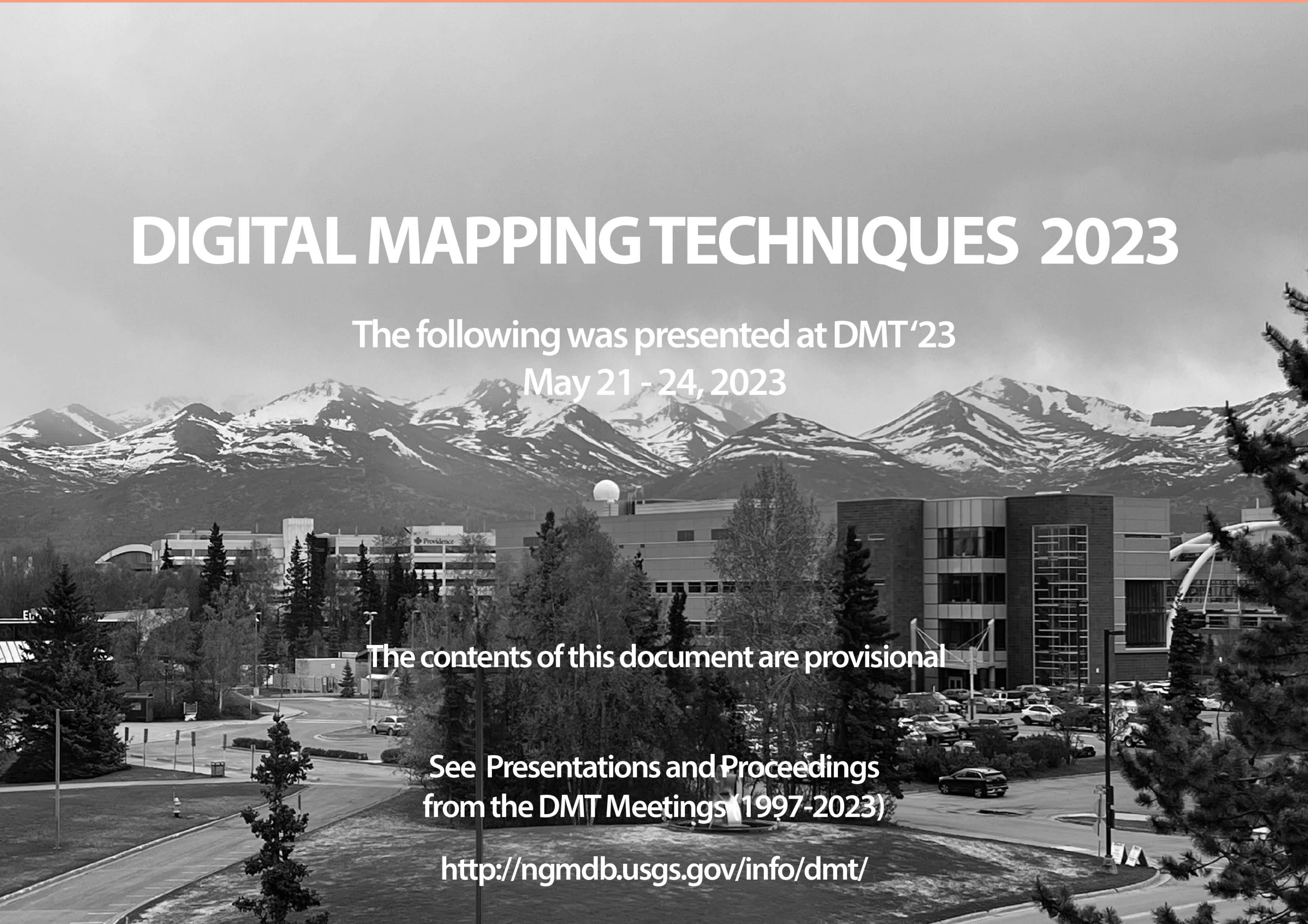

DIGITAL MAPPING TECHNIQUES 2023

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May 21 - 24, 2023

The contents of this document are provisional

See Presentations and Proceedings
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Mapping the Bedrock Topography of Indiana:

Merging existing spatial data sets and newly acquired field data to model the bedrock surface

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ABSTRACT

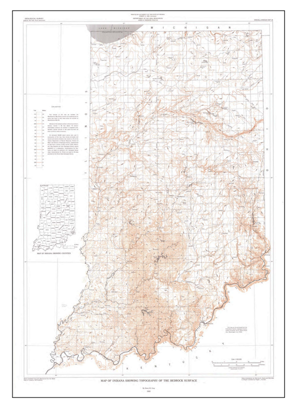
Creating a surface model of the bedrock topography is an essential step for mapping bedrock geology in landscapes with unconsolidated sediments covering all or part of the bedrock surface. Existing data that is available to map this surface may be plentiful in some regions and sparse to lacking in other areas. This legacy data can be from many different sources or agencies and needs to be scrutinized to find the best available data and omit inaccurate data. New data can be added to areas with sparse or conflicting information with new project drilling and field work and with geophysical tools such as the Tromino® seismograph.

