DEVELOPING A 3D GEOFRAMEWORK MODEL FOR KENTUCKY USING BEST AVAILIBLE DATA AND PRACTICES

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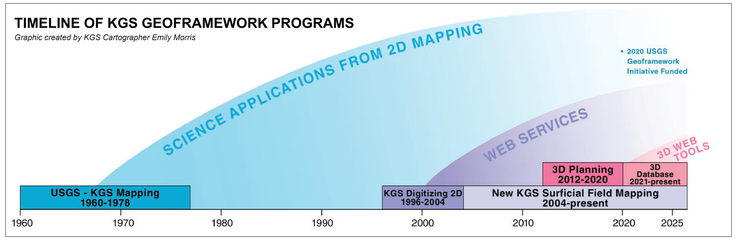
Abstract:

The Kentucky Geological Survey continues its efforts to develop 3D data elements from the best available 2D resources while documenting best practices for these processes and for the dissemination of available products to researchers and stakeholders. Digitized structure contours, geologic map units, and Digital Elevation Models were utilized within ArcGIS Pro to construct 3D surfaces for shale units in central and eastern Kentucky as well as the Jackson Purchase, with interpolative iterations being performed until each 3D object best represented current geologic understanding. Automated 3D surface interpolation using Jupyter Notebooks in ArcGIS Pro can be an efficient and effective method for creating 3D multipatch objects which closely represent geologic features that are otherwise difficult to visualize. For shales, 3D geologic units were produced for the Cumberland Fm, the Kope/Clays Ferry Fm, the Osgood Fm, the Crab Orchard Fm, the Borden Fm, and Pennsylvanian coal-baring marine shales. Regionally, the interpolated 3D shale units reflect the expected Cincinnati Arch structure when vertically exaggerated and will be useful in future landslide modeling and analysis. An in-depth inventory of data for surface interpolation in the Jackson Purchase was also conducted and datasets containing relevant structure contours were geo-referenced and digitized before being converted to 3D surfaces. Tops in the Jackson Purchase were modeled for the New Albany Shale, Paleozoic-Era bedrock, the McNairy Fm, the Porters Creek Clay, and the Wilcox Fm. These Jackson Purchase units represent some of the only remaining post-Paleozoic-Era strata in Kentucky and will be useful for studying erosional processes and seismic activity within continental deposits. In addition to stratigraphic horizons, a predictive 3D depth to bedrock model for the Ohio River Valley in Kentucky was interpolated using predictive models by Shangguan, et al. (2016) and USACE Hydrographic Surveys, showing river alluvium and bathymetric information, with geographic context. An elevation profile of the modeled Ohio River Valley's 3D bedrock surface closely aligned with the 1957 USGS Water Supply Paper #1411's Plate 3 deep channel bedrock profile, demonstrating the accuracy these methods can lend for modeling geologic surfaces in 3D.

TIMELINE OF KGS GEOFRAMEWORK PROGRAMS

Graphic created by KGS Cartographer Emily Morris



Acknowledgemnts:

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Global depth-to-bedrock framework:

Shangguan, W., T. Hengl, J. Mendes de Jesus, H. Yuan, and Y. Dai (2017), Mapping the global depth to bedrock for land surface modeling, J. Adv. Model. Earth Syst., 9, 65–88, doi:10.1002/2016MS000686.

Ohio River Hydrologic Survey Data:

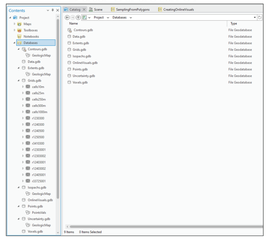
U.S. Army Corps of Engineers (USACE) at https://www.arcgis.com/apps/dashboards/4b8f2ba307684cf597617bf1b6d2f85d

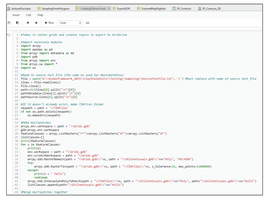
This project is built upon the multi-decadal effort and resulting data at the Kentucky Geological Survey.

