# DIGITAL MAPPING TECHNIQUES 2025

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**Visualizing Michigan Geology using 3D Models and Printing**
By John Esch and Ricky Haagsma, Michigan Geological Survey

Visualizing, sharing, and communicating 3D geological concepts is challenging, especially when engaging a variety of stakeholders. The expanding world of 3D modeling, visualization, and printing has opened up unlimited possibilities to improve how we communicate and conceptualize geoscience data. However, it can be challenging to synchronize GIS software with 3D printing software to create educational and outreach materials. To address this challenge, we developed a workflow to create 3D models in ArcGIS Pro which can then be 3D printed using Blender.

A simplified 3D geological model was created for Michigan consisting of 10 layers representing key geologic intervals from the surface to the Precambrian. This data is a subset of a more detailed 3D model consisting of 60 layers of Paleozoic formations and marker beds. A bedrock elevation surface was used to intersect the individual formation structure elevation surfaces to represent subcrops/outcrops. Additionally, an extensive data hygiene effort was done to ensure high-quality formation tops and well elevation data.

3D multipatch layers were created for each interval where the top of each layer and bottom were converted from a raster to a TIN. The Extrude Between tool was used to create the 3D multipatch layer which were then exported as .obj files. Blender software was used to convert the .obj files to printable .stl files.
The scale of the geologic layers was adjusted to fit the maximum print size for the Bambu Labs X1 Carbon 3D printer. Each layer was scaled down to .05% of the original size. The thickness of each layer was increased from .05% to .18% so the layers had adequate thickness to print. Each layer was printed vertically to reduce print time and amount of material needed.

The stackable 3D printed layers snap together giving a broad yet visually stunning, tactile and easy to understand geologic model. Stakeholders from students, educators, policy makers, legislators, general public to experienced geologists can hold the physical 3D model, rotate it, take apart and restack the layers revealing the varying geology in Michigan. The model layers can be clipped to a smaller area to allow for creation of a local block model. Additionally, the same data can be used for detailed 3D analysis along with other surficial or subsurface data, in a 3D web app, or as an animation.

# Visualizing Michigan Geology using 3D Models and Printing

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## Abstract

Visualizing, sharing, and communicating 3D geological concepts is challenging, especially when engaging a variety of stakeholders. The expanding world of 3D modeling, visualization, and printing has opened up unlimited possibilities to improve how we communicate and conceptualize geoscience data. However, it can be challenging to synchronize GIS software with 3D printing software to create educational and outreach materials. To address this challenge, we developed a workflow to create 3D models in ArcGIS Pro which can then be 3D printed using Blender.

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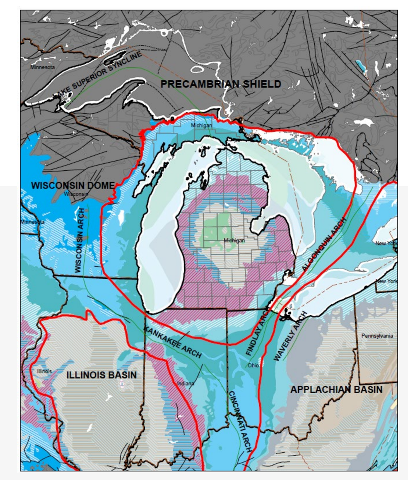
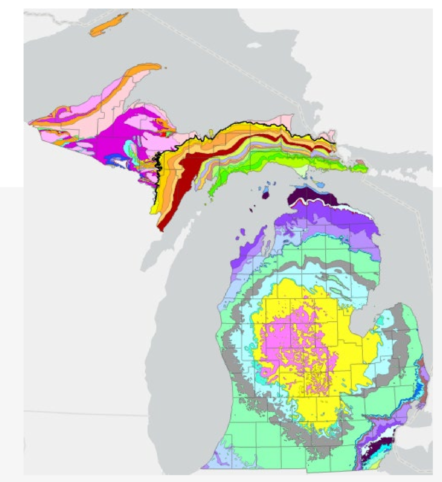
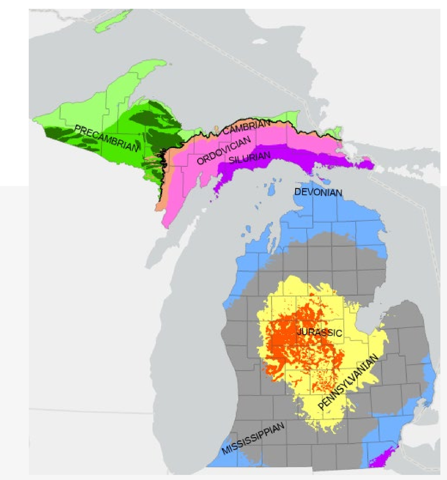


