582		44.99224	-84.57491	30N	2W	17	1335	6327	D	1
28516	Otsego					44.99881	-84.58627	30N	2W	17	1343	6270	O	1
28593	Otsego					44.98891	-84.59520	30N	2W	18	1315	6030	O	1
28630	Otsego					44.98819	-84.60746	30N	3W	13	1318	6289	D	1
28709	Otsego					44.99971	-84.58933	30N	2W	18	1345	6030	O	1
28738	Otsego					44.98969	-84.58569	30N	2W	17	1319	6060	WI	1
28797	Otsego					44.99522	-84.59393	30N	2W	18	1330	6025	O	1
28815	Otsego					44.99152	-84.58617	30N	2W	17	1319	6050	O	1
28840	Otsego					44.98627	-84.59901	30N	2W	19	1316	6050	O	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
28841	Otsego					45.01017	-84.57164	30N	2W	8	1333	6090	D	1
28924	Otsego					44.99693	-84.58369	30N	2W	17	1344	6044	O	1
28925	Otsego					44.98808	-84.59902	30N	2W	18	1320	6025	O	1
29679	Otsego	2308	2383	2541		44.99077	-84.61123	30N	3W	13	1315	6240	D	1
29853	Otsego	2294	2369	2534		45.00235	-84.58133	30N	2W	8	1338	6161	O	1
30084	Otsego					45.01531	-84.47288	30N	1W	6	1334	6071	D	1
30418	Otsego					44.99259	-84.59902	30N	2W	18	1318	6000	O	1
30618	Otsego					45.00275	-84.58935	30N	2W	7	1345	6080	D	1
30680	Otsego					45.00275	-84.58935	30N	2W	7	1345	6105	WI	1
30847	Otsego					44.95327	-84.38941	30N	1W	36	1323	6400	D	1
31325	Otsego					44.98590	-84.60426	30N	2W	19	1317	6235	D	5
31415	Otsego					44.98600	-84.60448	30N	2W	19	1317	6150	BD	2
32509	Otsego					44.99973	-84.58038	30N	2W	17	1331	6060	WI	2
32510	Otsego					44.99540	-84.58836	30N	2W	18	1332	5980	WI	2
32531	Otsego					44.99031	-84.59377	30N	2W	18	1322	6025	WI	2
35113	Otsego	2257	2332	2502		44.99035	-84.44035	30N	1W	16	1374	8710	GC	2
35922	Otsego					44.97396	-84.44005	30N	1W	21	1367	8183	D	
36616	Otsego					44.99371	-84.58495	30N	2W	17	1319	6070	D	
36623	Otsego					44.99931	-84.58040	30N	2W	17	1331	5915	WI	
36636	Otsego	2321	2396	2559		45.00600	-84.59569	30N	2W	18	1335	6039	D	1
36636	Otsego					45.00600	-84.59569	30N	2W	18	1335	6039	D	
36636	Otsego					45.00600	-84.59569	30N	2W	18	1335	6039	D	
37136	Otsego					44.99552	-84.58899	30N	2W	18	1334	6029	WI	
37366	Otsego					45.00380	-84.57659	30N	2W	8	1335	6305	D	
41541	Otsego					45.00459	-84.49168	30N	2W	12	1338	1705	G	
34268	Ottawa		2030	2152	2227	42.93424	-86.02595	6N	15W	1	638	5060*	D	2
34885	Ottawa	2570	2571	2692	2767	43.11667	-85.83628	8N	13W	3	891	7245	D	1
39591	Ottawa		2183	2307	2393	42.94096	-85.87766	6N	13W	5	731	4930	D	1
99969_139	Ottawa		1745	1842	1911	42.78379	-86.13119	05N	15W	30	617	5913	BD	
22638	Presque Isle	371	461	595		45.32012	-83.85440	34N	5E	20	844	5137	D	2
27199	Presque Isle	185	265	420		45.38253	-84.21398	35N	2E	29	809	5940	BD	1
29372	Presque Isle					45.25227	-83.76800	33N	5E	13	776	6738	DH	1