After the data is collected, the modeling of the bedrock surface can be done in many GIS applications with various statistical tools. The interpolation process in ArcGIS Topo To Raster is preferred here because points and lines can be used concurrently and many variables can be changed. The resultant layer is used to crop the bedrock formations and create the contacts of the units found at the bedrock surface.

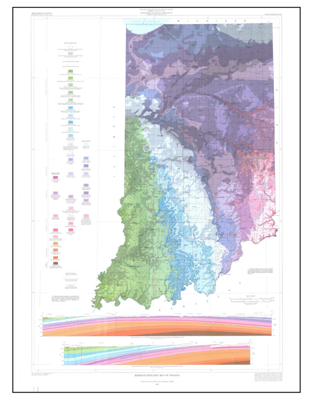
1 INTRODUCTION

Creating geologic maps has been part of the Indiana Geological and Water Survey's mission since its inception in 1863. Geologic maps have been created for the entire state at 1:500,000 (Gray et al, 1987) and at various smaller scales across the state. Our newest scale for mapping the geology of the state is 1:100,000 and the goal is to map the entire state at that scale by 2030.

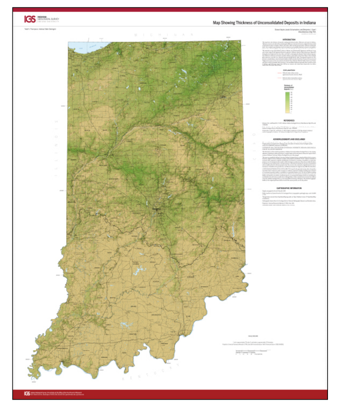
Because most of Indiana is covered with glacial sediments from a few feet to over 400 feet in thickness, mapping the interface between the unconsolidated glacial sediments and the bedrock surface continues to be an important product as more data is acquired. From the state bedrock topographic map by Henry Gray, 1982, to a revised version by Shawn Naylor et al, 2016, to our mapping in 2023, new bedrock data become available almost continuously to update this important surface used in most geologic maps.



1982 - Map of Indiana showing topography of the bedrock surface: Indiana Geological Survey Miscellaneous Map 36



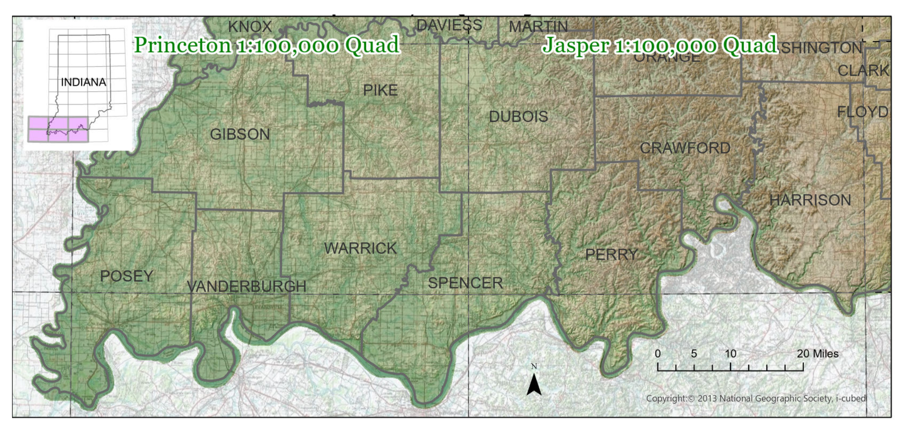
1987 - Map of Indiana showing the bedrock geology: Indiana Geological Survey Miscellaneous Map 48



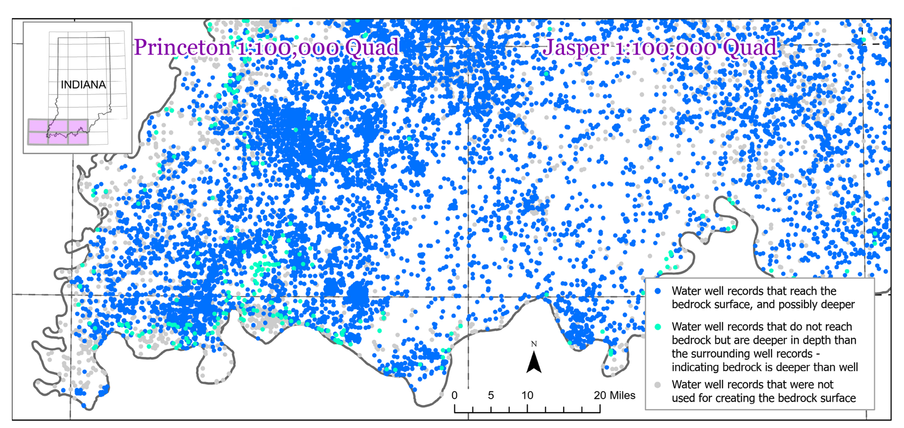
2016 - Map showing elevation of the bedrock surface in Indiana: Indiana Geological Survey Miscellaneous Map 94A

