Combining Cambrian Aquifer Isotope Data
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Introduction

The Pleistocene-age glaciations of the Wisconsin and Illinoisian had a significant effect in shaping the modern landscapes we see today. More recently, the Wisconsin glacial episode between 85 and 11 thousand years ago scoured the land, exposing the water-bearing units beneath the bottom of the ice sheets. As the glacier repeated advanced and retreated, meltwater from these movements penetrated permeable rock where it was exposed at the surface, entering both unconfined and confined aquifers. Several studies have been done measuring the presence of isotopes in wells drawing water from the deeper, confined aquifer made up of Cambrian age sandstone. Many of these studies have focused on the southeastern border of Wisconsin, between Milwaukee and Chicago, but have not expanded to take samples from other areas of the aquifer further to the north, or are limited to Illinois only. As a part of adding data points to existing isoscape maps of northeast Wisconsin, this project was to combine data sets from Illinois and southern Wisconsin-focused studies to new data from northeast Wisconsin.

Hydrogeology

The aquifer used by the wells used for the new data and studies pulled from is the Cambrian sandstone, one of the lower units of the Michigan Basin. The unit is exposed in areas of east and central Wisconsin, northeastern Illinois, and the western half of the upper peninsula of Michigan. The sandstone continues under the Michigan Basin, and is confined by the Precambrian granite below, and the Silurian and Ordovician confining units above. (United States Department of the Interior United States Geological Survey. (1987)). Areas that use this aquifer as a primary source of water often need to as a result of low water output capacity from unconfined or other confined aquifer systems such as the Silurian dolomite or Pleistocene glacial sediments.

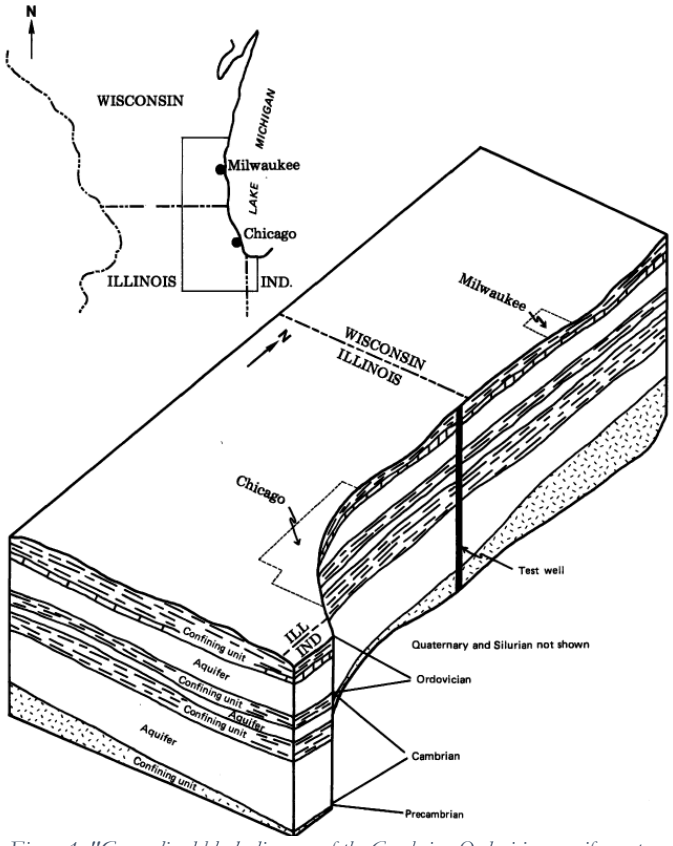

Figure 1: "Generalized block diagram of the Cambrian-Ordovician aquifer system in the area of Chicago-Milwaukee groundwater model. (United States Department of the Interior United States Geological Survey. (1987))

Methods

Three points of data were generated from isotope tests on well samples taken in the late summer/early fall of 2021 in East-Central Wisconsin. All three wells were confirmed to be drawing water from the Cambrian aquifer, and also cased through the Maquoketa Shale to prevent cross-contamination from the overlying unconfined aquifer. Two wells, CY287 and UN043, were flushed before the sample was taken for carbon isotope testing, which is still pending. This process involved withdrawing a full volume of water from the well, determined from the depth and circumference of the well from the well construction report. Sample ZZ818 was drawn from an outdoor spigot which did not pass through a water softener, but will not be tested for carbon isotopes.