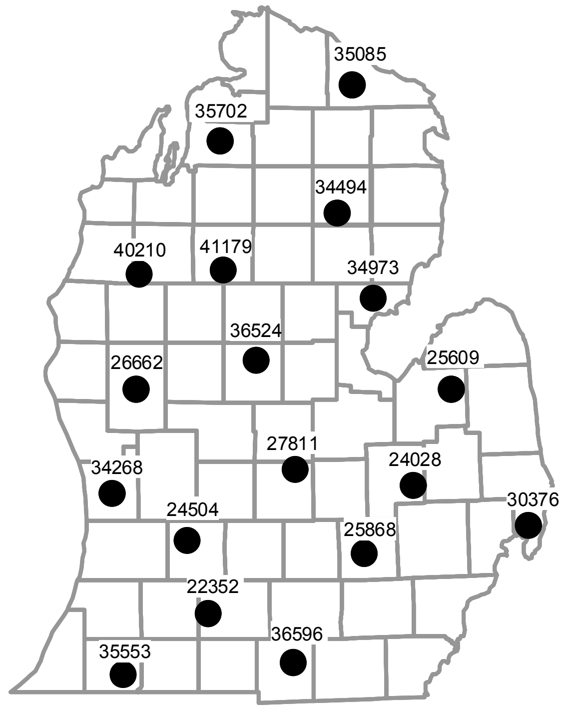
Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
34957	Presque Isle					45.22206	-84.24019	33N	2E	30	857	6193	DH	
35085	Presque Isle	575	660	823		45.24635	-84.04134	33N	3E	14	903	6667	D	1
34537	Roscommon	3686	3761	3993	4235	44.29655	-84.79610	22N	4W	16	1141	12288	D	1
37134	Roscommon	2853	2943	3127		44.47452	-84.39557	24N	1W	14	1202	11401	D	1
37409	Roscommon	3892	3967	4181	4418	44.21285	-84.46533	21N	1W	17	1240	11995	D	1
39941	Roscommon					44.18321	-84.70416	21N	3W	29	1171	5370	O	
41032	Roscommon	3293	3368	3582	3807	44.35943	-84.82008	23N	4W	29	1171	11930	D	1
35444	Saginaw	2789	2814	3085	3123	43.29148	-83.97328	10N	4E	10	608	3779	D	2
35852	Saginaw	2704	2729	3003	3035	43.18686	-84.05434	9N	3E	13	653	3537	D	1
36137	Saginaw	2895	2935	3240		43.41144	-83.83603	12N	5E	25	618	3309	D	1
25357	Sanilac		1429	1585	1587	43.21796	-82.70857	9N	15E	16	769	6784	D	3
30974	Sanilac	1777	1797	2023	2025	43.45595	-82.72035	12N	15E	20	785	8975	D	3
33999	Sanilac	1982	1987	2206	2169	43.28814	-82.75597	10N	15E	19	765	8511	D	1
35779	Sanilac	1490	1500	1621	1679	43.35292	-82.72822	11N	15E	30	775	7824	D	1
27907	Shiawassee	2308	2318	2506	2530	42.85657	-84.25114	5N	2E	5	843	7056	D	1
30727	Shiawassee	2681	2696	2918	2936	42.95372	-84.35925	6N	1E	5	783	7672	D	1
22814	St. Clair					42.78161	-82.53681	4N	16E	15	607	2610	D	1
23146	St. Clair					42.77801	-82.53680	4N	16E	15	618	2592	D	1
23205	St. Clair					42.77871	-82.54118	4N	16E	15	622	0	D	2
23231	St. Clair					42.77114	-82.53113	4N	16E	23	606	0	D	2
23234	St. Clair					42.78601	-82.53667	4N	16E	15	616	0	D	2
23249	St. Clair					42.78213	-82.53134	4N	16E	14	618	0	D	2
23303	St. Clair					42.77473	-82.53702	4N	16E	15	618	2522	D	1
23327	St. Clair					42.78575	-82.53262	4N	16E	14	620	2520	D	1
23367	St. Clair					42.77163	-82.51611	4N	16E	23	592	0	D	2
23384	St. Clair					42.77819	-82.53227	4N	16E	14	613	2545	D	1
23409	St. Clair					42.78221	-82.52730	4N	16E	14	604	2510	D	1
23525	St. Clair					42.79347	-82.52819	4N	16E	11	615	2525	D	2
23541	St. Clair					42.78543	-82.54225	4N	16E	15	619	2532	D	1
23542	St. Clair					42.78919	-82.53770	4N	16E	10	616	2526	D	2
23543	St. Clair					42.78952	-82.52801	4N	16E	11	614	2516	D	2
23556	St. Clair					42.78936	-82.53279	4N	16E	11	619	2536	D	2

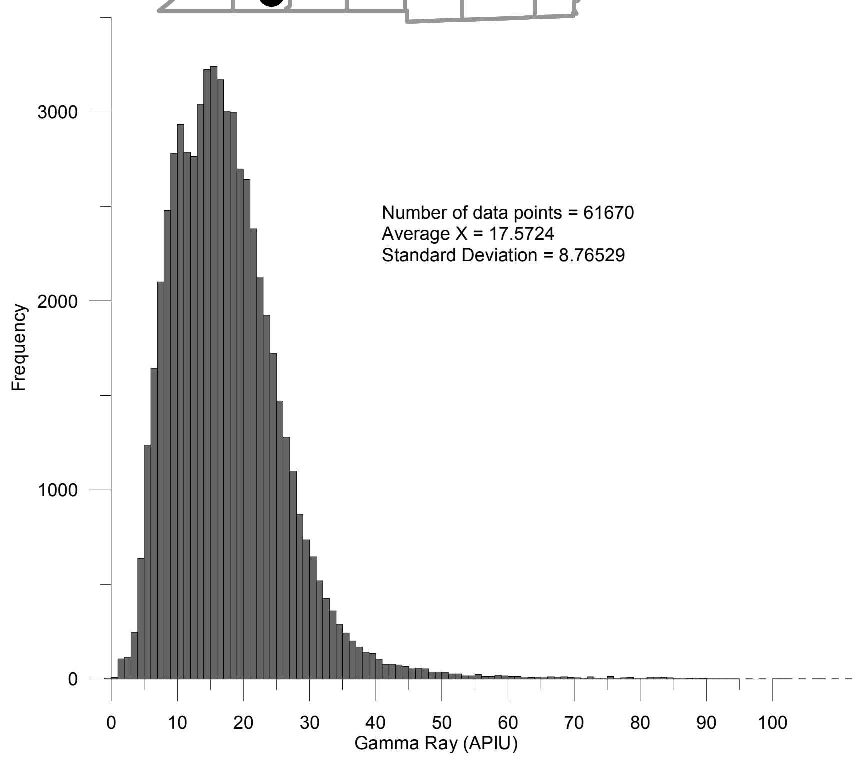
Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
23671	St. Clair					42.79347	-82.52309	4N	16E	11	606	2507	D	2
23672	St. Clair					42.79714	-82.52819	4N	16E	11	614	2512	D	2
23707	St. Clair					42.78968	-82.52309	4N	16E	11	605	2508	G	2
23729	St. Clair					42.79697	-82.52294	4N	16E	11	617	2517	D	2
23797	St. Clair					42.77442	-82.54225	4N	16E	15	622	2522	D	2
23821	St. Clair					42.79708	-82.53279	4N	16E	11	621	2521	D	2
23840	St. Clair					42.78675	-82.50251	4N	16E	13	599	2630	D	2
23866	St. Clair		758	880		42.77860	-82.52238	4N	16E	14	601	2549	D	1
23908	St. Clair					42.79347	-82.51801	4N	16E	11	605	2554	D	2
23934	St. Clair					42.80455	-82.52378	4N	16E	2	617	2637	D	2
24026	St. Clair					42.78609	-82.52238	4N	16E	14	603	2492	D	2
24051	St. Clair					42.79006	-82.50825	4N	16E	12	602	2571	O	2
24313	St. Clair					42.78657	-82.50743	4N	16E	13	602	0	D	1
24360	St. Clair					42.76668	-82.54154	4N	16E	22	625	2585	D	1
24372	St. Clair					42.79708	-82.51818	4N	16E	11	606	2540	D	1
24393	St. Clair					42.79526	-82.53044	4N	16E	11	620	2535	D	1
24468	St. Clair					42.76436	-82.50057	4N	16E	24	588	2446	D	1
24534	St. Clair					42.78623	-82.51779	4N	16E	14	597	0	D	1
24796	St. Clair					42.76372	-82.52168	4N	16E	23	601	2593	D	1
24894	St. Clair					42.78036	-82.53842	4N	16E	15	622	0	D	1
24895	St. Clair					42.78379	-82.53498	4N	16E	15	620	2521	D	1
24896	St. Clair					42.79161	-82.53027	4N	16E	11	619	2705	D	1
24897	St. Clair					42.77640	-82.53971	4N	16E	15	618	2539	D	1
24967	St. Clair					42.78985	-82.51797	4N	16E	11	603	2671	D	1
25022	St. Clair					42.78797	-82.53027	4N	16E	11	618	2517	D	2
25133	St. Clair					42.79888	-82.53059	4N	16E	11	622	2709	D	5
25134	St. Clair					42.77980	-82.54470	4N	16E	15	623	2685	D	1
25216	St. Clair					42.80266	-82.52625	4N	16E	2	618	2722	D	1
25217	St. Clair					42.77606	-82.54470	4N	16E	15	622	2690	D	1
25230	St. Clair					42.80057	-82.51840	4N	16E	11	607	2693	D	1
25269	St. Clair					42.79901	-82.52555	4N	16E	11	620	2540	G	1
25285	St. Clair					42.80097	-82.52309	4N	16E	11	621	2540	D	1

Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
25644	St. Clair					42.79903	-82.52248	4N	16E	11	618	2585	D	1
25739	St. Clair					42.80065	-82.52806	4N	16E	11	621	2700	D	6
25779	St. Clair					42.78588	-82.52866	4N	16E	14	614	2577	D	1
25780	St. Clair		535	654		42.59884	-82.56890	2N	16E	0	579	4186	D	1
25894	St. Clair					42.81531	-82.53894	4N	16E	3	613	2694	D	1
26066	St. Clair					42.76850	-82.54924	4N	16E	22	626	2600	D	1
26117	St. Clair					42.79183	-82.52751	4N	16E	11	616	0	D	1
26142	St. Clair					42.79040	-82.52477	4N	16E	11	604	2528	D	1
26153	St. Clair					42.79541	-82.52606	4N	16E	11	619	2549	D	1
26154	St. Clair					42.79526	-82.52309	4N	16E	11	609	2537	D	3
26173	St. Clair					42.79199	-82.52381	4N	16E	11	603	2542	D	1
26206	St. Clair					42.77857	-82.53886	4N	16E	15	618	2566	D	1
27008	St. Clair					42.76026	-82.51398	4N	16E	23	601	2481	D	1
27266	St. Clair					42.78395	-82.53265	4N	16E	14	619	2550	D	1
27267	St. Clair					42.78185	-82.53472	4N	16E	15	620	2550	D	1
27268	St. Clair					42.78007	-82.53686	4N	16E	15	614	2545	D	1
27613	St. Clair					42.79084	-82.52856	4N	16E	11	622	2550	D	1
27614	St. Clair					42.78549	-82.53018	4N	16E	14	617	2554	D	1
27787	St. Clair					42.81601	-82.51907	4N	16E	2	623	2655	D	1
27957	St. Clair					42.76953	-82.52908	4N	16E	23	610	2539	D	1
28091	St. Clair					42.76255	-82.53398	4N	16E	22	612	2540	D	1
28278	St. Clair					42.75859	-82.50714	4N	16E	24	591	2448	D	1
30376	St. Clair		727	823		42.69367	-82.63069	3N	15E	14	603	4550	D	1
32711	St. Clair					42.77796	-82.49737	4N	16E	13	598	2487	G	2
32726	St. Clair					42.78657	-82.50742	4N	16E	13	602	2601	Obs	2
32915	St. Clair					42.76359	-82.51640	4N	16E	23	605	2610	D	2
38964	St. Clair		1531	1695		42.90919	-82.97129	6N	13E	30	801	6696	D	3
38965	St. Clair		1484	1639		42.99864	-82.80874	7N	14E	34	804	6310	D	1
39602	St. Clair		1671	1847	1880	43.12860	-82.75756	8N	15E	18	791	6751	D	1
40698	St. Clair		1558	1720	1752	43.13029	-82.70612	8N	15E	16	769	6500	D	1
31335	St. Joseph		1159	1247		41.95671	-85.43117	6S	10W	11	892	5283	D	2
31708	St. Joseph		1043	1129		41.93576	-85.54834	6S	11W	23	844	3065	D	1

