Geophysical Subsurface Investigation of the Serpent Mound Area (Ohio, USA) Using Electrical Resistivity Ground Imaging (ERGI): Evaluation of Bedrock Controls on Surface Features

Michael J. Zaleha[1] & William F. Romain[2]

[1]*Department of Geology, Wittenberg University, Springfield, Ohio 45501-0720*
mzaleha@wittenberg.edu
[2]*Newark Earthworks Center, The Ohio State University, Newark, Ohio 43055*
romainwf@aol.com

Newark Earthworks Center

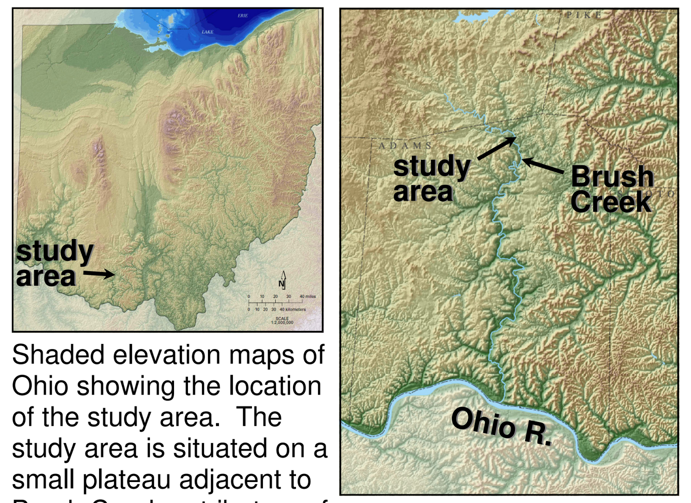
Abstract

Serpent Mound, a prehistoric Native American effigy mound in the form of a snake, is the largest serpent effigy in the United States (~424 m long). This study used electrical resistivity ground imaging (ERGI) to evaluate whether surface features associated with the Mound and surrounding area were influenced by the subsurface geology. The study focused on two areas: one south of the mound where three topographic depressions are evident, the other within the effigy. The study area is situated on a small plateau adjacent to a tributary of the Ohio River. Bedrock is Upper Silurian dolostone overlain by unconsolidated sediment.

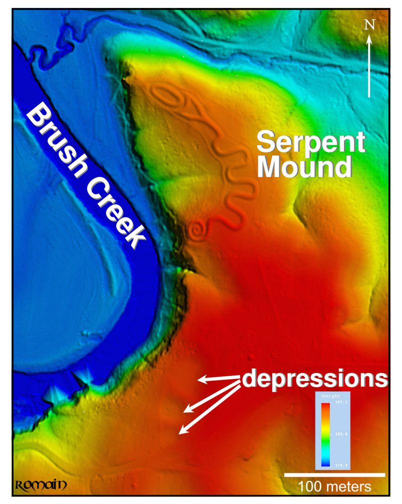
The three depressions (~30 m in diameter, relief of 0.7-1.6 m) are thought to be either areas where material was excavated for use in mound construction (i.e., borrow pits) or sinkholes formed by dissolution and collapse of the underlying carbonate bedrock. ERGI results show a layer of low-resistivity surficial sediment that is readily discernible from the higher resistivity bedrock. Surface topography generally parallels bedrock topography. A high resistivity feature beneath one depression likely represents a collapse breccia. Beneath another depression, a potential silt-filled void is evident, possibly overlain by a collapse breccia. Collectively, the ERGI results suggest that the depressions are sinkholes.

Two ERGI surveys were conducted within the effigy. Some researchers contend that a portion of one Mound convolution may have undergone erosion or damage (and was later repaired) in association with sinkhole subsidence or sub-Mound drainage associated with a closed depression, citing the convolution's location at the head of a gully. An ERGI survey across this convolution indicates an underlying high resistivity feature that is possibly a collapse breccia associated with sinkhole formation, a small void, or subsurface weathered bedrock. Regardless, the feature is consistent with the aforementioned scenario. A second ERGI survey was conducted in the head-oval area to investigate whether a large cave or cavern system exists in the subsurface, as purported by some people. ERGI results in this area indicate no such features. The likely karst features evident on all ERGI profiles are comparable to solution voids and weathering features evident in bedrock outcrops.