Midwest Basins & Arches



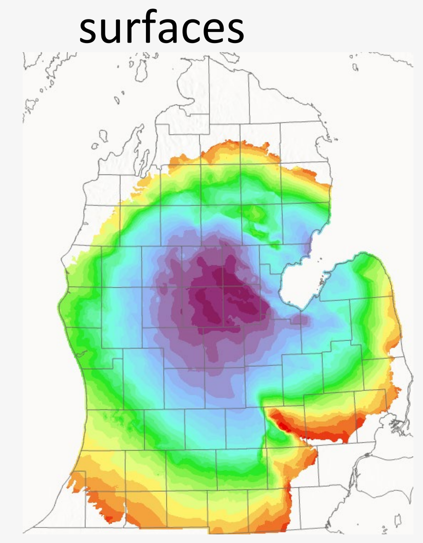
Bedrock Geology



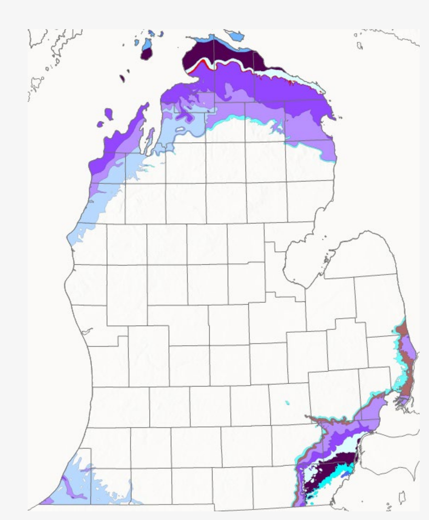
Bedrock Geology Simplified

## Data Sources

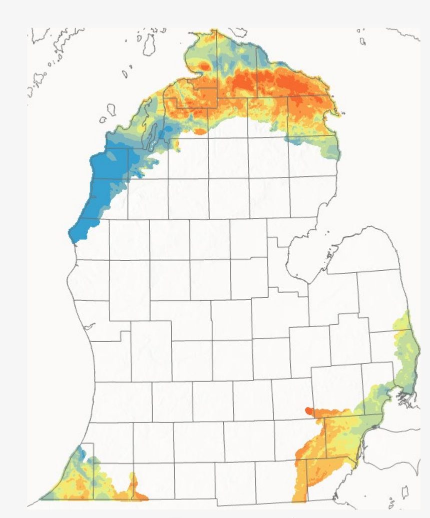
- Digital Elevation Model, 10m resampled down to 1000m
- Formation Tops from Oil and Gas database
- Bedrock tops from Wellogic water well database, bedrock outcrops, bedrock shorelines and soils (SSURGO) with shallow bedrock
- Statewide shoreline GIS file buffered 2 miles out to combine with formation subcrop polygons for clipping initial rasters
- Statewide shoreline GIS file simplified to eliminate tiny shoreline perturbation details that are not needed for a 3D model and 3D prints as this scale. This simplified shoreline file is combined with the geologic period's full subcrop extent and is used in the ArcGIS Pro Extrude Between tool
- Statewide bedrock geology polygons
- Statewide bedrock topography surface raster
- Statewide Precambrian surface raster
- Geologic period uppermost formation structure elevation surfaces



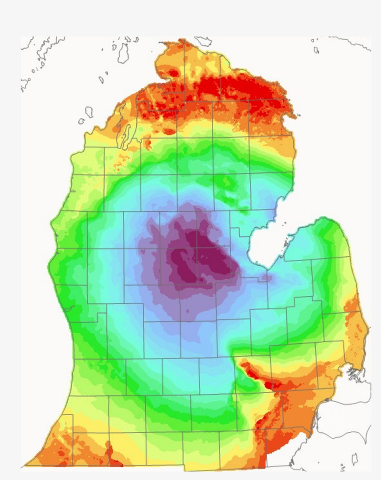
Devonian subsurface top structure elevation surface