2 BEDROCK TOPOGRAPHIC DATA

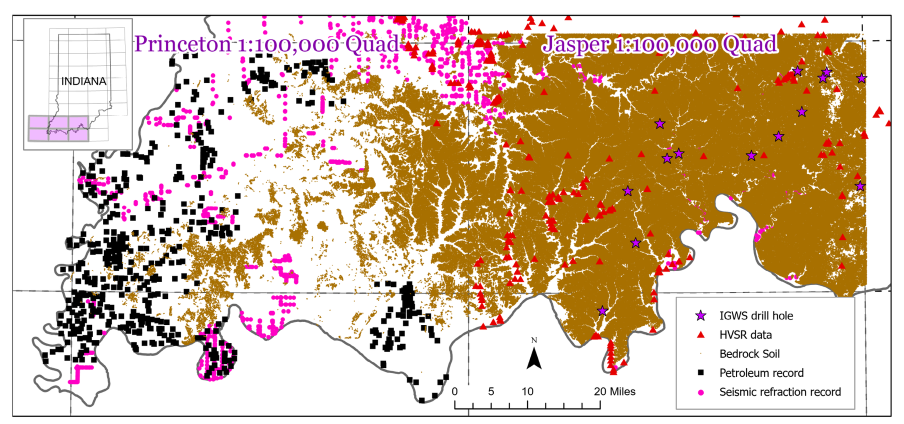
- Water well records (IDNR – Division of Water): Most prolific source for bedrock surface data; requires checking of locations and lithologies that were listed at the bedrock surface.
- Petroleum data records (DNR, IGWS): Bedrock surface information may be present, but requires searching records for descriptons of unconsolidated lithologies at the surface or casing depths. Surface casing depths can be used as an approximation for the depth to the bedrock surface with caution.
- Engineering data (INDOT): DOT data, especially useful for depth-to-bedrock information often listed in bridge borings.
- Coal mine records (NCRDS): Bedrock surface information may be present if the descriptions of the unconsolidated sediments above the coal are present.
- Industrial Mineral data (IGWS): Bedrock elevations may be present.
- Seismic refraction data (IGWS): Geophysical data collected in 1950s and 1960s at the Survey for the purpose of finding bedrock valleys.
- Gamma-ray log data (IGWS): Geophysical downhole data collected from the 1980s to present.
- Soil data (Natural Resources Conservation Service): Point data created by the IGWS from soil polygons where the parent material could be bedrock (lithic soils).
- Project drill sites (IGWS): New project data with precise depths to bedrock collected for the new mapping effort.
- Outcrop data (IGWS): Project data collected while mapping the geology of the area.
- Tromino data (IGWS): Passive seismic horizontal-to-vertical spectral ratio (HVSR) data collected by the Survey since 2014.
- Thalwegs (IGWS): Key interpretive layer to create paleovalleys and drainage on the bedrock surface model (river valley or karst?).
- Bedrock topographic contours - some areas of the bedrock surface could be hand-contoured to refine perceived bedrock topography.



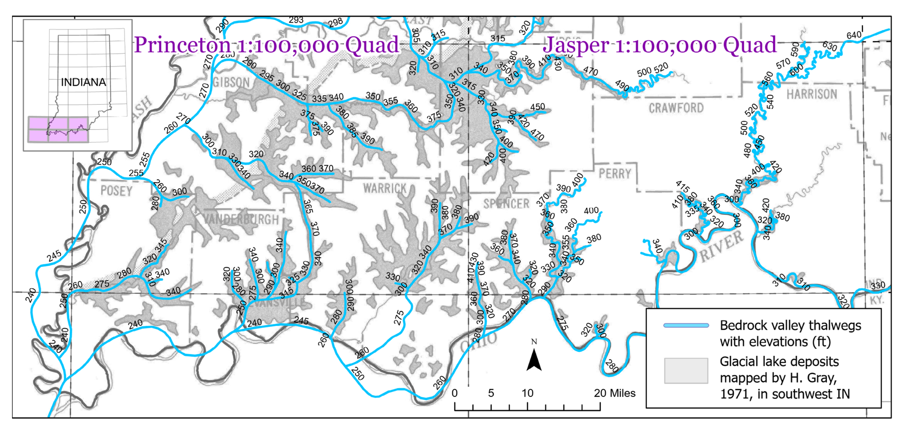
Southwestern Indiana - STATEMAP project areas for 2022-2023