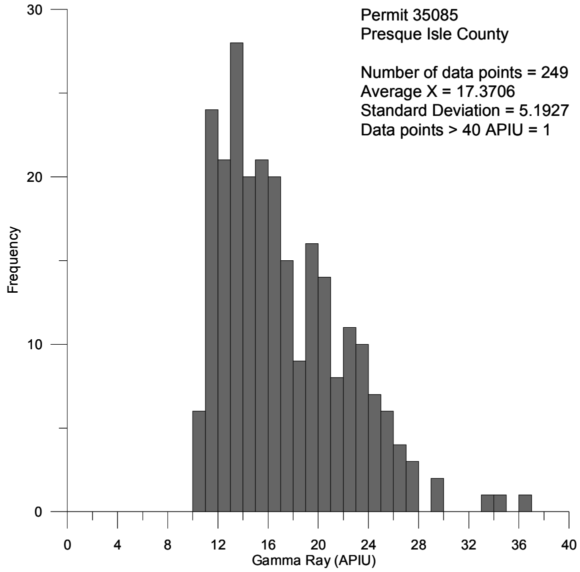
Permit	Name	RGRC	DNDE	DRRV	DRB	Latitude	Longitude	Twn	Rng	Sec	KB	TD	Type	Omit
23890	Tuscola					43.56652	-83.43100	13N	9E	8	678	10130	D	2
25609	Tuscola	2595	2645	2994	2973	43.54415	-83.18904	13N	11E	16	738	9296	D	1
35456	Tuscola	2610	2625	2886	2911	43.33251	-83.52020	11N	8E	27	709	3590	D	1
40136	Tuscola	2607	2657	3027	3061	43.58277	-83.56999	14N	8E	30	626	11230	G	1
40856	Tuscola	2845	2895	3255	3259	43.55610	-83.40060	13N	9E	10	717	10756	O	1
27501	Van Buren					42.08930	-86.21775	4S	16W	30	812	2770	D	1
28590	Van Buren		1455	1538	1585	42.38922	-85.94393	1S	14W	16	764	3422	D	1
31018	Van Buren		1268	1331	1387	42.26054	-85.92611	2S	14W	27	711	3265	D	1
38517	Van Buren		1334	1381	1484	42.13889	-85.84557	4S	13W	8	967	3372	D	1
24161	Washtenaw		1541	1614		42.37596	-84.07237	1S	3E	22	960	5159	D	1
24396	Washtenaw		1272	1404	1402	42.27547	-84.02309	2S	3E	25	939	4758	D	1
26856	Washtenaw		637	763		42.12545	-83.85543	4S	5E	17	862	3934	D	1
34223	Washtenaw		1242	1350		42.35971	-83.73385	1S	6E	28	942	6300	D	1
25560	Wayne		113	195		42.30641	-83.17566	2S	11E	19		3752	BD	1
00146BD	Wayne					42.12997	-83.22808	4S	10E	22	588	3920	D	1
29037	Wexford	2579	2604	2768	2968	44.34344	-85.80295	23N	12W	31	911	6519	D	1
30342	Wexford					44.43009	-85.81716	24N	12W	31	1091	6202	D	1
30903	Wexford					44.49885	-85.79924	24N	12W	6	1056	6130	O	1
31016	Wexford	2484	2519	2643		44.50402	-85.81591	24N	12W	6	1061	6145	O	1
31016	Wexford					44.50402	-85.81591	24N	12W	6	1061	6145	O	1
31803	Wexford					44.48107	-85.79559	24N	12W	17	1060	6410	G	1
34612	Wexford	3942	3972	4185	4412	44.21061	-85.37390	21N	9W	14	1412	10430	D	1
35099	Wexford	2985	3030	3202		44.46946	-85.45745	24N	9W	18	1022	10100	BD	1
35099	Wexford					44.46946	-85.45745	24N	9W	18	1022	10100	BD	
40210	Wexford	3043	3058	3272	3426	44.18603	-85.74747	21N	12W	27	964	9635	D	1