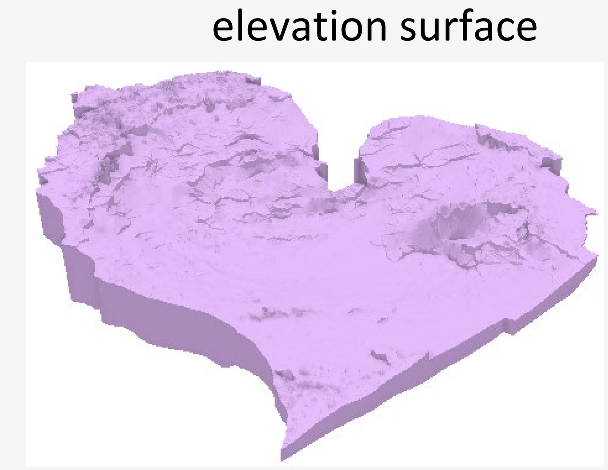
Devonian subcrop/outcrop extent



Devonian subcrop/outcrop extent bedrock top elevation surface



Devonian mosaic of subsurface and subcrop/outcrop surfaces



Devonian 3D multipatch

## Simplified 3D Model Creation Methodology

A significant amount of time was spent cleaning up the formation tops data creation of the and structure elevation surfaces. A 400m grid spacing was used for all raster surfaces except for the land surface DEM which was 1000m.

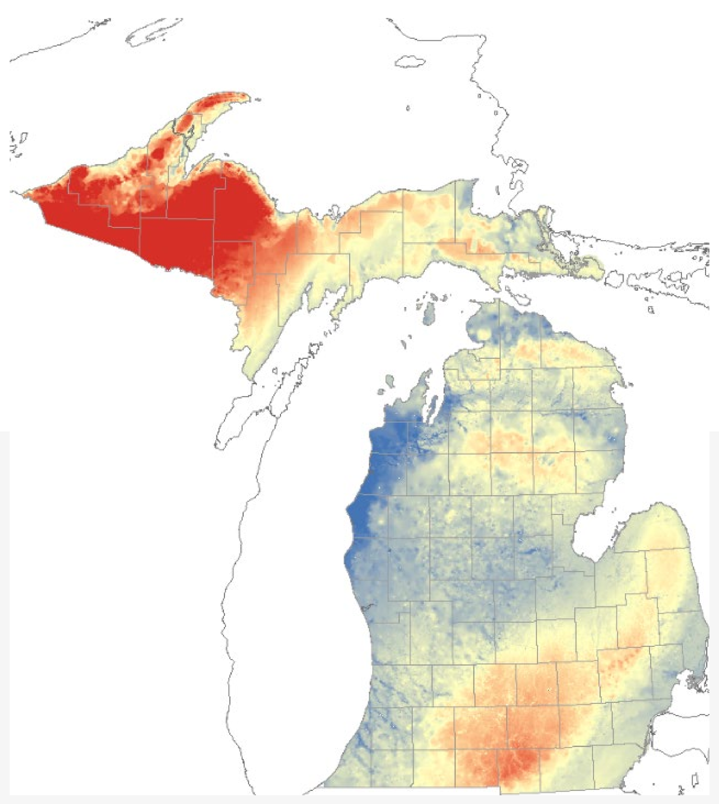
For each geologic period, the upper surface consists of 2 parts, (A) the deeper structure elevation top portion and (B) the portion of that geologic period that is intersects the bedrock surface subcrop/outcrop extent. These 2 portions are then mosaiced together.
For the (A) for each geologic period, create structure elevation surface for the uppermost formation of each geologic period.
Clip this uppermost formation to the inner edge of the formation subcrop polygon.
For the (B) subcrop/outcrop portion of the geologic period , clip out from the peninsula wide bedrock topography surface the subcrop/outcrop extent for that geologic period. This clip extent extends 2000 meters basinward so there is overlap between (A) and (B and includes the subcrop/outcrop extent for all the lower formations of that geologic period.
Run the ArcGIS **Mosaic to New Raster** tool to combine these 2 surfaces.
Run ArcGIS Pro **Raster to TIN** tool using a small Z tolerance of 3, and 3 million Maximum Number of Points and a Z Factor of 1 to create a TIN for each surface.
Once a TIN is created for top and bottom (top of geologic period below) of each geologic period. Run the ArcGIS Pro **Extrude Between** tool with the top and bottom TINs and the bounding polygon of each geologic period polygon (merged with the simplified shoreline polygon. The resultant geologic period multipatch can be viewed in ArcGIS as a 3D volume. For 3D printing multipatches, run the ArcGIS Pro **Add 3D Formats to Multipatch** with Wavefront OBK( (.obj) selected. Then run the ArcGIS Pro **Export 3D Objects** and select Wavefront OBK (.obj). This geologic period .obj file in then used in the 3D printing process.