IN Department of Natural Resources water wells used to map the bedrock surface in SW Indiana



Indiana Geological and Water Survey data used to map the bedrock surface in southwestern Indiana



Bedrock valleys and interpreted paleovalleys with Pleistocene lake deposits in southwestern Indiana

3 MOHO TROMINO: OUR NEWEST TOOL TO ADD DEPTH-TO-BEDROCK DATA

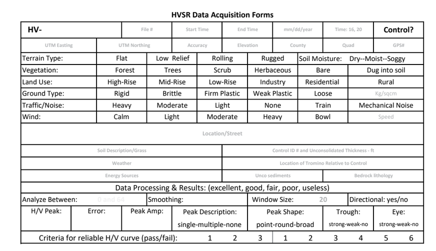
The IGWS acquired its first Tromino seismometer in 2014. This instrument has aided our mapping efforts by providing additional information on bedrock depths in areas where data is sparse, and with an affordable price tag. This portable device uses the horizontal-to-vertical spectral ratio (HVSR) method to measure ambient seismic noise (Johnson and Lane, 2016). When a resonance frequency (f0) is determined by analysis of the data, and a calibration curve is created based on sites with known depths to bedrock, an approximate thickness of the overburden can be calculated.

The accuracy of this data is determined by many factors including the variations of the unconsolidated sediments, the irregularity and type of lithologies of the bedrock, and the quality of the data used in the calibration curve. Errors in the results are typically less than 25% (Chandler and Lively, 2012).

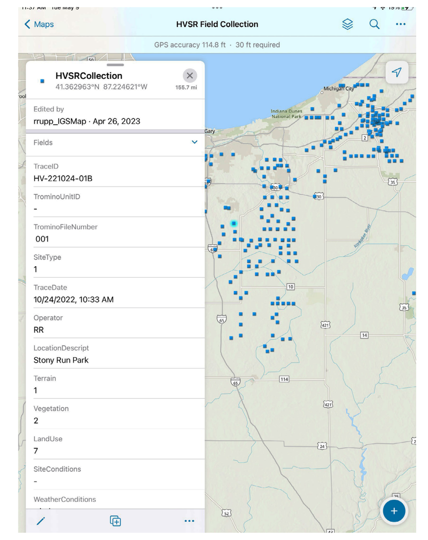
In Indiana, areas that need extra care when using this method include regions where the bedrock can be softer than the unconsolidated sediments. This occurs in northeastern Indiana where the Coldwater Shale underlies thick glacial sediments that may include overconsolidated till. Another type of problem can arise when the underlying bedrock surface is steeply sloping as in the Teays bedrock valley that underlies a portion of northern Indiana. Steep sides on a paleobedrock valley can give erroneous values, but when transects across these valleys are conducted, the errors can be corrected or tossed.

The IGWS collects HVSR data in areas where depth-to-bedrock information is needed for mapping or where determination of the deepest part of a bedrock valley is key to a single site, such as a groundwater monitoring well. Transects across bedrock valleys and grid patterns across larger areas are used for data collection depending on the needs of the project.

Tromino set-up with original field sheets



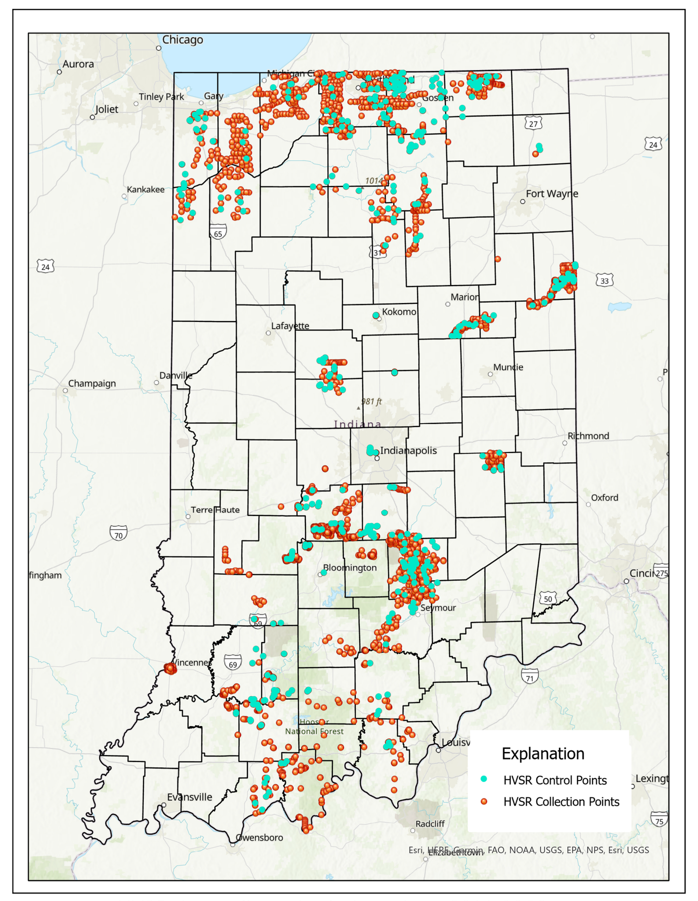
Field sheets once used by the IGWS for entering HVSR location data and results after processing