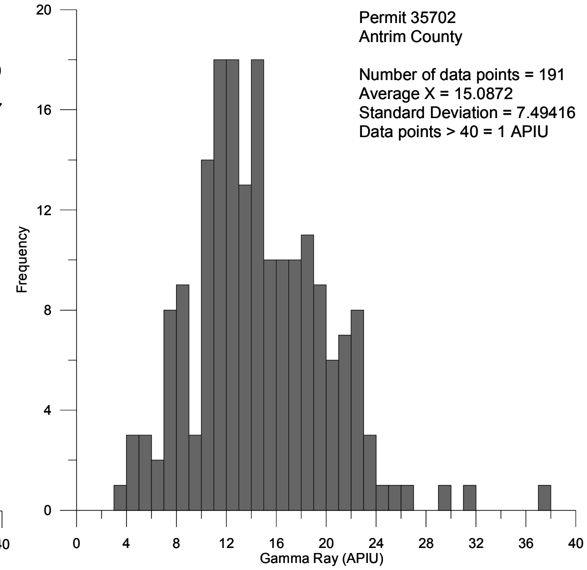
Appendix B: Histograms

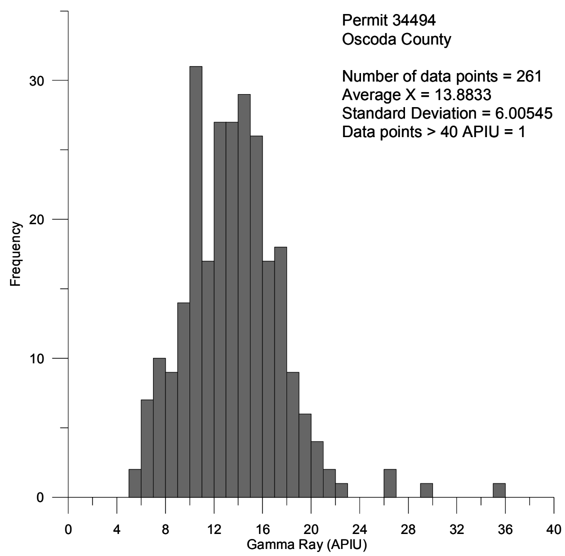


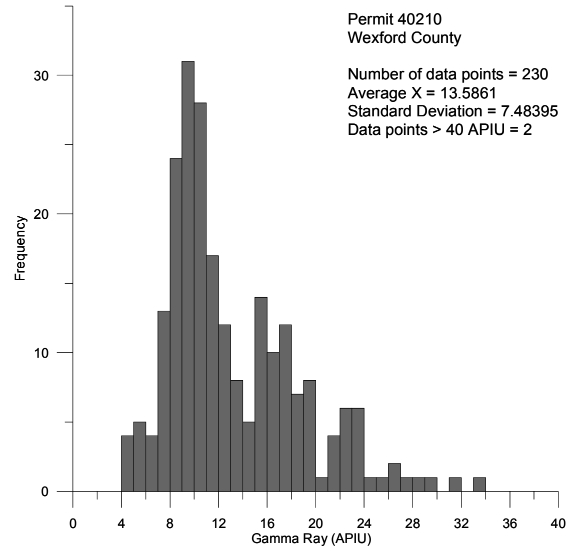


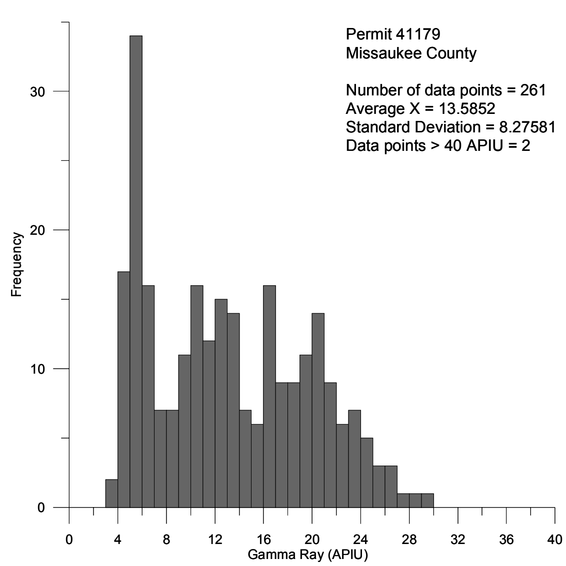
Locations and permit numbers for 18 wells distributed throughout the study area are identified above. Histograms for each of the 18 wells are shown on the following pages and the composite histogram for all 302 wells is shown directly above. The individual histogram plots illustrate gamma ray values for the Dundee-Rogers City interval (x-axis) versus the frequency of each gamma ray value (y-axis). The thickness of the Dundee-Rogers City unit varies throughout the basin and consequently, the maximum histogram frequency is not uniform. In contrast, the gamma ray range (x-axis) is 0-40 APIU for every histogram to allow for comparison.

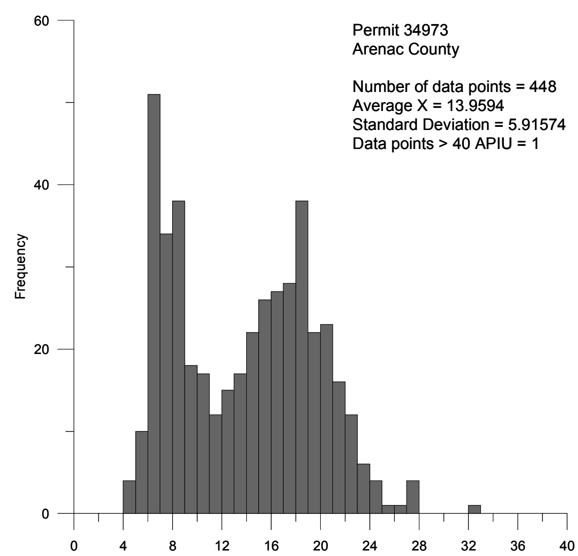

Permit 35085
Presque Isle County
Number of data points = 249
Average X = 17.3706
Standard Deviation = 5.1927
Data points > 40 APIU = 1
Frequency
Gamma Ray (APIU)

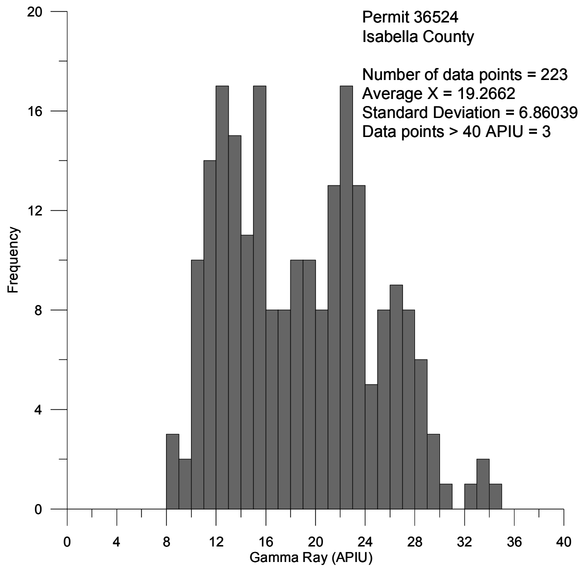

Permit 35702
Antrim County
Number of data points = 191
Average X = 15.0872
Standard Deviation = 7.49416
Data points > 40 = 1 APIU
Frequency
Gamma Ray (APIU)

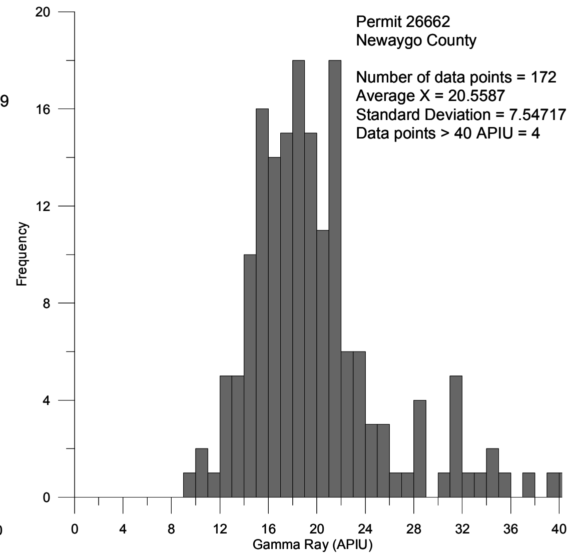

Permit 34494
Oscoda County
Number of data points = 261
Average X = 13.8833
Standard Deviation = 6.00545
Data points > 40 APIU = 1
Frequency
Gamma Ray (APIU)

