Automated Geologic Cross-Section Generation for Ohio using GemPy

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Abstract

Geologic cross-sections show us a history of the Earth and are an important tool in understanding historic geology. We develop a fully automated, open-source workflow that utilizes large datasets to construct sections of the state of Ohio with no input from the user other than the ends of the section. The implementation uses GemPy, an open-source python geomodeling library, to build models from real, freely available geologic and topographic data. Cross-sections are extracted from these 3D models and plotted using the python plotting library matplotlib. Resulting sections show the overall structure of the geology and the general time period it originates from. This implementation can rapidly produce low-cost sections (compared with manually intensive or proprietary systems), and it provides a foundation for future augmentations such as the inclusion of well and borehole data and improved accuracy for the pre-Ordovician and post-Permian time periods.

Data

The Structure Contour maps, produced by the Ohio Division of Geologic Society in 2002, are used as geologic bedrock data that cover the state of Ohio. Topographic information was taken from digital elevation models supplied by the Shuttle Radar Topography Mission and cropped to the extent required. Other information, such as the surface orientations required to compute the geologic models, are calculated as the model is built, case by case.

From Coordinate Pair to Cross-Section

After determining the coordinate pair for the endpoints of the cross-section, the implementation uses those endpoints to extract geographically relevant data from the structure contour data. After transforming this data into a format readable by GemPy (x, y, z, type), the data is added to a GemPy model and secondary calculations, such as orientation of surface, are made. Once all the necessary information is loaded into the model, the model is computed using Kriging interpolation of the geologic structure contour data. From the resultant 3D model, we can plot the requested 2D section using matplotlib.

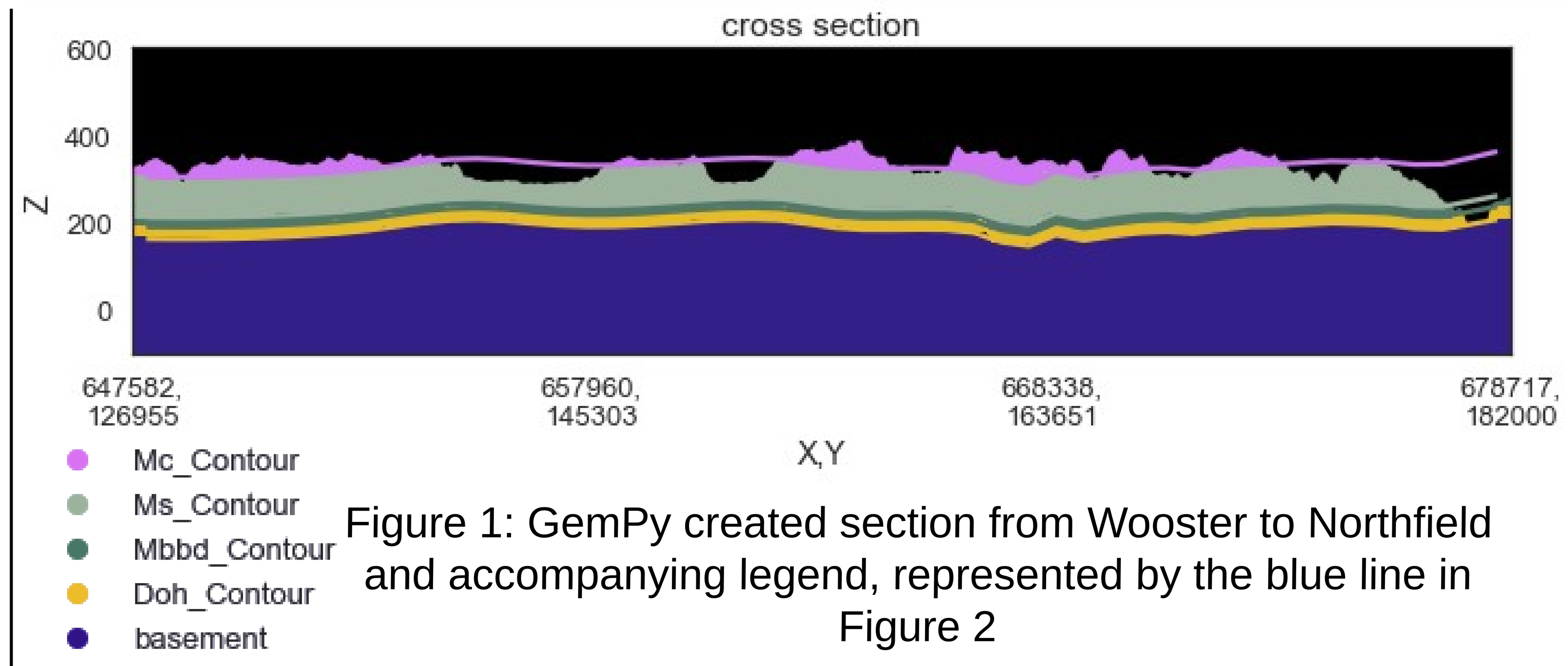

Figure 1: GemPy created section from Wooster to Northfield and accompanying legend, represented by the blue line in Figure 2

Results

While the accuracy or detail of sections produced from our implementation doesn't match those produced from the USGS, the generated models take significantly less time, energy, and money to produce. Our implementation allows for a quick estimate of what the section looks like and the final cross-section can be produced in a matter of minutes with no input from users needed, allowing non-geologists and geologists to create similar sections. The implementation is also entirely open-source, meaning it can be replicated and improved on without license barriers. However, the accuracy of the recreated sections, from the stratigraphic thickness, presence of units, etc. has room for improvement. One way sections could be improved is with the addition of well and borehole data. One way that this could be done is with the help of GemGIS, a python module from the team that developed GemPy for spatial data processing.