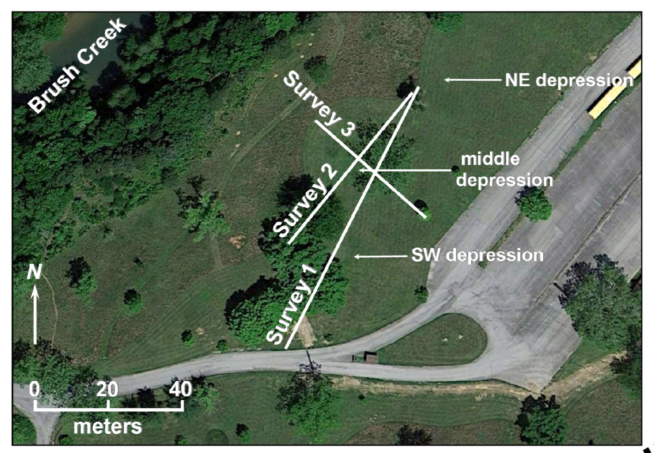
Aerial photograph of the Serpent Mound Native American effigy, the largest serpent effigy in the United States.



Shaded elevation maps of Ohio showing the location of the study area. The study area is situated on a small plateau adjacent to Brush Creek, a tributary of the Ohio River. The area is located in the unglaciated portion of Ohio (from *Shade Elevation Map of Ohio*, Ohio Geological Survey).

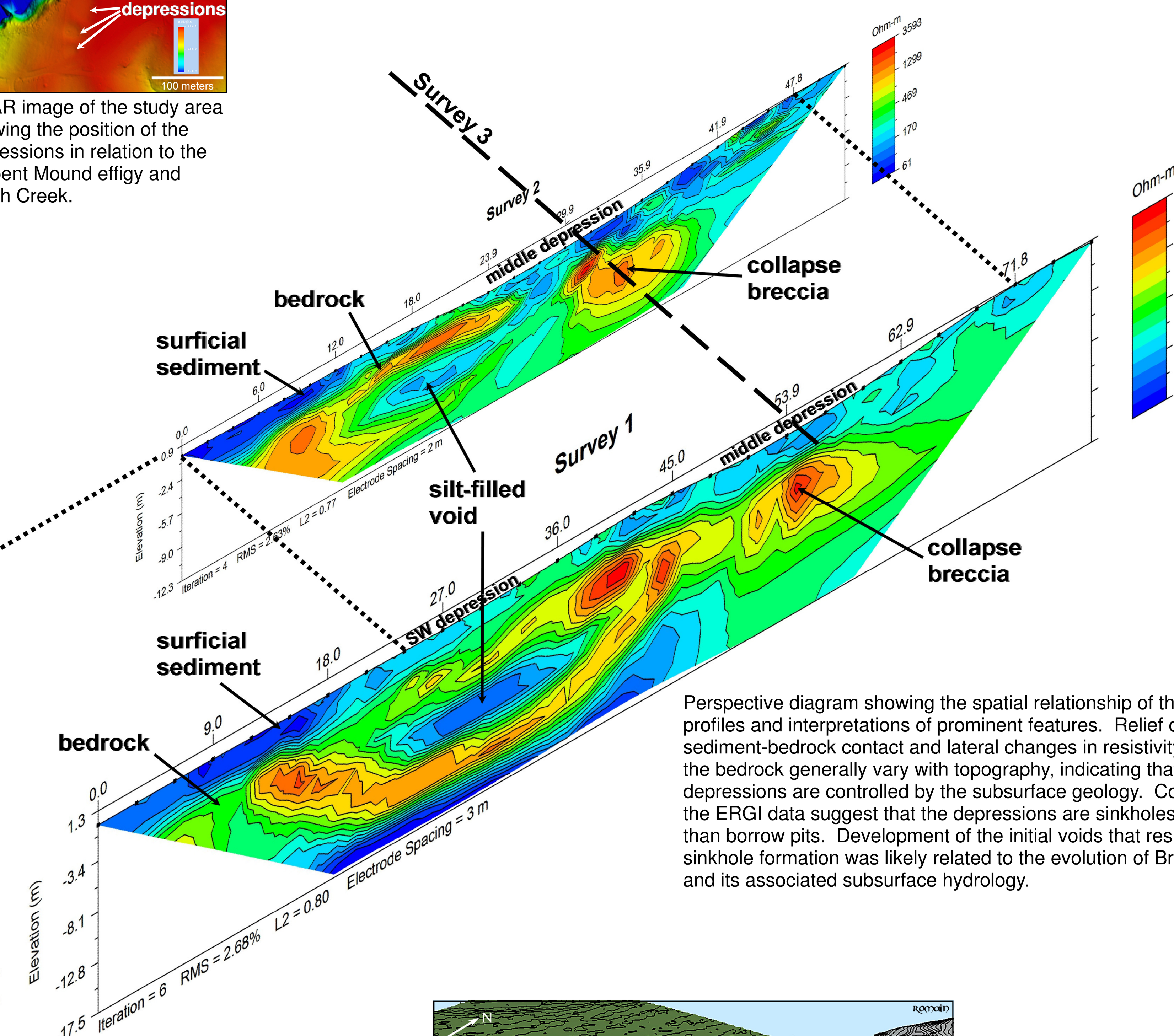
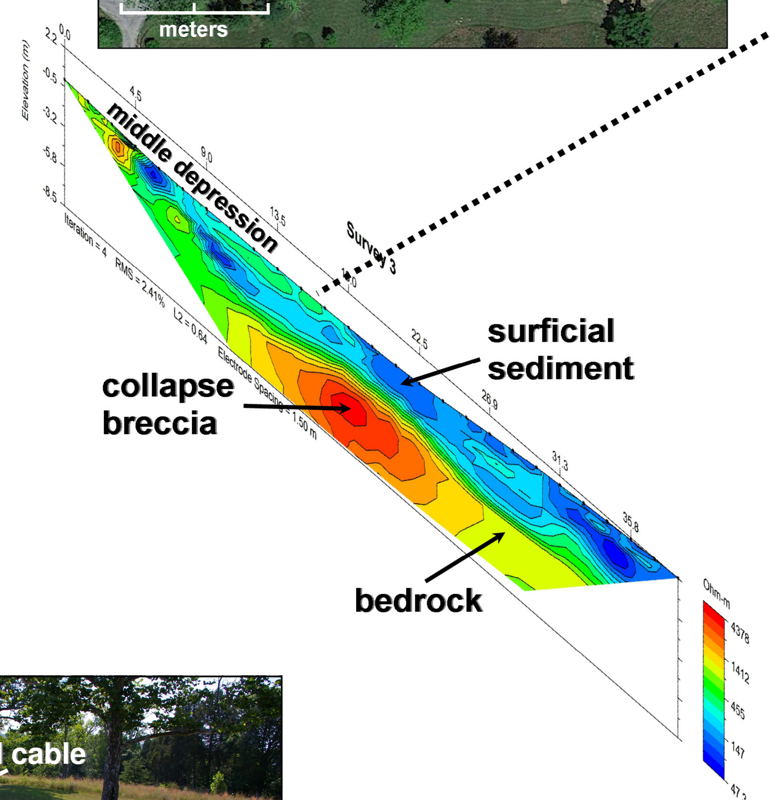