Additional data was pulled from six papers that studied or included data covering the concentration of isotopes in the Cambrian aquifer. When choosing which papers would be appropriate for the combined dataset, the study needed to fit three criteria: the study must have taken or be focused on water samples from the Cambrian aquifer as a part of the Michigan Basin, have some method of identifying the location of where the sample was taken, and list isotopic data for at least one of the following isotopes: $\delta^{34}S$, $\delta^{2}H$, $\delta^{18}O$, and/or ^{13}C. Studies which fit these criteria are very limited, so many of the papers used violate one or more of these criteria as a factor of necessity to fill the table.

Papers which had some degree of location information available for their samples were used to build a supplementary set of maps. The papers with location varied significantly in how specific the locations of the samples were, which made including all of the data on the maps not possible. Gilkeson, R.H., et Al. listed the Township/Range/Sections for each well, which could be cross-referenced with the well depth to locate exact latitude and longitude. Other studies, namely Kelly, W.R. et Al., Siegel, D.I. (1990), and Perry Jr., E.C., et Al, use map figures and identifiers to display the location of each sample taken. These maps were used with the Georeference tool in ArcGISPro; the maps were overlain over county and city maps of the United States and transformed to fit the projected coordinate system used on the base map. The locations of the samples were added to an existing point shapefile based on the projection of the figure, but their approximate latitude and longitude were not added to the excel spreadsheet. $\delta^{2}H$ and $\delta^{18}O$ point maps were created based on the available latitude and longitude data, and the transcribed data.

