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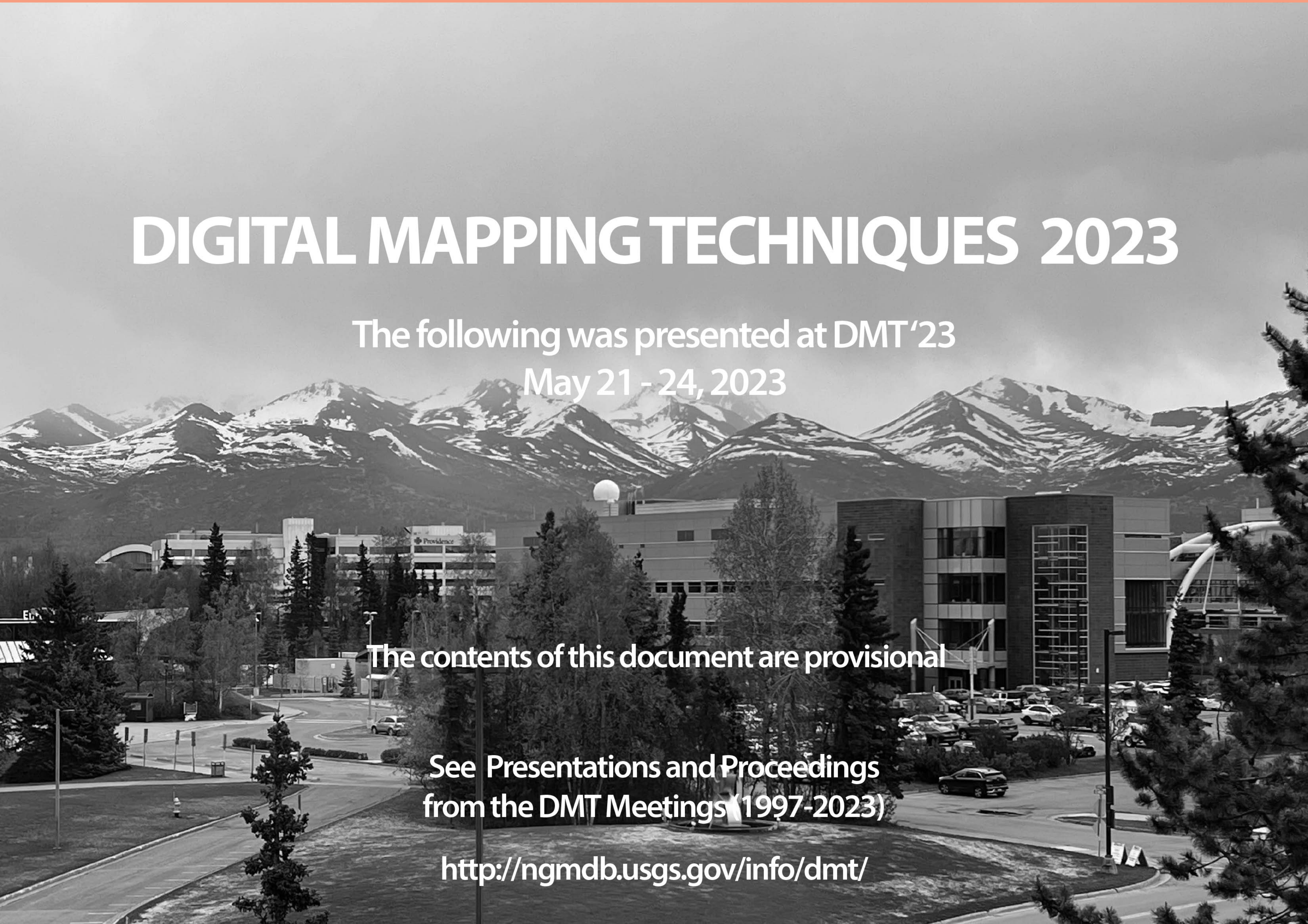

DIGITAL MAPPING TECHNIQUES 2023

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The contents of this document are provisional