**Geologic Period Uppermost Formations used in the modeling**

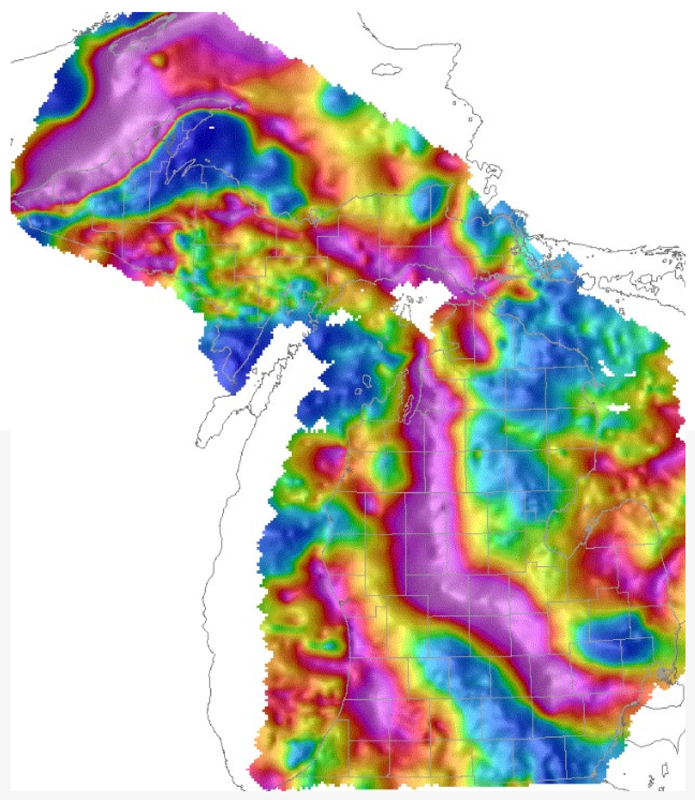
- Glacial: 10m DEM
- Jurassic: Jurassic Red Beds
- Pennsylvanian: Saginaw Formation
- Mississippian: Bayport Limestone
- Devonian: Ellsworth Sh./Berea SS.
- Silurian: Bass Islands Formation
- Ordovician: Cincinnatian
- Cambrian: Trempealeau Formation
- Precambrian: top of the Precambrian

Western Michigan University

## Key Surfaces Besides Formation Top Structures Surfaces



Bedrock topography (elevation) surface



Bouguer Gravity Anomaly Map. Used in the modeling of the Midcontinent rift

One of the most important layers is an updated bedrock elevation surface which was used to intersect the individual formation structure elevation surfaces.

## Limitations/Compromises

- For some formation tops, poor or inconsistent formation top picks
- Attempting to model the Precambrian Midcontinent rift with very little real data besides gravity and magnetic data
- Areas of bedrock outcrops and thin Glacial Deposits <50 feet, because of this 100 feet was added to the land surface DEM for the Glacial layer.
- Thin and often discontinuous units like the Jurassic Red Beds and the thinning of formations toward the up dip margins like the Pennsylvanian Saginaw Formation
- The  very irregular and bedrock surface and deep bedrock valleys
- Reconciling the generally smooth subsurface portion of the formation (and often fewer formation tops toward the margins) with the eroded often very irregular bedrock topographic surface

Glacial (yellow)
Jurassic (cyan)
Pennsylvanian (light blue)
Mississippian (dark blue)
Devonian (purple)
Silurian (light yellow)
Ordovician (blue)
Cambrian (red)
Midcontinent Rift (light brown)
Precambrian (dark brown)