A special shoutout to Anna Pearson at the University of Washington for helping to develop our framework for 3D interpolation.

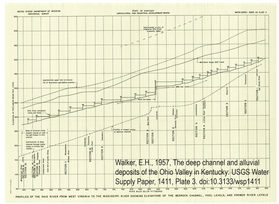
Software is provided through the ESRI enterprise license at the University of Kentucky.

Data Structure:

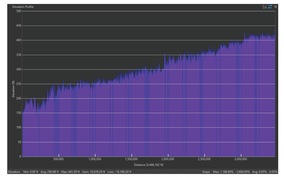




Model Validation:



Profile of the Ohio River from West Virginia to the Mississippi River showing elevations of the bedrock channel, pool levels, and former river levels.

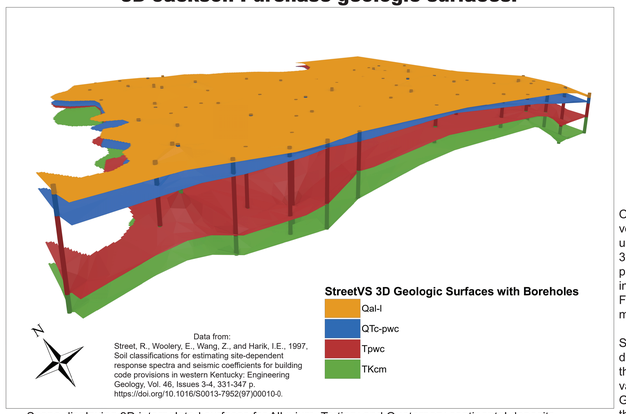


Elevation profile for the modeled Ohio River Valley deep channel bedrock surface. Measured in ArcGIS Pro, this closely agrees USGS Water-Supply Paper 1411 by Walker, 1957.

Scan QR codes with your phone and try them!

(No, REALLY!)

3D Jackson Purchase geologic surfaces:

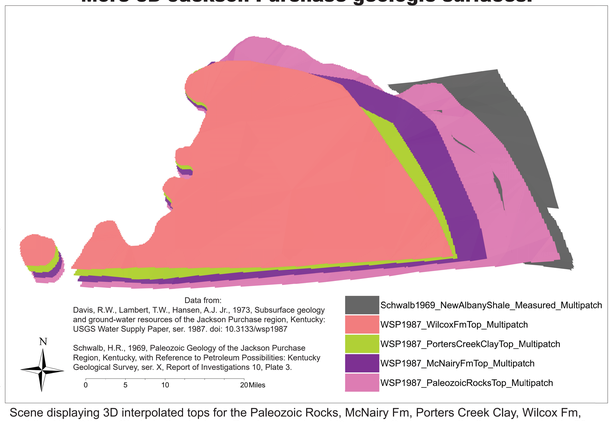


Scene displaying 3D interpolated surfaces for Alluvium, Tertiary and Quaternary continental deposits, Tertiary, and Cretaceous and Tertiary: Clayton and McNairy Formations in the Jackson Purchase region of Kentucky. Surfaces vertically exaggerated to 30x. Boreholes created using similar automation methods.

Original point data measuring seismic wave velocity with correlation to Geologic units were used to make rasters from each point dataset. 3D boreholes were also made using the pre-formatted points with an automated script in Jupyter Notebooks within ArcGIS Pro. Features were then interpolated into 3D multipatches. (LEFT)