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A fractured carbonate system comprises the Silurian-aged bedrock across eastern Wisconsin, USA, potentially acting as a conduit for contaminated surface water, such as manure-treated field effluent, to reach groundwater. Glacial deposits overlying the Silurian bedrock help filter contaminated surface water with thicker deposits having greater filtration potential. In light of revisions to state administrative codes ATCP 50 and NR 151 to regulate manure spreading, a current and timely mapping effort to derive a seamless depth-to-bedrock (DTB) map across the Silurian bedrock region in eastern Wisconsin is needed. The most recent DTB map and outline of the Silurian across eastern Wisconsin was created in 1979 at 1:250,000 scale. Advancement of geographic information system (GIS) technologies and 43 years of additional subsurface information are available to generate a more current and precise DTB map. We used Empirical Bayesian Kriging with Regression Prediction (EBKRP) in Esri ArcGIS Pro to first model a bedrock elevation surface, and then derive DTB by subtracting that surface from a ground-surface digital elevation model. We chose EBKRP over other interpolation methods because the calculation of an unknown value at a given location is dependent on the theoretical best fit of the variance of the known values over the interpolated area, rather than strictly distance. The theoretical best fit captures the spatial relationship across an area and provides the ability to coincidently generate a map of model error. Additionally, the map includes data from the novel application of airborne electromagnetic (AEM) data collected via SkyTEM Canada Inc. in collaboration with the United States Geological Survey and the Wisconsin Geological and Natural History Survey in 2021. AEM data was collected along helicopter flight lines and were inverted to produce electrical resistivity data at nearly 300 m depth with 1-2 m near-surface resolution. The resistivity transitions in the shallow subsurface were used to estimate DTB.

Depth-to-Bedrock Model of the Silurian Across Eastern Wisconsin

Wisconsin Geological and Natural History Survey
DIVISION OF EXTENSION
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State of Wisconsin
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Abstract

- Silurian-aged bedrock across eastern **Wisconsin (WI)** is a fractured carbonate bedrock system susceptible to surface water contamination.
- WI State statutes ATCP50 and NR151 are under current revision to regulate manure spreading over shallow fractured bedrock.
- The WGNHS is in collaboration with DATCP in generating a 12,000 sq. km **depth-to-bedrock (DTB)** model of the Silurian across eastern Wisconsin.
- In contrast to the current Silurian DTB map referenced in WI legislation (Baeten, 2022; Sherrill, 1979), modern advanced **geographic information system (GIS)** technologies allow for applied spatially-interpolative modeling techniques to generate a timely, seamless, and more accurate and precise Silurian DTB map at higher resolution.
- We applied the **Empirical Bayesian Kriging with Regression Prediction (EBKRP)** Geostatistical Analyst Tool in Esri ArcGIS Pro 3.1.0 to generate the DTB model by following these steps:
  1) Generate a 50x50 sq. meter raster **bedrock elevation (BrElev)** surface model with EBKRP with 170K BrElev points
  2) Subtract the generated BrElev surface model from a ground-surface **digital elevation model (DEM)** to calculate the DTB map deliverable surface.
- We empirically investigated and iterated different EBKRP input model parameters, as well as, DTB point data source to maximize output quality.
- The map presented here includes data from the novel application of airborne electromagnetic (AEM) data collected by helicopter flight via SkyTEM Canada Inc. in collaboration with the USGS, the WGNHS, and the WI DATCP in 2021.
- The map deliverables will be given to DATCP to aid farmers in determining DTB for determining best manure spreading planning practice.


Photo: Lisa Haas

EBKRP Model Parameters

ArcGIS Pro 3.1.0 geostatistical analyst tool Empirical Bayesian Kriging with Regression Prediction (EBKRP).

- **Raster size - 50 x 50 m** • **Max/Min Neighbors - 8**
- **Sector Type - 8** • **Radius - 341 ft (104 m)**
- **Search Neighborhood Parameters - Standard circular**
- **Explanatory raster - USGS NED 2017 DEM (USGS, 2017)**
- **Measurement error** was uniquely assigned to each data point to manage its influence, or weight, in the model. Measurement error was calculated by multiplying the length of geolocation confidence radius by an estimated land surface slope of 2% (Table 1, below).