Conclusion

Our implementation makes it possible for rudimentary and generalized cross-sections to be produced quickly, with no expert input, and of any region in Ohio. The resulting cross-sections produced from our implementation work as a proof-of-concept for future work. The geologic accuracy could be improved through use of additional or updated data. Examples of additional data sources include well and borehole data to determine the accuracy of the stratigraphy produced, isopach maps to adjust thickness, surficial and Quaternary information to account for places where the depth to bedrock is significant. Structure contours from other states could be added as well, a task that would be expedited greatly with the availability of a continuous, integrated geologic map of the Continental United States.

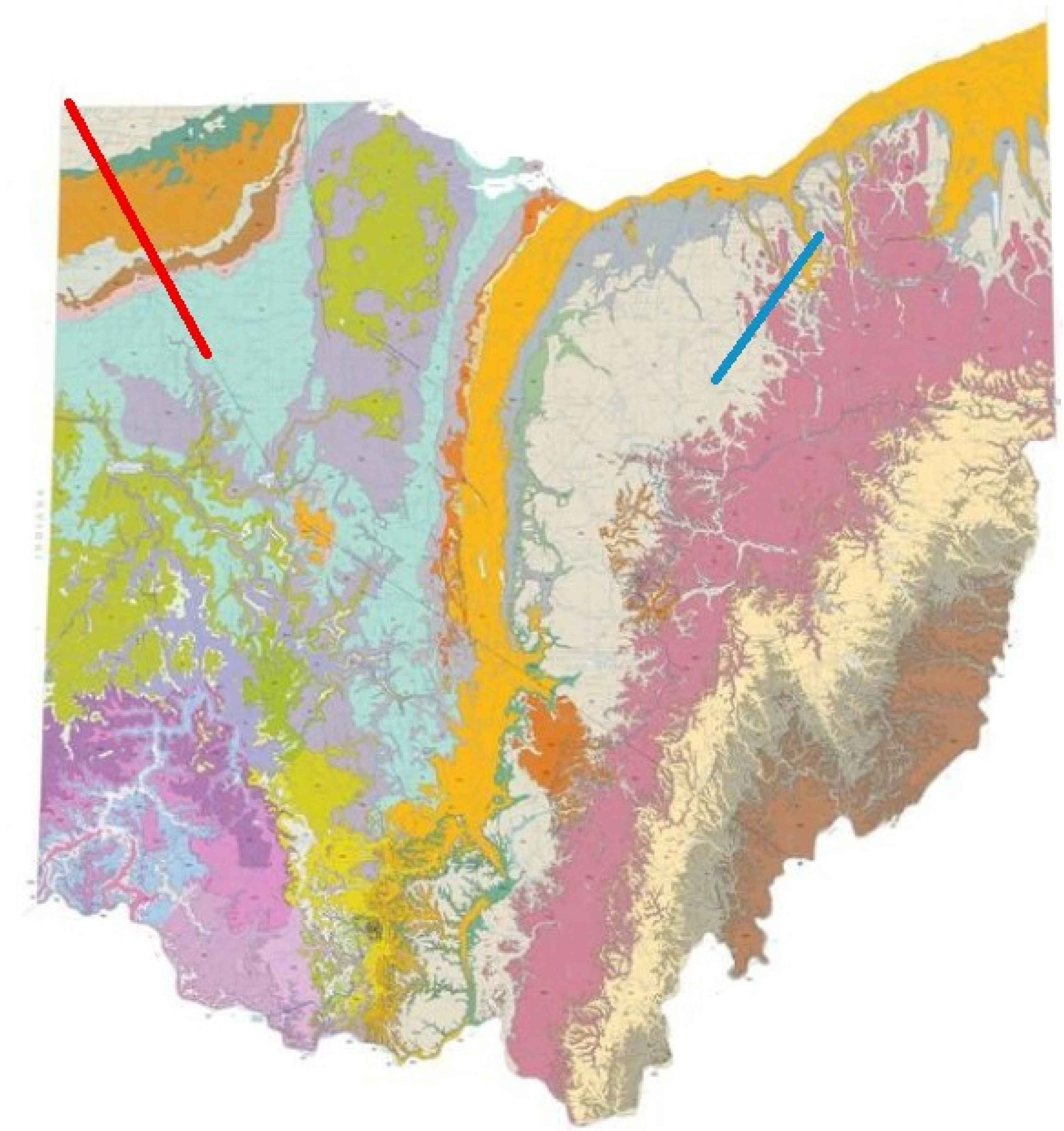

Figure 2: Ohio Division of Geological Survey (ODGS) Bedrock Map of Ohio (2006), with emphasis on two sections: Michigan Basin halfway to the Bellefontaine Peak (red) and Wooster to Northfield