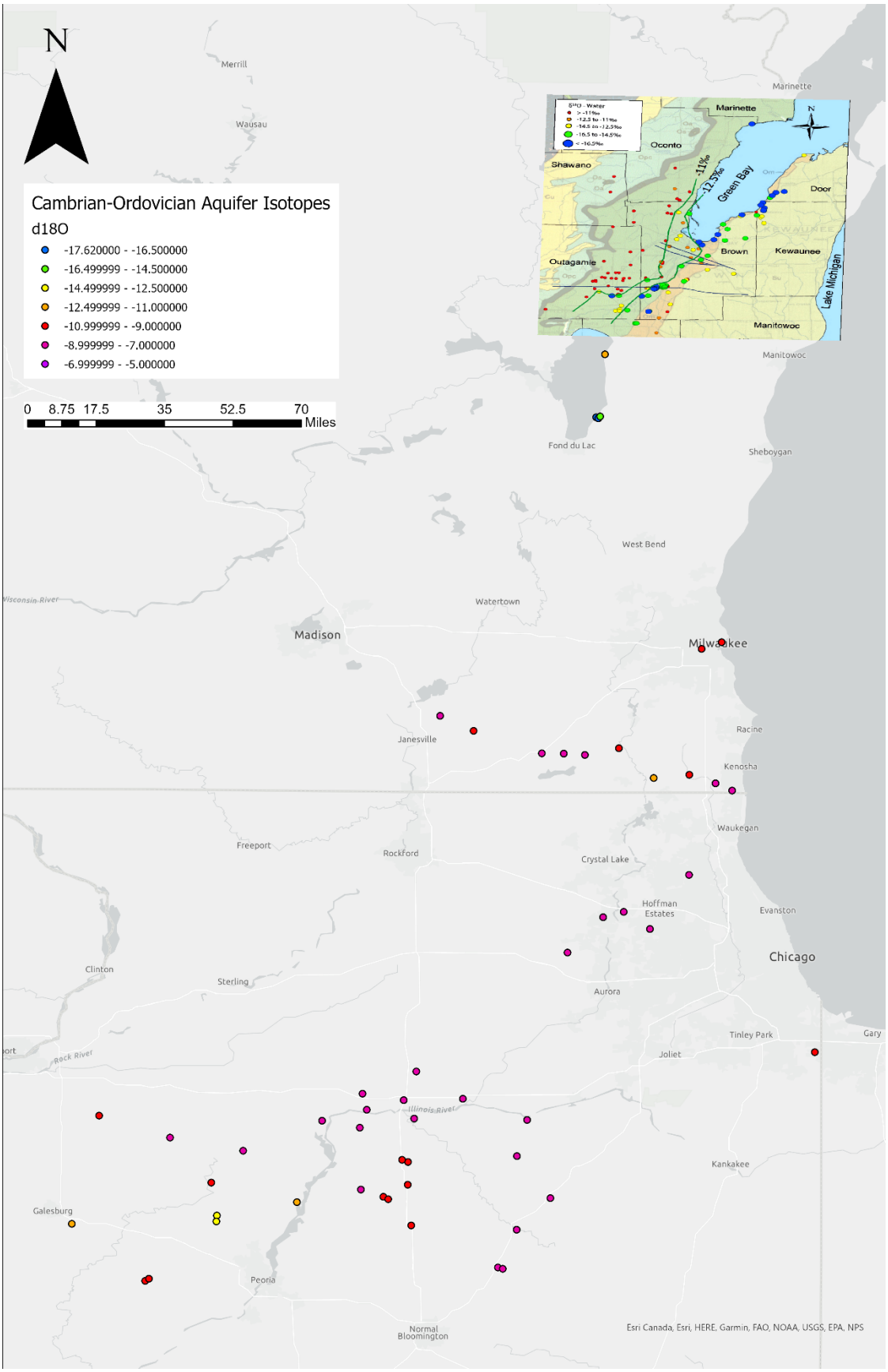

Figure 2: $\delta^{18}O$ map with combined data from samples taken in summer/fall 2021, Gilkeson, R. H., et Al, and Kelly, W.R., et Al.

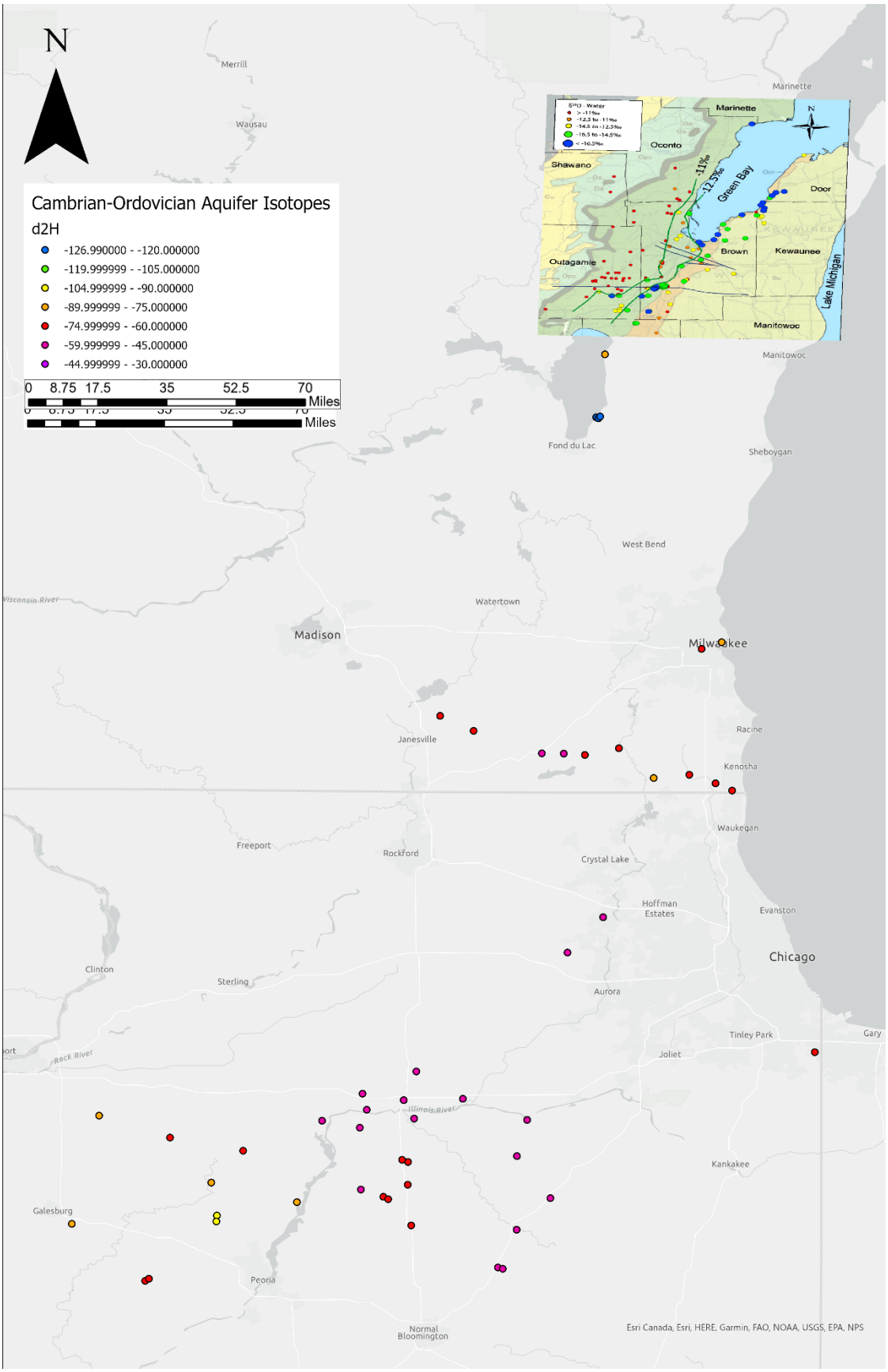
N
Cambrian-Ordovician Aquifer Isotopes
d2H
-126.990000 - -120.000000
-119.999999 - -105.000000
-104.999999 - -90.000000
-89.999999 - -75.000000
-74.999999 - -60.000000
-59.999999 - -45.000000
-44.999999 - -30.000000
0 8.75 17.5 35 52.5 70
Miles
Merrill
Wausau
Marinette
Oconto
Shawano
Green Bay
Door
Kewaunee
Brown
Outagamie
Manitowoc
Lake Michigan
-11‰
-12.5‰
Fond du Lac
Sheboygan
West Bend
Watertown
Madison
Milwaukee
Janesville
Racine
Kenosha
Waukegan
Freeport
Rockford
Crystal Lake
Hoffman Estates
Evanston
Chicago
Clinton
Sterling
Aurora
Tinley Park
Gary
Joliet
Rock River
Illinois River
Kankakee
Galesburg
Peoria
Normal
Bloomington
Esri Canada, Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS