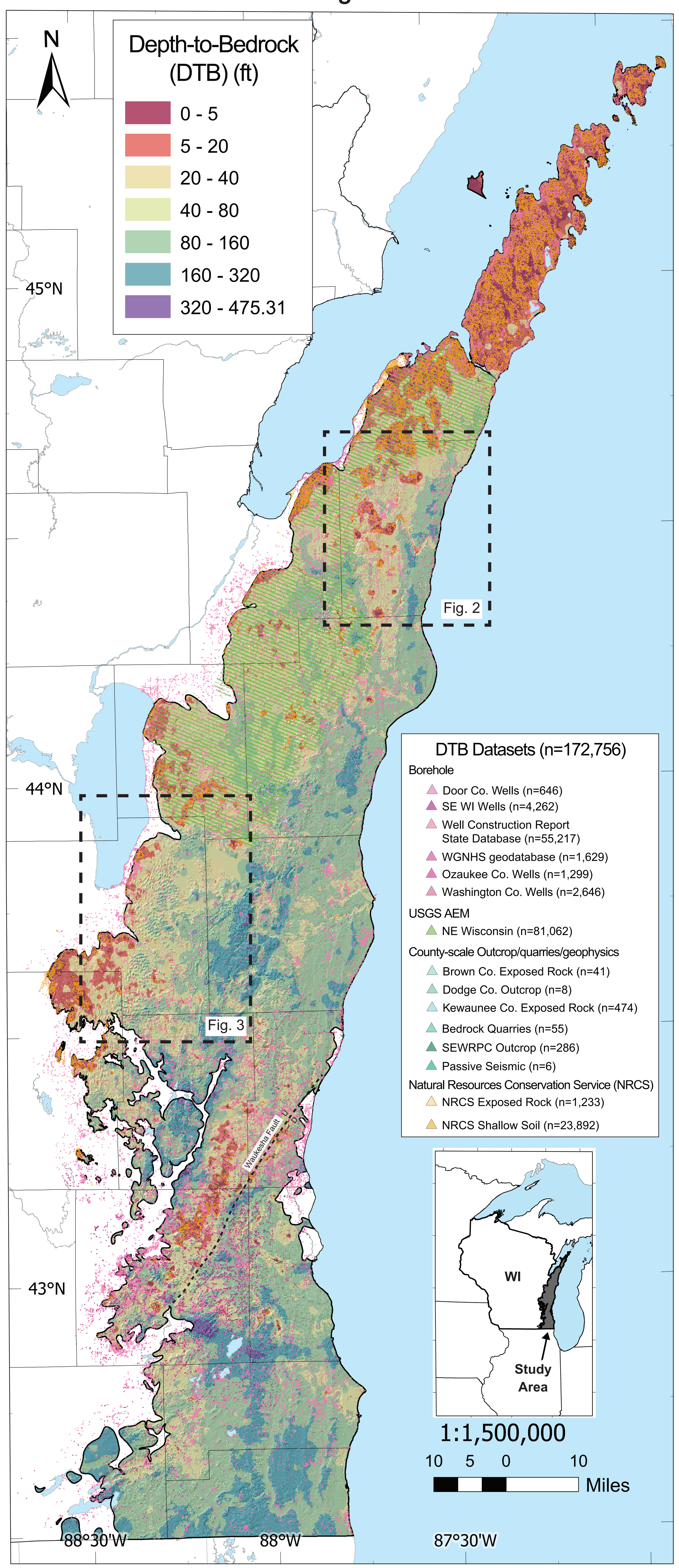
Data Source	Geolocation Confidence (ft (m))	Measurement Error (ft (m))
Boreholes	50-3750 (15-1140)	1-75 (0.3-23)
USGS AEM	750 (229)	15 (4.6)
National Resources Conservation Services (NRCS)	150-1000 (45-305)	3-20 (0.9-6)
County-Scale Outcrop or Bedrock Exposure	50 (15)	1 (0.3)
Quarries	300 (91)	6 (1.8)

Pros to Interpolation Method:

- Inexact interpolator where interpolated areas can be modeled as local maxima/minima.
- Seamless model generation across entire study area with coincident model error raster output (Fig. 2 and 3).
- EBK interpolation takes into account both distance and statistical variance of the modeled value between points.
- Additional model weight constraint can be uniquely specified to each point via specifying measurement error.
- Explanatory rasters (e.g. DEM) can be input to guide the interpolation, similar to elevation in rain shadow modeling.