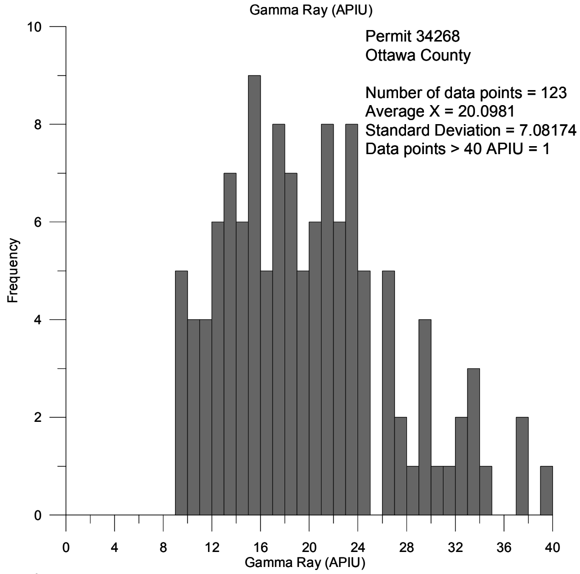

Permit 40210
Wexford County
Number of data points = 230
Average X = 13.5861
Standard Deviation = 7.48395
Data points > 40 APIU = 2
Frequency
Gamma Ray (APIU)

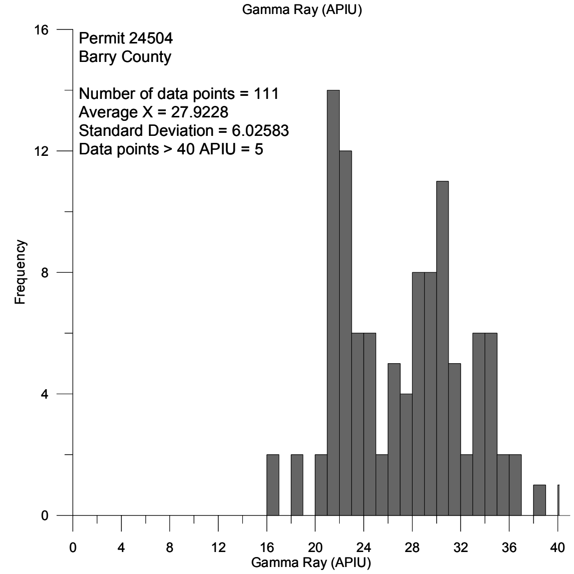

Permit 41179
Missaukee County
Number of data points = 261
Average X = 13.5852
Standard Deviation = 8.27581
Data points > 40 APIU = 2
Frequency
Gamma Ray (APIU)

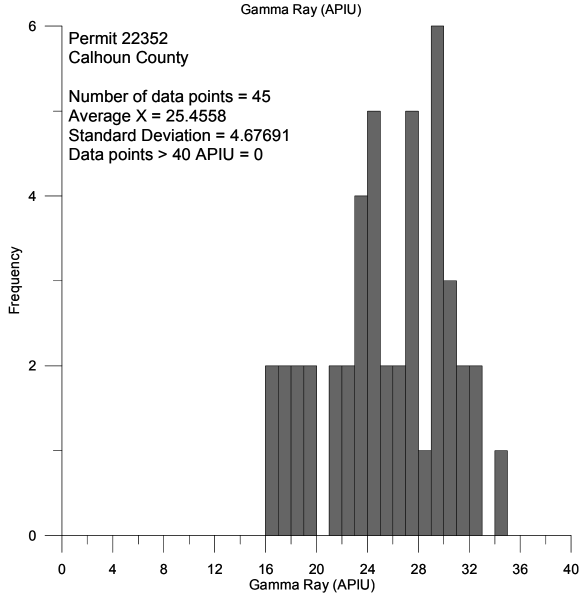

Permit 34973
Arenac County
Number of data points = 448
Average X = 13.9594
Standard Deviation = 5.91574
Data points > 40 APIU = 1
Frequency
Gamma Ray (APIU)

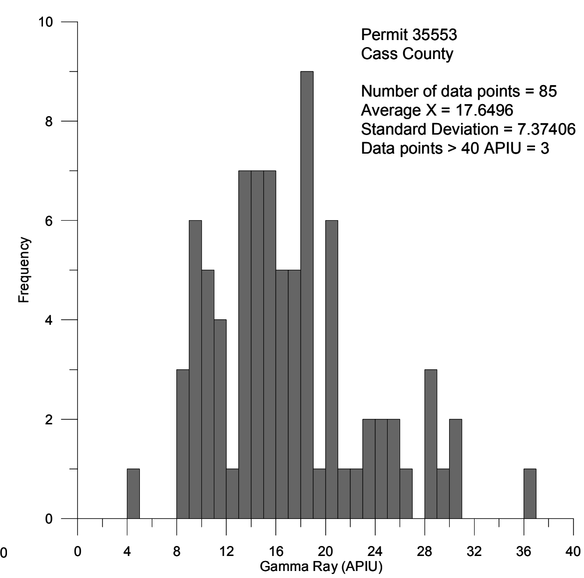

Permit 36524
Isabella County
Number of data points = 223
Average X = 19.2662
Standard Deviation = 6.86039
Data points > 40 APIU = 3
Frequency
Gamma Ray (APIU)