Figure 3 (see page 4): δ^2H map with combined data from samples taken in summer/fall 2021, Gilkeson, R. H., et Al, and Kelly, W.R., et Al. Legend/ natural break (jenks) are based off of the color scheme used in Luczaj, J., et Al.

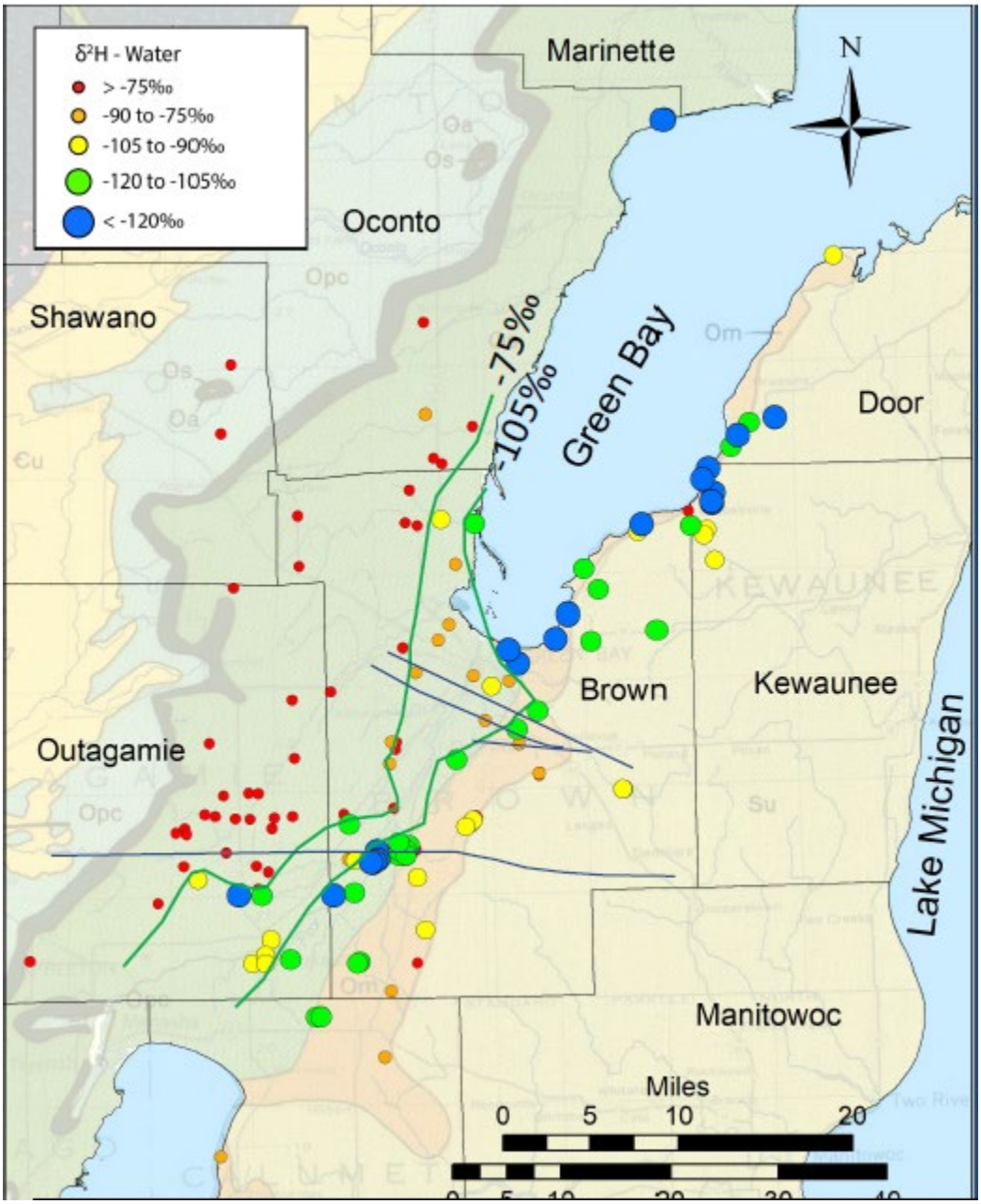

Figure 4: δ^2H map used in figure 3 from Luczaj, J., et Al.