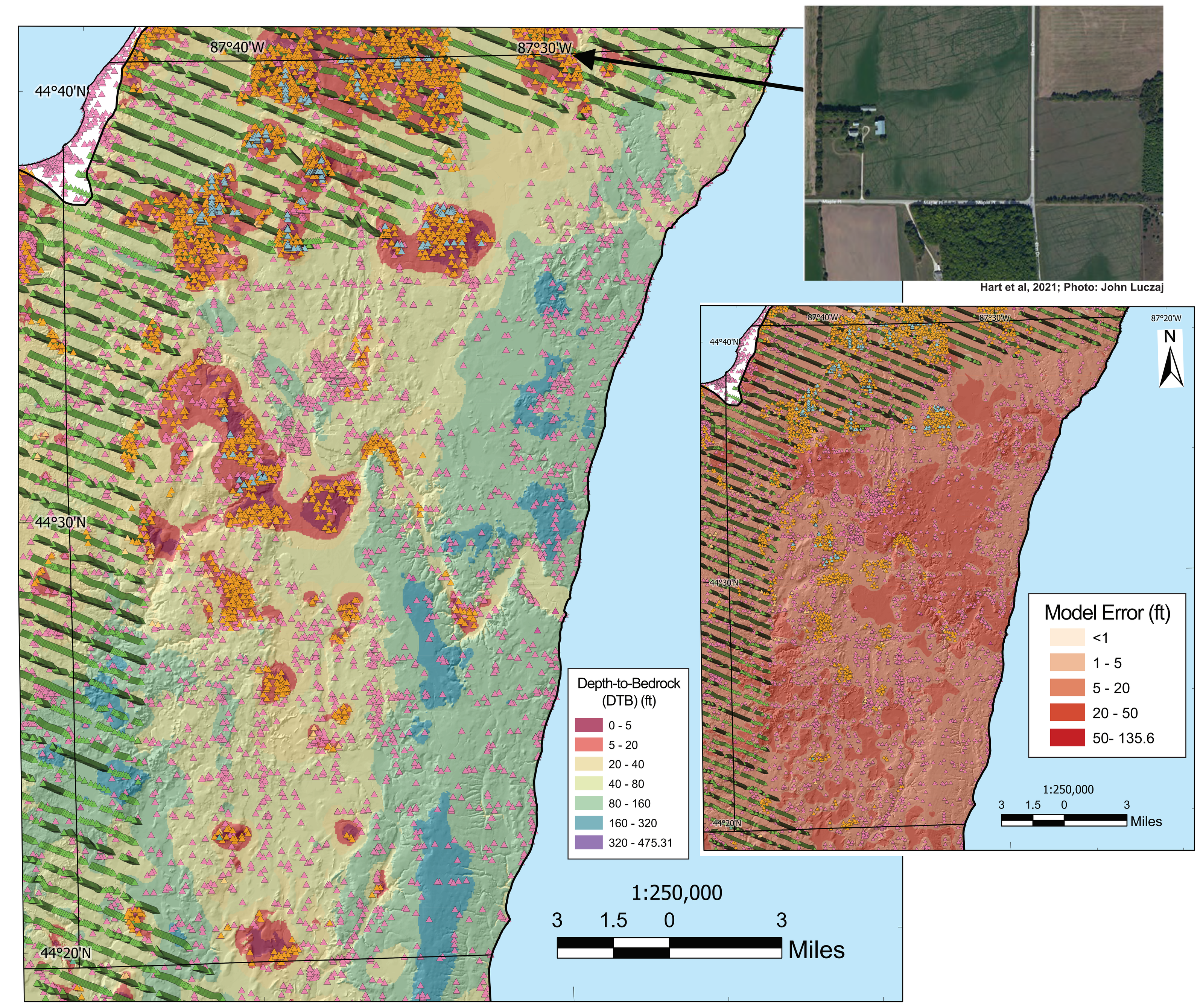
Current DTB Model Output

Modeling Extent

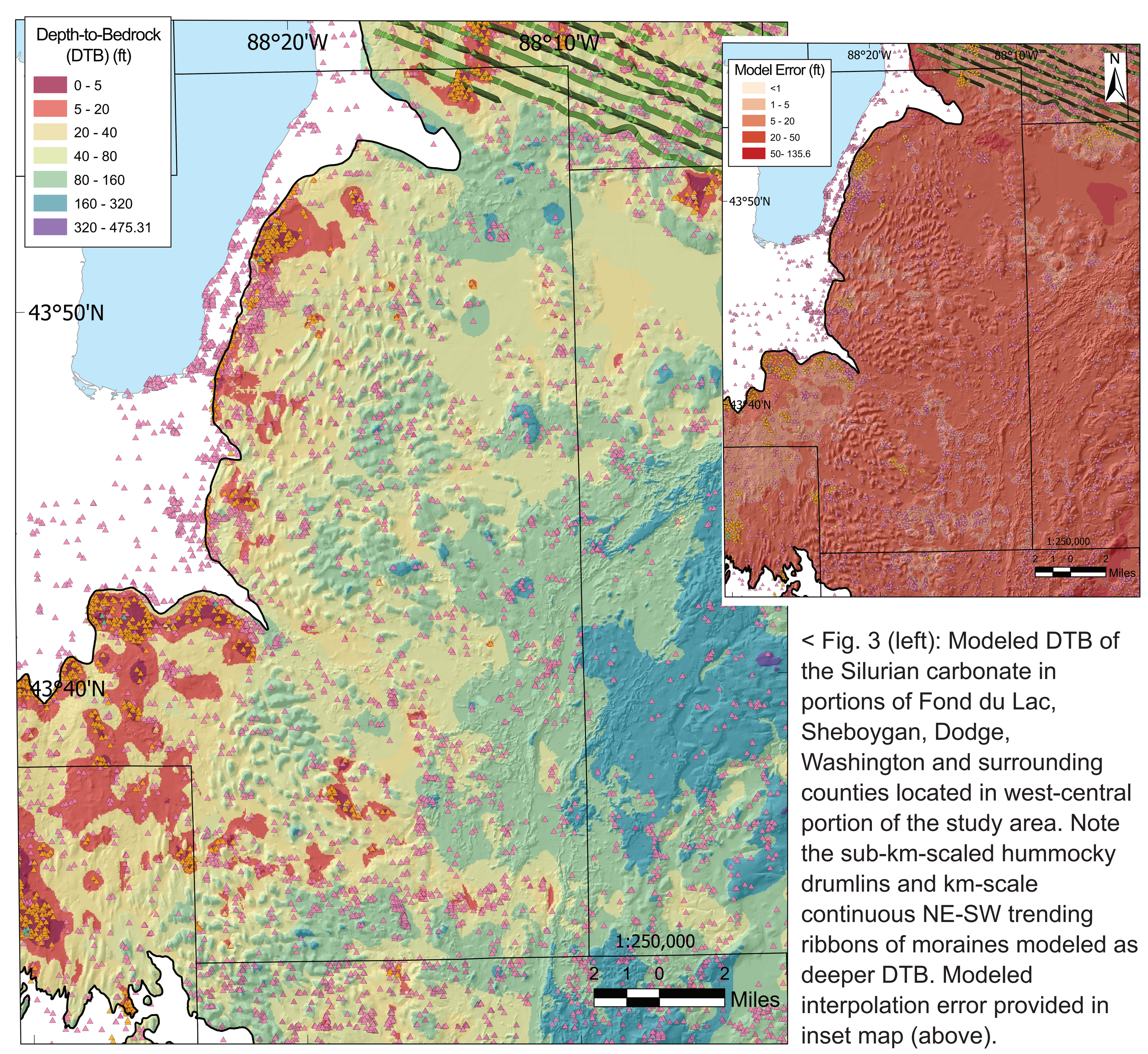


- < Fig. 1 (left): DEM subtracted EBKRP BrElev surface modeling DTB across eastern Wisconsin.
- AEM measurements were crucial for identifying buried Br valleys, namely in unzonable areas where subsurface data exist.
- NRCS exposed Br and shallow soil depth datasets prevented overestimation of DTB.
- Borehole datasets prevented underestimation of DTB.

Focus Extents



^ Fig. 2 (above): Modeled DTB of the Silurian carbonate in Kewaunee Co., located in northeastern portion of the study area. Note the mile-scaled <5 ft DTB knobs and ledges observed throughout county. Modeled interpolation error provided in inset map (above, right).