ArcGIS Field Map currently used for data entry while in the field (location and conditions)

The IGWS has recently transitioned from paper to digital data entry in the field by capturing location data and entering field notes on a tablet or cell phone.

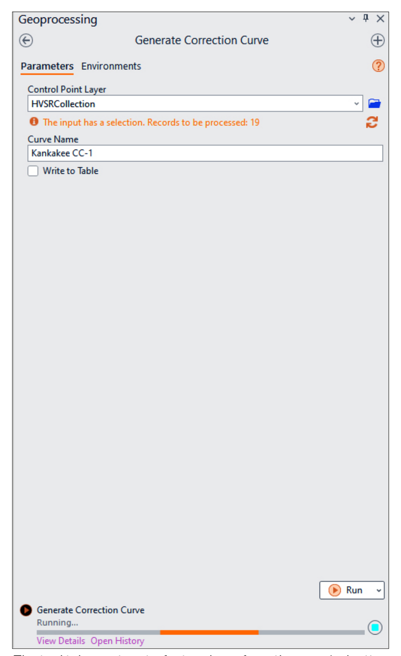
Using past field sheets, a new and improved GIS database was created. Now we have an updated, live version for geologists and field technicians to use in ArcGIS Field Maps. Our existing Microsoft Access database was imported and locations of all recorded Tromino points can be seen while in the field. The data can be collected, and in the office, the layer can be pulled into ArcPro where additional analysis can be performed.



HVSR data collected in Indiana from 2014-2023

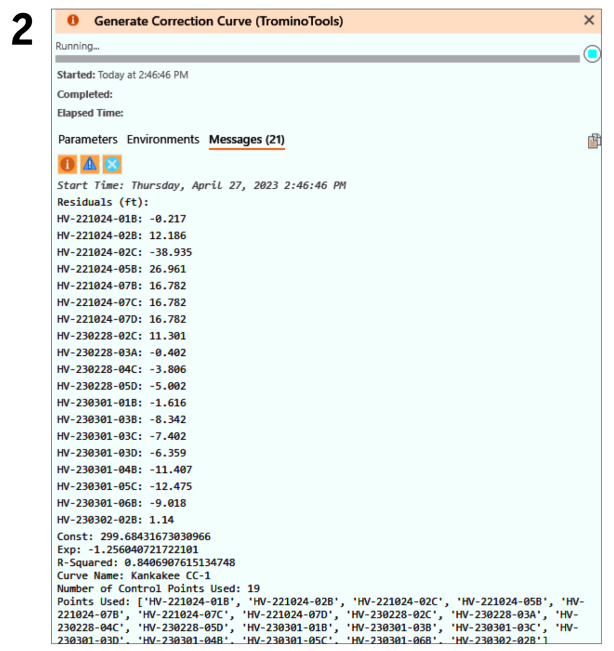
New IGWS script in ArcPRO: Select control points, create calibration curve, and select HVSR data points to run (with curve) to get estimated bedrock elevations

1



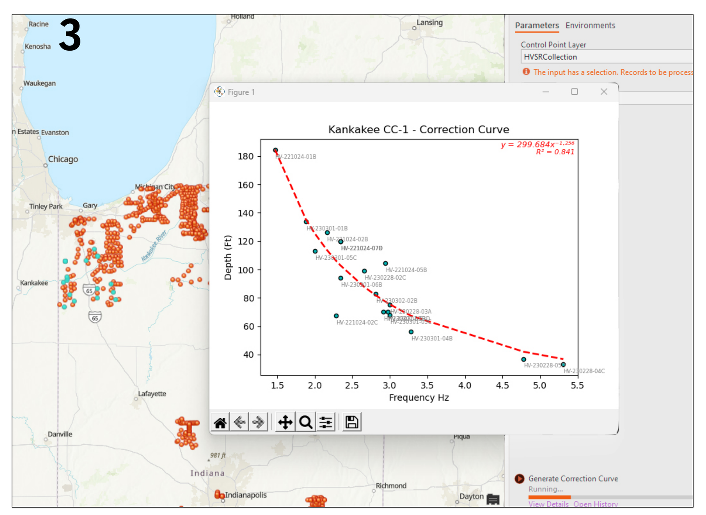
The tool takes as input a feature layer from the map (selection is honored) and a curve name. Optionally, the user can choose to write the results to a table.