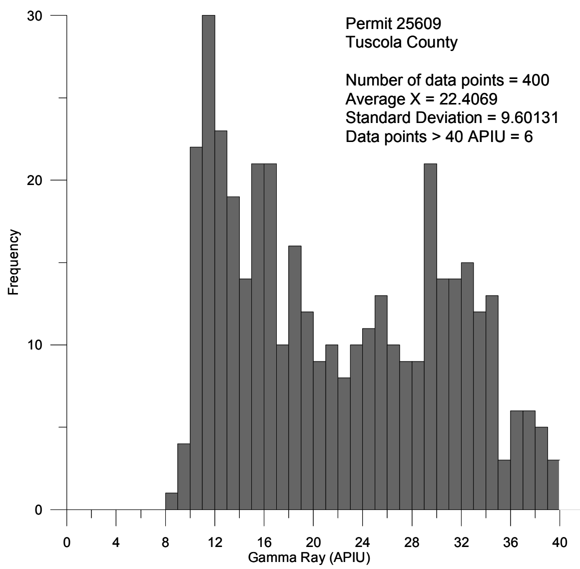

Permit 26662
Newaygo County
Number of data points = 172
Average X = 20.5587
Standard Deviation = 7.54717
Data points > 40 APIU = 4
Frequency
Gamma Ray (APIU)

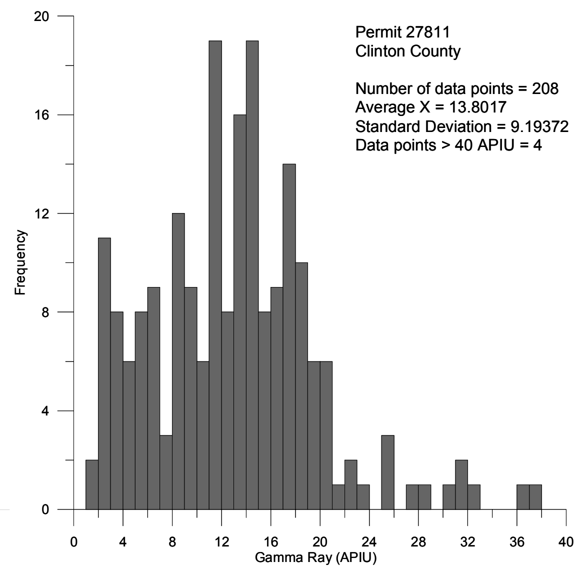

Permit 34268
Ottawa County
Number of data points = 123
Average X = 20.0981
Standard Deviation = 7.08174
Data points > 40 APIU = 1
Frequency
Gamma Ray (APIU)

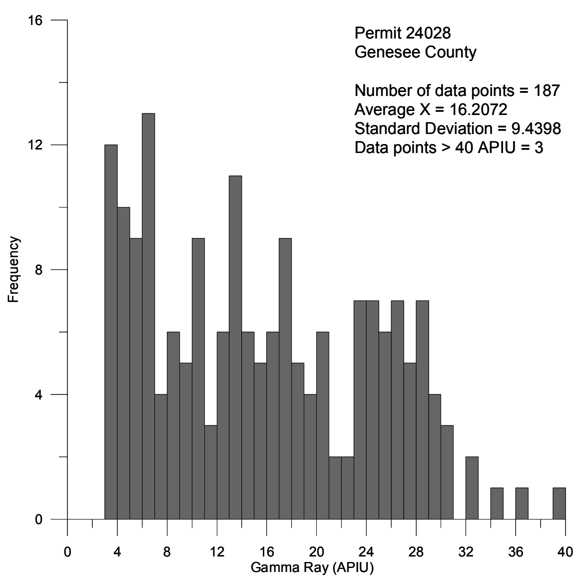

Permit 24504
Barry County
Number of data points = 111
Average X = 27.9228
Standard Deviation = 6.02583
Data points > 40 APIU = 5
Frequency
Gamma Ray (APIU)

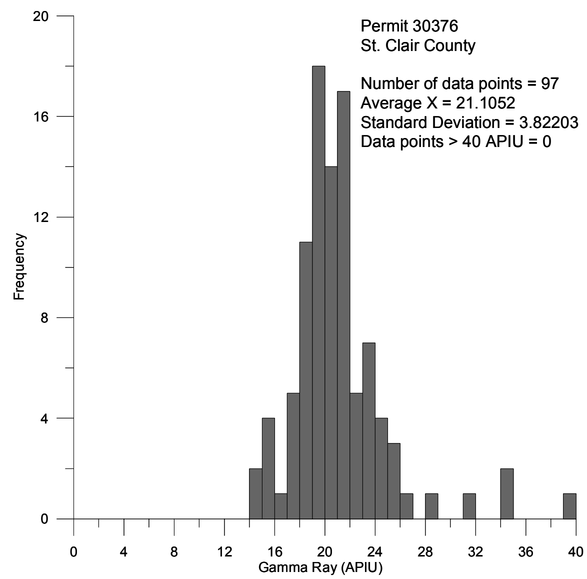

Permit 22352
Calhoun County
Number of data points = 45
Average X = 25.4558
Standard Deviation = 4.67691
Data points > 40 APIU = 0
Frequency
Gamma Ray (APIU)

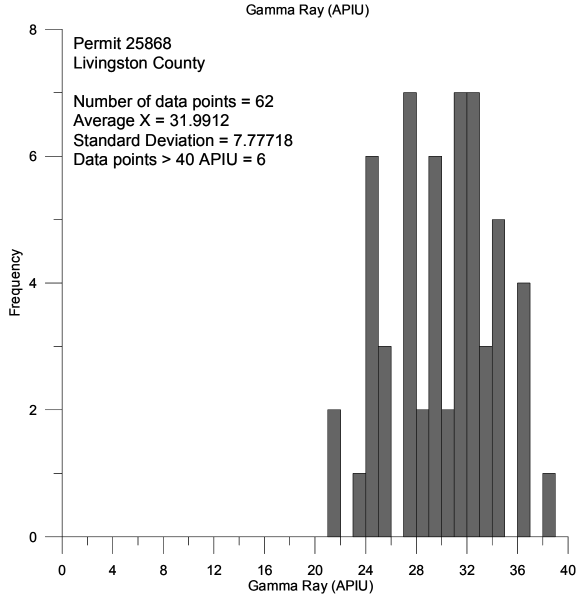

Permit 35553
Cass County
Number of data points = 85
Average X = 17.6496
Standard Deviation = 7.37406
Data points > 40 APIU = 3
Frequency
Gamma Ray (APIU)