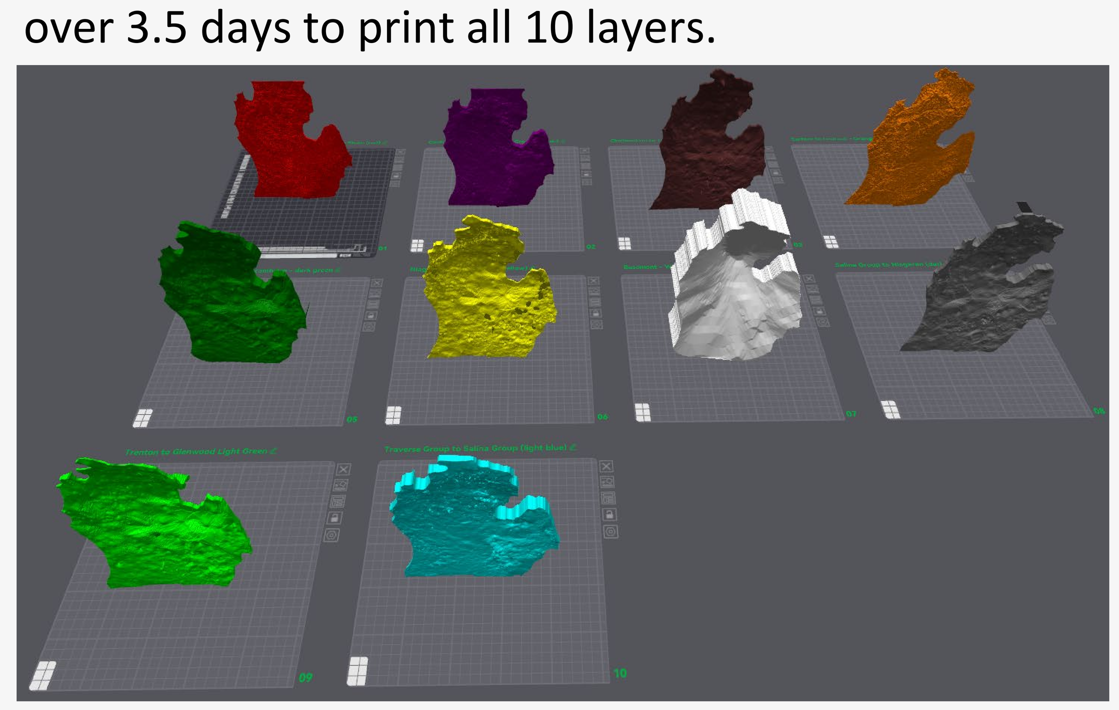
## 3D Printing Methodology

Bambu Studio, is able to work with .obj files, however to remain consistent due to other file issues, Blender was used to convert all files to .STL so they would insert consistently from ArcGIS Pro. Once the conversion was completed to STL, each of the files were imported into Bambu Slicer and then scaled down to .05% of the original file in order to fit on the build plate. Each layer was also colored and identified/labeled so that it can be easily identified. The colors are based on the standard USGS colors for geologic periods.

Scaling the models down from its original size, some detail was lost. In order to bring back that detail, the Z axis was increased from .04% to .50%, that was enough to show the detail that was cut back on during the scale down process.

The models can be printed both horizontally or vertically, for this model, vertically was chosen as it required the least amount of additional supports to be generated by Bambu Slicer to complete the printing process.

Total material used for 1,116.25 grams of material, and took just over 3.5 days to print all 10 layers.

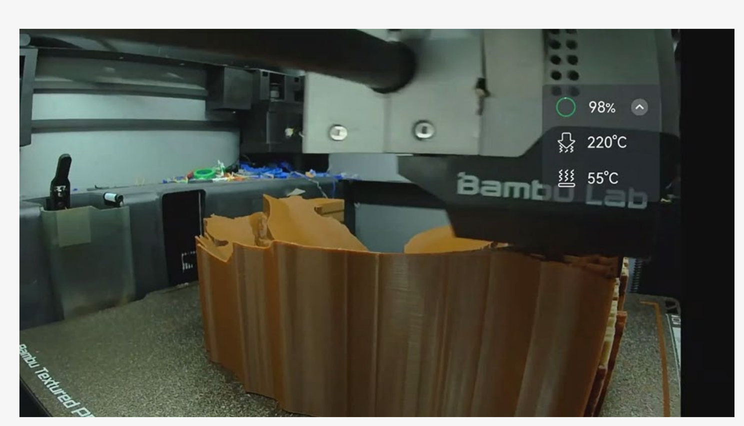


Version 1 importer into Bambu Slicer.

## Materials

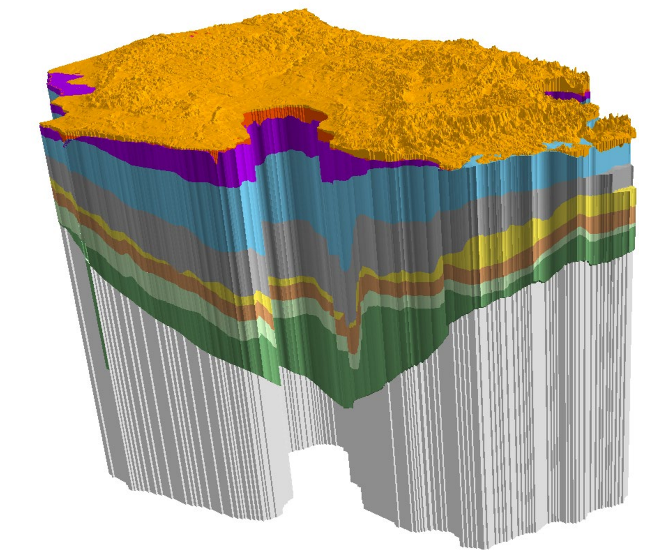
**Bambu Lab X1-Carbon Printer**- 256x256x256mm print area
**Bambu Lab P1S Printer -** 256x256x256mm print area