2



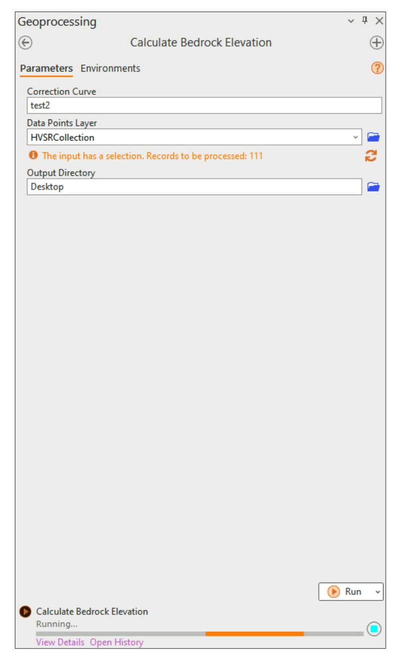
The results window shows the residual for each control point used, the resulting power-law function parmeters, a count of the number of points used, and a list of each control point used.

3



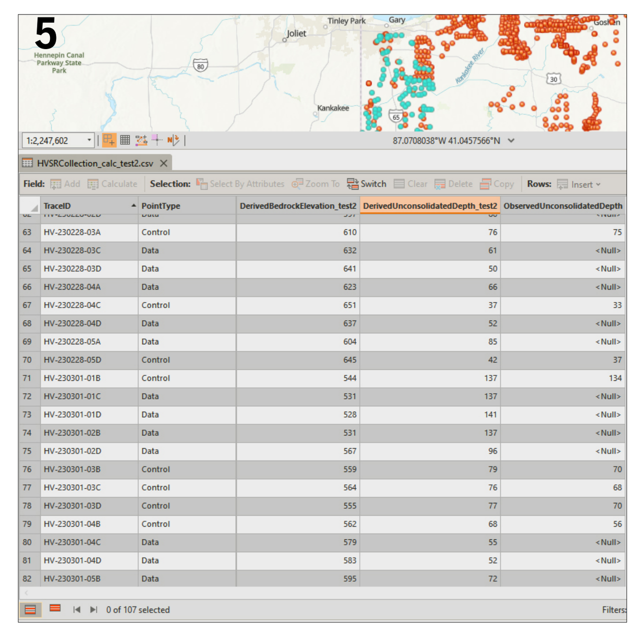
While running, the tool generates an interactive chart window (users can pan and zoom) displaying the power-law function fit curve plotted with the control points used each labeled with the trace ID. The function parameters are also printed in this window. This image can be saved to a file for later reference.

4



To calculate depths, the tool takes three inputs: a correction curve (identified by either curve name or object ID in the correction curve table), a feature layer from the map (selection is honored), and an output directory where the results will be saved as a .csv file.

5



The tool calculates bedrock depths and elevations for all points selected in the feature layer, as well as the control points used to create the calibration curve. It generates a .csv file with fields for derived depth and derived elevation, as well as point type (data vs. control), and observed depth (only populated for control points). Upon completion, the resulting .csv file is added to the current map document. The user can then join this table to the HVSR points feature layer and use field calculator to copy the derived depths from the .csv to the feature layer if they are satisfied with the results.

4 MODELING THE BEDROCK TOPOGRAPHY

Making the bedrock topographic surface can be done by hand-contouring bedrock surface elevation data with pen and paper as was done in the past. Today many computer programs can model this surface with interpolation processes. We use Topo To Raster in ArcPro because multiple types of data can be added to the tool, and features such as faults, scarps, paleovalleys, and karst can be modeled. The first surface created with the bedrock data often needs correction as portions of the resultant grid may rise above the land surface in cases where bedrock is near the surface. We often lower the elevation of the LiDAR grid and smooth this surface to allow for a soil horizon and mute the level of detail that will be reflected in the bedrock topographic surface. Many settings, such as number of iterations and other variables can be adjusted. We normally use the "contour" and "remove sink" variables. The basic steps in this process can be modeled in one Python script with the following steps:

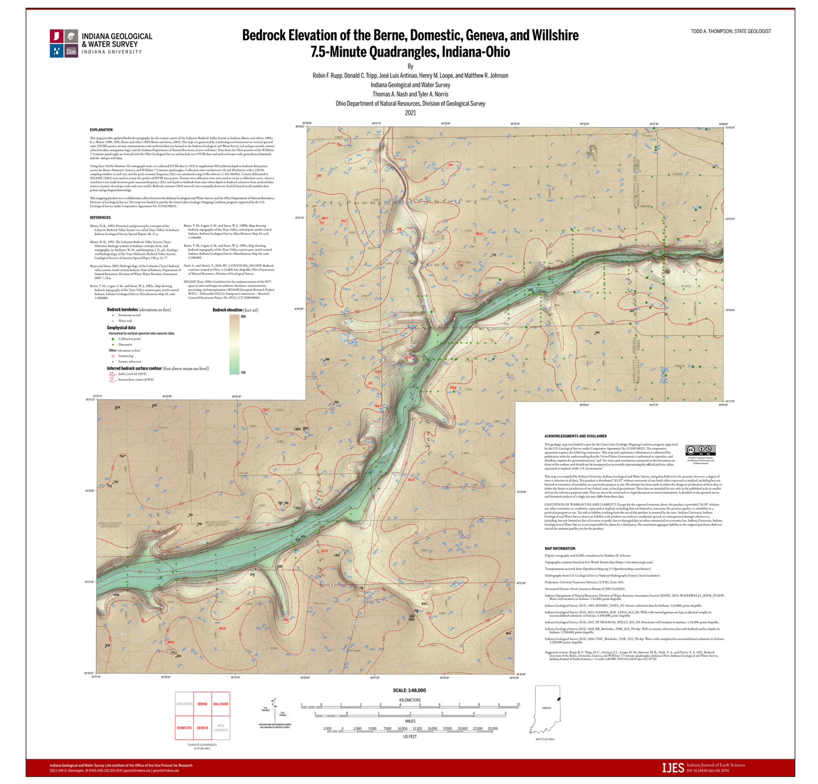
Step 1. TopoToRaster: Create an intermediate bedrock surface with the following layers (BR-1)
- * all point data with bedrock elevations
- * polyline data such as thalwegs and existing bedrock contours

Step 2. Raster Calculator
Lidar - BR-1= Unco-1

Step 3. Raster Calculator
Correction for above land surface: Unco-1 >=0 = Unco_ZerosOnes

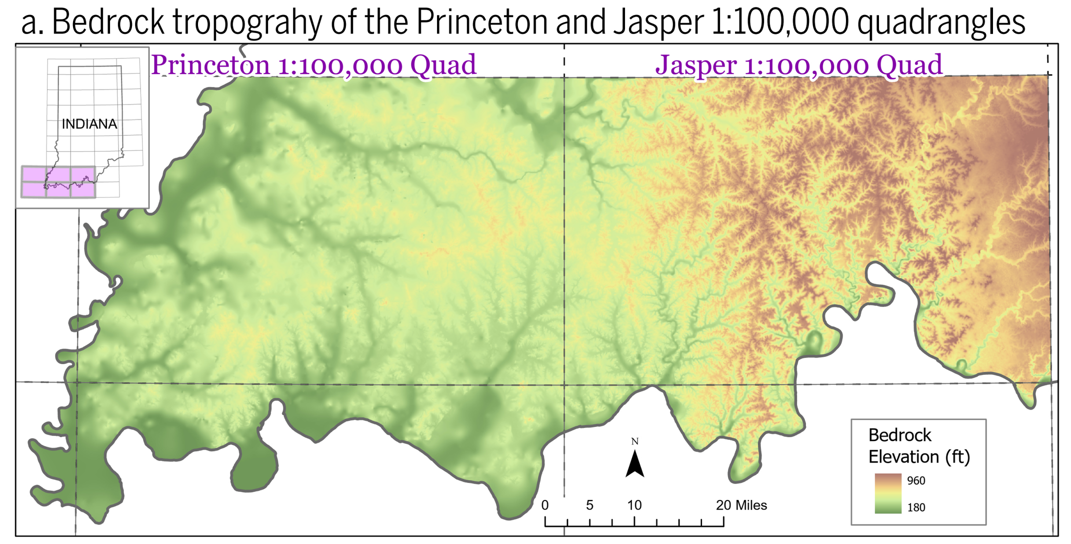
Step 4. Raster Calculator
Unco_ZerosOnes x Unco-1 = Unconsolidated Thickness

Step 5. Raster Calculator
Lidar - Unconsolidated Thickness = Bedrock Surface

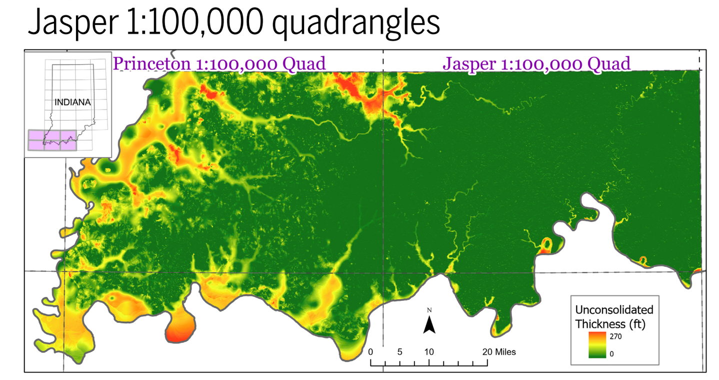


This map of the bedrock topography of the Berne, Domestic, Geneva, and Willshire 7.5-minute quadrangles (Indiana and Ohio) was created using 253 HVSR data points placed along transects crossing the deep paleovalley, and the process described in this poster. This cooperative mapping product between Indiana and Ohio was funded in part by the Great Lakes Geologic Mapping Coalition program (supported by the U.S. Geological Survey).