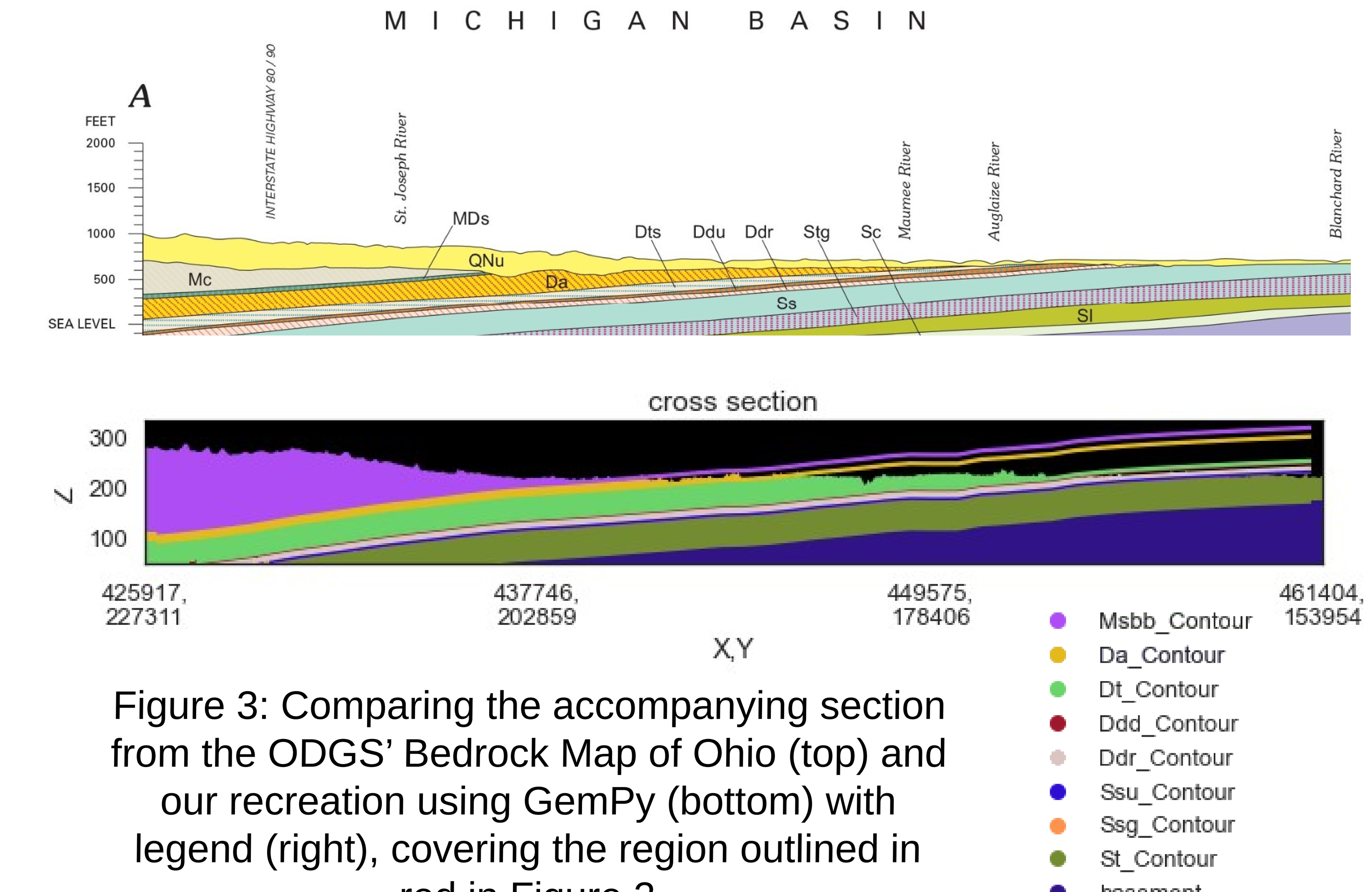

Figure 3: Comparing the accompanying section from the ODGS' Bedrock Map of Ohio (top) and our recreation using GemPy (bottom) with legend (right), covering the region outlined in red in Figure 2

References:
1. Slucher, E.R., Swinford, E.M., Larsen, G.E., Schumacher, G.A., Shrake, D.L., Rice, C.L., Caudill, M.R., Rea, R.G., and Powers, D.M., 2006, Bedrock geologic map of Ohio: Ohio Division of Geological Survey, Digital Map Series BG-1, scale 1:500,000
2. M. de la Varga, A. Schaaf, and F. Wellmann. "GemPy 1.0: open-source stochastic geological modeling and inversion". In: Geoscientific Model Development 12.1 (2019), pp. 1–32. doi: 10.5194/gmd-12-1-2019