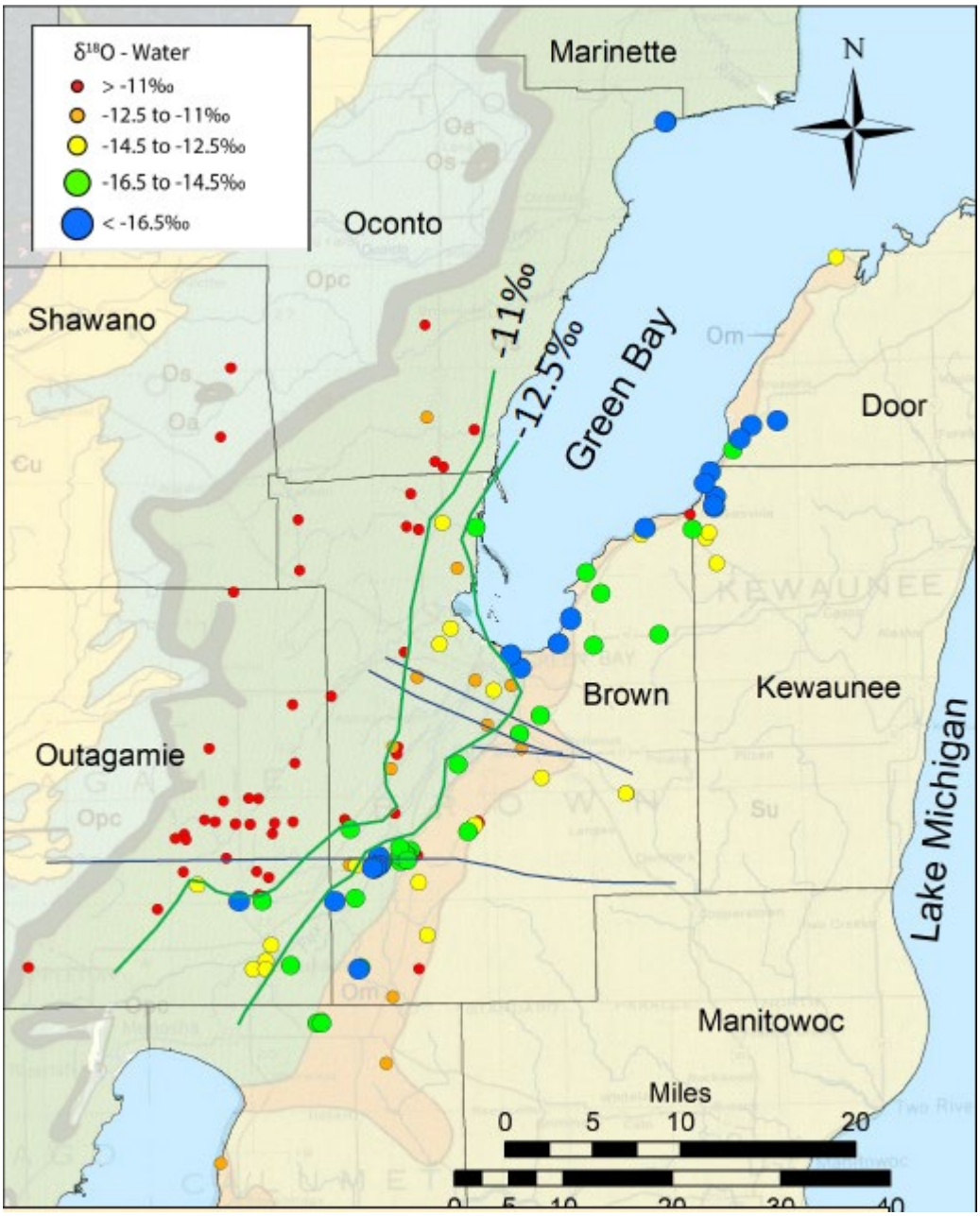

Figure 5: δ18O maps used in figure 2 from Luczaj, J., et Al.