a. Bedrock tropograhy of the Princeton and Jasper 1:100,000 quadrangles



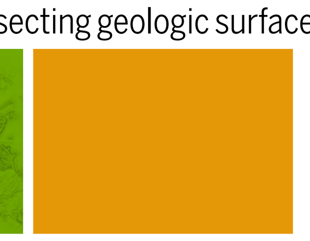
b. Unconsolidated thickness of the Princeton and Jasper 1:100,000 quadrangles



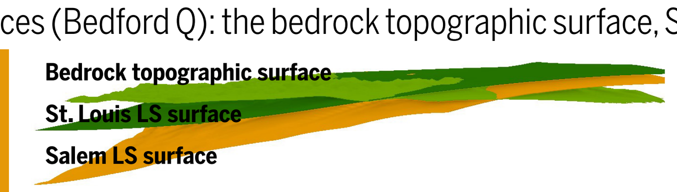
The bedrock topography (a) and unconsolidated thickness (b) of two southwest Indiana 1:100,000 quadrangles (plus potions of neighboring southern and western quadrangles) where the IGWS is currently mapping bedrock units for the 2022-2023 STATEMAP bedrock map deliverables.

3D model of intersecting geologic surfaces (Bedford Q): the bedrock topographic surface, Salem Limestone, and St. Louis Limestone

Grid of BR topography

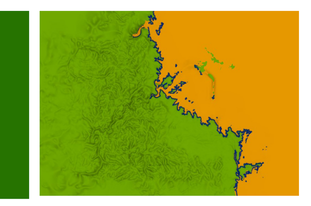


Grid of Salem LS surface



3D image of surface elevation grids demonstrating how bedrock formation grids (top of bedrock units) intersect the bedrock topographic surface producing "crop lines." These crop lines—where the bedrock units are eroded and exposed—are used to create the final bedrock geologic map.

St. Louis LS crop—yellow



Salem LS crop—black

5 REFERENCES CITED

Bleuer, N. K., 1989, Historical and geomorphic concepts of the Lafayette Bedrock Valley System (so-called Teays Valley) in Indiana: Indiana Geological Survey Special Report 46, 11 p.

Chandler, V.W., and Lively, R.S., 2014, Evaluation of the horizontal-to-vertical spectral ratio (HVSR) passive seismic method for estimating the thickness of Quaternary deposits in Minnesota and adjacent parts of Wisconsin: Minnesota Geological Survey Open File Report 14-01, p. 1–54.

Gray, H.H., 1971, Glacial lake deposits in southern Indiana—engineering problems and land use: Indiana Geological Survey Report of Progress 30, 15 p., 1 pl., 8 figs.

Gray, H.H., 1982, Map of Indiana showing topography of the bedrock surface: Indiana Geological Survey Miscellaneous Map 36, scale 1:100,000.

Gray, H. H., Ault, C. H., and Keller, S. J., 1987, Bedrock geologic map of Indiana: Indiana Geological Survey Miscellaneous Map 48, scale 1:500,000.

Johnson, C.D., and Lane, J.W., Jr., 2016, Statistical comparison of methods for estimating sediment thickness from horizontal-to-vertical spectral ratio (HVSR) seismic methods—an example from Tylerville, Connecticut, USA, *in* Symposium on the Application of Geophysics to Engineering and Environmental Problems, March 20–24, 2016, Denver, Colo., Proceedings: Denver, Colorado, Environmental and Engineering Geophysical Society, p. 317–323. <https://water.usgs.gov/ogw/bgas/publications/SAGEEP2016-Johnson>, date accessed, April 30, 2023.

Naylor, S., Schumacher, J., and Sperl, B.J., 2016, Map showing elevation of the bedrock surface in Indiana: Indiana Geological Survey Miscellaneous Map 94A, scale 1:500,000.

Rupp, R.F., Tripp, D.C., Antinao, J.L., Loope, H.M., Johnson, M.R., Nash, T. A., and Norris, T.A., 2021, Bedrock elevation of the Berne, Domestic, Geneva, and Willshire 7.5-minute quadrangles, Indiana-Ohio: Indiana Geological and Water Survey, Indiana Journal of Earth Sciences, v. 3, scale 1:48,000. DOI 10.14434/ijes.v3i1.31742