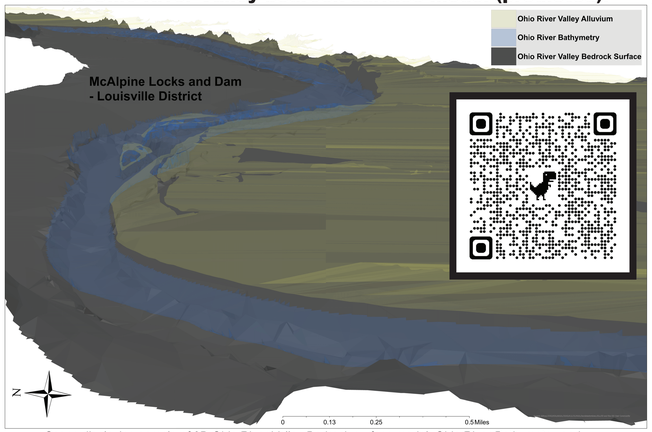
Structure contours were georeferenced and digitized in Arc Pro, converted to rasters, and then to 3D multipatches. Full dataset contains various partial and complete surfaces from the Geothermal project, the DVGQData project, the Solis project, and others. Contour data included a projected and measured set for the New Albany Shale. (RIGHT)

More 3D Jackson Purchase geologic surfaces:



Scene displaying 3D interpolated tops for the Paleozoic Rocks, McNairy Fm, Porters Creek Clay, Wilcox Fm, and the New Albany Shale in the Jackson Purchase region of Kentucky. Surfaces vertically exaggerated to 30x.

3D Ohio River Valley bedrock surface model (predicted):

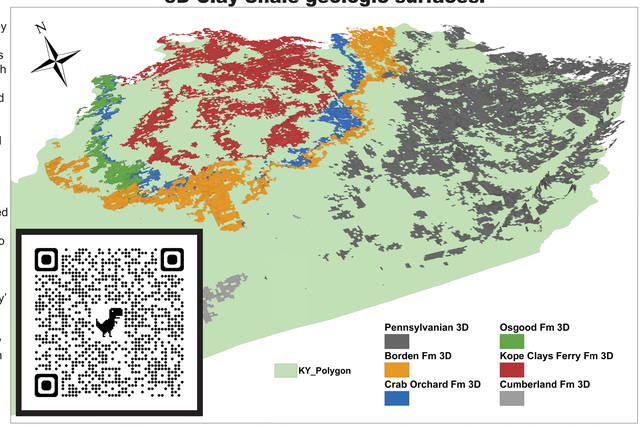


Scene displaying sample of 3D Ohio River Valley Bedrock surface model, Ohio River Bathymetry, and River Valley Alluvium at Louisville KY. Scene vertically exaggerated to 10x to bring out 3D valley U-shape.

A Ohio River center line, a river edge line, a 500ft buffer line, and a river valley boundary line were all merged, and points were generated along these lines every 50 ft. The KY DEM, bedrock depth rasters, and Ohio River depth raster were then extracted to the points. A field for the final bedrock elevation was added and used to assign a single elevation for each point of the predicted bedrock surface by subtracting the bedrock depth from the KY DEM, and then for the points on the river also subtracting the river depth. The 1km predicted bedrock depth raster was used were there existed holes in the 250m raster. These points were converted into a 50ft raster before being interpolated into a 3D multipatch surface. (LEFT)

Using the 'DVGQ_24K_GeoSciML_Poly' and 'KGS_Contacts_24K' layers from KGS's 1:24,000 Geologic Map Data for Kentucky, formations were meticulously extracted using their sort codes and run through two KGS automated workflows in Jupyter Notebooks for creating 3D surface features, and 3D multipatches were interpolated and sorted by formation. The Jessamine Dome is clearly visible with 30x vertical exaggeration. (RIGHT)

3D Clay Shale geologic surfaces:



Scene displaying 3D Clayshale surfaces for the Pennsylvanian Marine Coal-baring Shales, the Borden Fm, the Crab Orchard Fm, the Osgood Fm, the Kope Clays Ferry Fm, and the Cumberland Fm in Kentucky. Surfaces are vertically exaggerated to 30x. Data obtained from KGS's 1:24,000 Geologic Map Data for Kentucky.

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