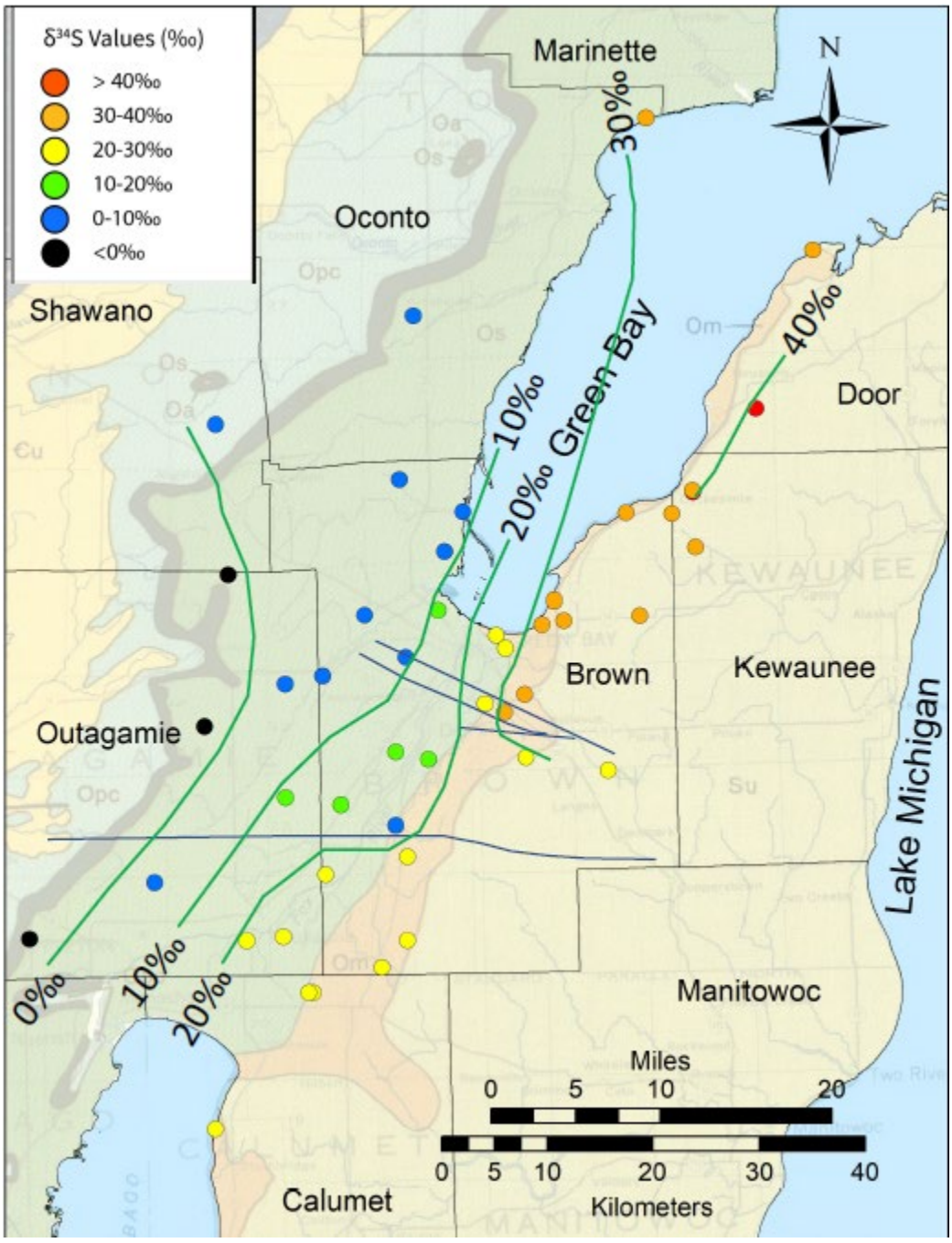

Figure 6: $\delta^{34}S$ isoscape map from Luczaj, J., et Al.

Discussion and Challenges

When combining the data of the samples taken in 2021 and some of the studies, it is possible to assume there is a trend to heavier isotope concentrations of $\delta^{2}H$ and $\delta^{18}O$ towards northeastern Illinois as you get closer to the center of the Michigan Basin, but this assumption ignores the blatant lack of data from the papers which did not provide complete location information to fill the gap between the Chicago area of Illinois and the Fond Du Lac area of Wisconsin. There are two reasons as to why values are more negative in Wisconsin compared to Illinois, those being glacial melt and latitudinal gradient distance from the Gulf of Mexico, but the data as displayed does not completely follow this trend. This may be in part due to having to georeferenced some data. As stated before, some papers, namely Gilkeson, R.H., et Al included Township/Range/Section data which, when cross-referenced with the depth of the well, would yield an accurate latitude and longitude for the well each sample came from. This, however, was not the case in the majority of the wells sampled, which either gave a vague description, placed their points on a map, or had no description of location at all. This makes coming to any conclusion regarding any trends in isotope concentrations across all of the wells included in the combined data set impossible. Without mostly accurate location data, the points have no meaning and could be assigned arbitrarily to any place within a vaguely described region. For example, samples from Perry Jr. and Montgomery are identified by a locality or county and given an identifying sample number based on unknown criteria. Additionally, these data are not associated with any provided well depths, so we cannot cross-reference locations in the Illinois well records to try and identify the wells used in the study. For this reason, the data from Perry Jr. and Montgomery's paper is excluded from the isoscape maps.

It is clear that studies on the isotopes present in the Cambrian aquifer exist, however, how accessible the data used in these studies seems to vary significantly. Other papers included maps with samples identified by points on a county or regional map, but the accuracy of points referenced from these maps is limited. When georeferencing these, the best possible method was to overlay these low-quality images on a map in ArcGISPro, which does not provide completely accurate latitude and longitude for the points transcribed. It is overall better than completely excluding these points from the maps, but is not an adequate substitute for accurate latitude-longitude data. The maps act as a good draft, but without the accurate location data, they cant be used in any publications in good faith. On its own, the excel spreadsheet is one of the better outcomes of this project. It can be continuously expanded upon as more data points are added, and can be easily combined into future data sets should more data from existing studies become available. It is already set up for the eventual results of the ^{13}C reports for samples CY287 and UN043, so the same file can be re-added into a future shapefile to recreate a more accurate isoscape map at a later date.

The sulfur isoscape map from Luczaj, J. et Al. is included in the figures, as some data pulled from Siegel (1990) included information on sulfur isotopes measured from the samples, but the majority of the papers do not include samples with sulfur measured. Due to the lack of data, it was not possible to make a map using $\delta^{34}S$ measurements, or interpret anything from it.

Literature Cited

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Kelly, W.R., Panno, S.V., Hackley, K.C., Hadley, D.R., & Mannix, D.H. (2018). Paleohydrogeology of a paleozoic sandstone aquifer within an intracratonic basin: Geochemical and structural controls. Journal of Hydrology, 565, 805-818. https://doi.org/10.1016/j.jhydrol.2018.09.004

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