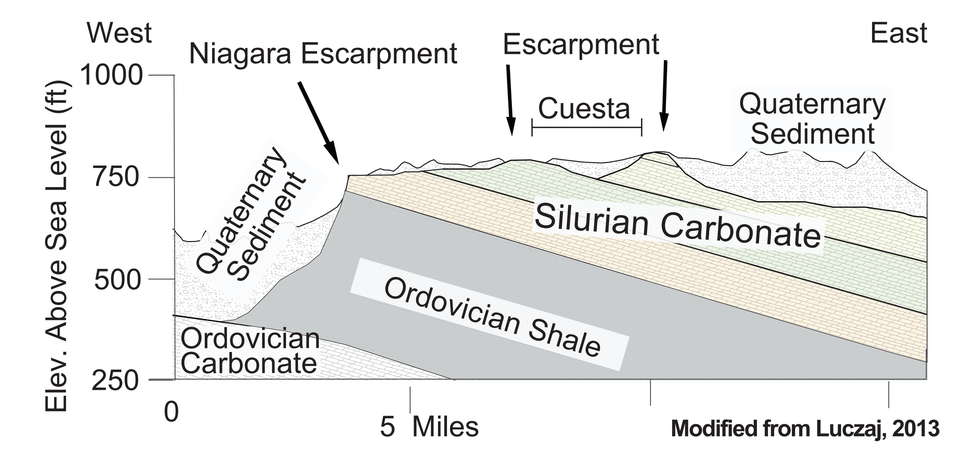


< Fig. 3 (left): Modeled DTB of the Silurian carbonate in portions of Fond du Lac, Sheboygan, Dodge, Washington and surrounding counties located in west-central portion of the study area. Note the sub-km-scaled hummocky drumlins and km-scale continuous NE-SW trending ribbons of moraines modeled as deeper DTB. Modeled interpolation error provided in inset map (above).

Model Output Observations

- The current EBKRP model parameters and input DTB point dataset with measurement error generated a reasonable BrElev model (not shown).
- The BrElev model raster subtracted from the USGS 2017 DEM generated a reasonable DTB model of the Silurian carbonate bedrock across eastern Wisconsin (Fig. 1).
- Point measurement error, based on DTB field collection method and geolocation confidence, minimized erroneous “bull’s-eye” or “striping” features in the model output.
- Applying a DEM as an explanatory raster to guide the EBKRP interpolation improved the model output across Br plateaus, cuestas, and escarpments. These features are prominant along the study area’s western boundary.
- Shallow bedrock landforms, such as escarpments and cuestas, are explainable by the general dip of bedrock to the (south)east followed by significant Quaternary glacial and stream erosion (see schematic below).

Generalized Geologic Cross Section of Eastern Wisconsin



- Northern end of the study area is modeled predominantly very shallow (<5ft) DTB (Fig. 1), consistent with traditional DTB mapping efforts (Carson et al., 2016). Zones within this area of greater DTB are consistent with previously mapped glacial margin deposits and outwash plains.
- Continuing south, instances of shallow DTB are more common as isolated or grouped km-scale knobs, escarpments, or cuestas (Figs. 1, 2, and 3).
- South-central portion of the study area modeled a NE-SW trending shallow DTB escarpment (Fig. 1). The Waukesha Fault follows along the south-side of the escarpment. The escarpment is located on the uplifted block of the Waukesha Fault (Braschayko, 2005).

Future Work

- Incorporate county-level external review comments and additional datasets, such as geoprobe and shallow bedrock fractures.
- Understand instances where the model output mismatches *a priori* geologic information.
- Improve geolocation estimate of wells with reliable DTB value.
- Collect field passive seismic measurements to quality control model output for DTB <20ft.
- Generate 5’ and 20’ DTB contour feature class.
- Deliver seamless DTB raster, model error raster, and 5’, 20’ map contours as DATCP project deliverables.

Funding

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References

- Baeten, J. 2022, Silurian Thickness of Unconsolidated Materials, WI DNR Data Open Data Portal, https://data-wi-dnr.opendata.arcgis.com/, accessed May 2023.
- Braschayko, S.M., 2005, The Waukesha Fault and its relationship to the Michigan Basin: a literature compilation, UW-Extension - WGNHS, WOFR2005-05.
- Carson, E. C., Brown, S. R., Mickelson, D. M., Schneider, A. F., 2016, Quaternary Geology of Door County, Wisconsin. UW-Extension, WGNHS, Bulletin 109.
- Hart, D.J., Mauel, S.W., Luczaj, J.P., Stewart, E.K., 2021, Depth-to-Bedrock Mapping in Wisconsin, UW-Madison, WGNHS, WOFR 2021-04.
- Luczaj, John A., 2013, "Geology of the Niagara escarpment in Wisconsin." Geosci. Wis 22: 1-34.
- Sherrill, M.G., 1979, Contamination potential in the Silurian Dolomite aquifer, eastern Wisconsin, U.S. Geological Survey, WRI78-108, plate scale 1:250000, doi: 10.3133/wri78108.