**PLA**-made from polylactic acid, a thermoplastic polyester derived from renewable sources like corn or sugarcane
**PETG**-polyethylene terephthalate glycol. It's a type of plastic that's commonly used in manufacturing and 3D printing.

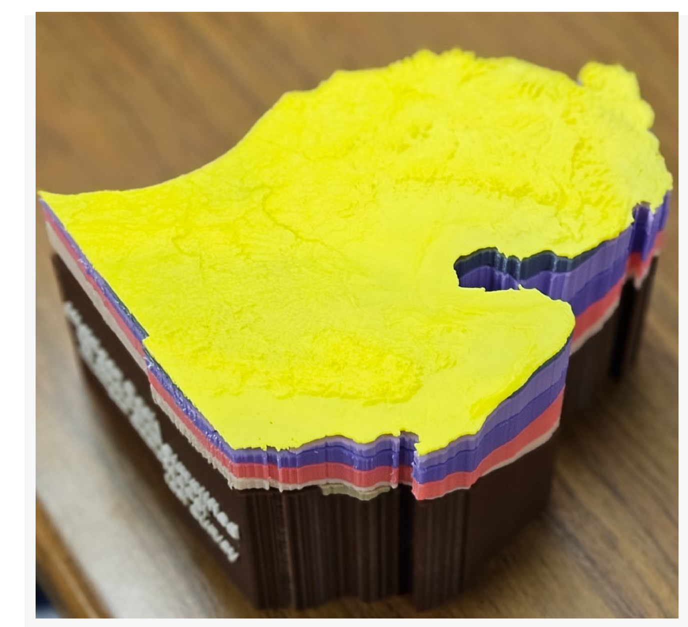


Precambrian layer printing

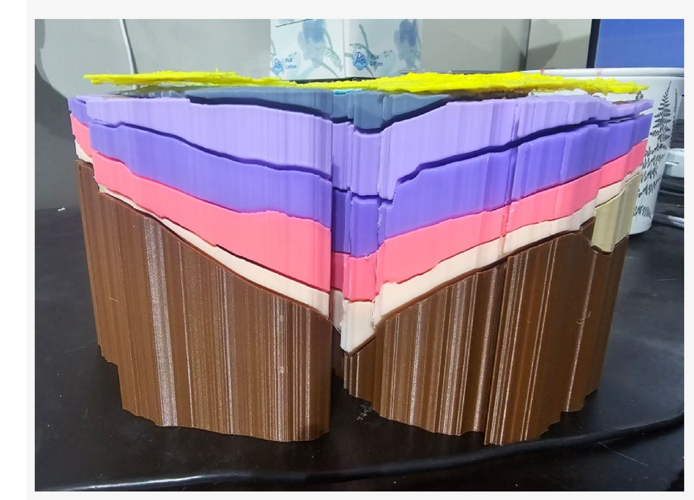
3D printer-Bambu lab X1-Carbon



**Version 1**
10 layer
lithostratigraphic model based on formation marker beds



**Version 2**
10 layer
time stratigraphic model based mostly on Paleozoic Periods



The model area covers Michigan's Lower Peninsula (40,000 square miles) and extends from ground surface to a flat base arbitrarily assigned with -17,000 feet below sea level

Final printed version:
Horizontal Scale 1:2,500,000
Vertical Scale  1:60,000 Vertical Exaggeration x40

## Benefits of 3D printed Geologic Models

- Cost Effective
- Enhanced Visualization and Education
- Accessibility for diverse audiences
- Provides additional educational tools
- Provides easier access to geological specimens and geological ideas/concepts
- Portability
- Precision reproduction

## Future Versions

- Create 15-17 layer model by breaking out the 5 lower Paleozoic eras into an upper and lower portions
- Better model the Precambrian and  Midcontinent Rift
- Fine tune the land surface DEM resampling to get the most detail needed for the scale of the 3D model /3D print
- Finish Michigan's Upper Peninsula  3D model

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