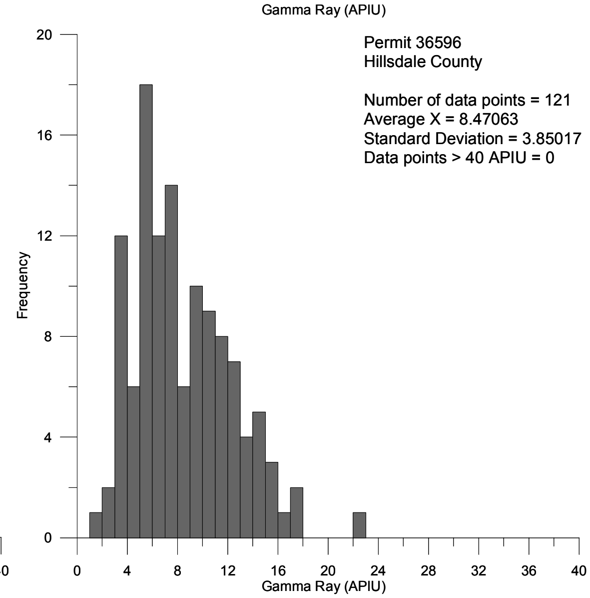

Permit 25609
Tuscola County
Number of data points = 400
Average X = 22.4069
Standard Deviation = 9.60131
Data points > 40 APIU = 6
Frequency
Gamma Ray (APIU)


Permit 27811
Clinton County
Number of data points = 208
Average X = 13.8017
Standard Deviation = 9.19372
Data points > 40 APIU = 4
Frequency
Gamma Ray (APIU)


Permit 24028
Genesee County
Number of data points = 187
Average X = 16.2072
Standard Deviation = 9.4398
Data points > 40 APIU = 3
Frequency
Gamma Ray (APIU)


Permit 30376
St. Clair County
Number of data points = 97
Average X = 21.1052
Standard Deviation = 3.82203
Data points > 40 APIU = 0
Frequency
Gamma Ray (APIU)


Permit 25868
Livingston County
Number of data points = 62
Average X = 31.9912
Standard Deviation = 7.77718
Data points > 40 APIU = 6
Frequency
Gamma Ray (APIU)


Permit 36596
Hillsdale County
Number of data points = 121
Average X = 8.47063
Standard Deviation = 3.85017
Data points > 40 APIU = 0
Frequency
Gamma Ray (APIU)

Appendix C: Surfer Gridding Report

Nearest Neighbor Statistics

	Separation	Delta Z
Minimum:	0.00759393	0.09040000
25%-tile:	0.05350652	4.322
Median:	0.09387544	12.59449
75%-tile:	0.14844219	24.3466
Maximum:	0.37164484	66.71
Midrange:	0.18961938	33.4002
Range:	0.36405091	66.6196
Interquartile Range:	0.09493566	20.0246
Median Abs. Deviation:	0.04316621	9.25019
Mean:	0.10653948	16.83974195
Trim Mean (10%):	0.10214495	15.45625125
Standard Deviation:	0.06658871	15.19119000
Variance:	0.00443406	230.77225363
Coef. of Variation:	0.62501439	0.90210349
Coef. of Skewness:	0.95823779	1.19231368
Root mean Square:	0.12563724	22.67926724
Mean Square:	0.01578472	514.34916270

Complete Spatial Randomness

Lambda:	21.00911591
Clark and Evans:	0.97666238
Skellam:	629.26182803

Gridding Rules

Anisotropy Ratio:	1
Anisotropy Angle:	0

Output Grid

Grid Size:	186 rows x 200 columns
Total nodes:	37200

Grid Geometry

[longitude]	
X Minimum:	-86.44577
X Maximum:	-82.52238
X Spacing:	0.01971553 (degrees)
[latitude]	
Y Minimum:	41.74535
Y Maximum:	45.4092
Y Spacing:	0.01980460

Grid Statistics

Z Minimum:	4.60206001
Z 25%-tile:	40.67084440
Z Median:	52.47149827
Z 75%-tile:	61.89949068
Z Maximum:	105.12414807
Z Midrange:	54.86310406
Z Range:	100.52208802
Z Interquartile Range:	21.22864628
Z Median Abs. Deviation:	10.40104608
Z Mean:	51.08730226
Z Trim Mean (10%):	51.14665166
Z Standard Deviation:	15.26765019
Z Variance:	233.10114222
Z Coef. of Variation:	0.29885411
Z Coef. of Skewness:	-0.13272763
Z Root mean Square:	53.31991743
Z Mean Square:	2843.01359470

Appendix D: Surfer Color Files

Correlative Traverse Group study color scale

Used for 0-150 APIU range. Contour interval: 15 APIU.

```
ColorMap 1 1
    0.000000   0  51 153
   10.073892 102 102 204
   19.211823   0   0 255
   30.000000   0 204 255
   40.000000 153 255 255
   50.246305  51 204 153
   60.000000 153 255 153
   70.443350 255 255   0
   80.295566 255 102  51
   90.640394 255   0   0
  100.000000   0   0   0
```

Blue (low Traverse Group study) color scale

Used for 0-30 APIU range. Contour interval: 3 APIU.

```
ColorMap 1 1
    0.000000  51   0 102
   10.000000   0   0 126
   20.000000   0  51 186
   30.000000   0 137 205
   40.000000   0 191 255
   50.000000 113 230 255
   60.000000 175 255 255
   70.000000 190 255 255
   80.000000 164 255 204
   90.000000 139 208 157
  100.000000   0   0   0
```