LiDAR image of the study area showing the position of the depressions in relation to the Serpent Mound effigy and Brush Creek.

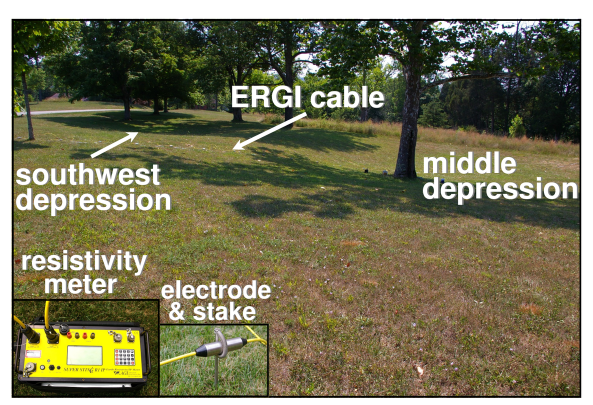


Google Earth aerial photograph of the study area showing the approximate positions of the three survey profiles, depressions, and the relation of the study area to Brush Creek.

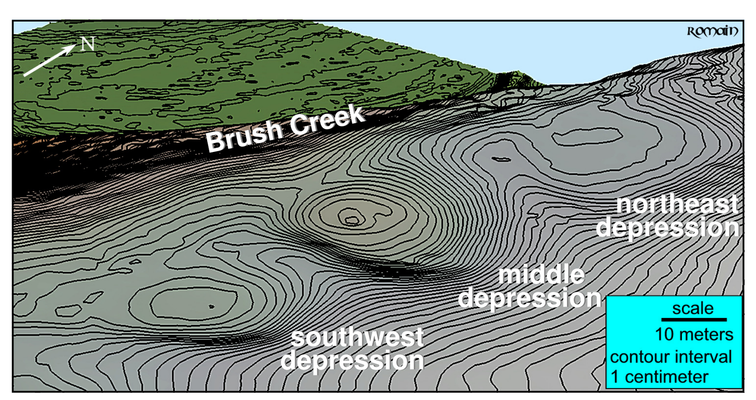
Topographic Depressions

Perspective diagram showing the spatial relationship of the ERGI profiles and interpretations of prominent features. Relief on the sediment-bedrock contact and lateral changes in resistivity within the bedrock generally vary with topography, indicating that the depressions are controlled by the subsurface geology. Collectively, the ERGI data suggest that the depressions are sinkholes rather than borrow pits. Development of the initial voids that resulted in sinkhole formation was likely related to the evolution of Brush Creek and its associated subsurface hydrology.

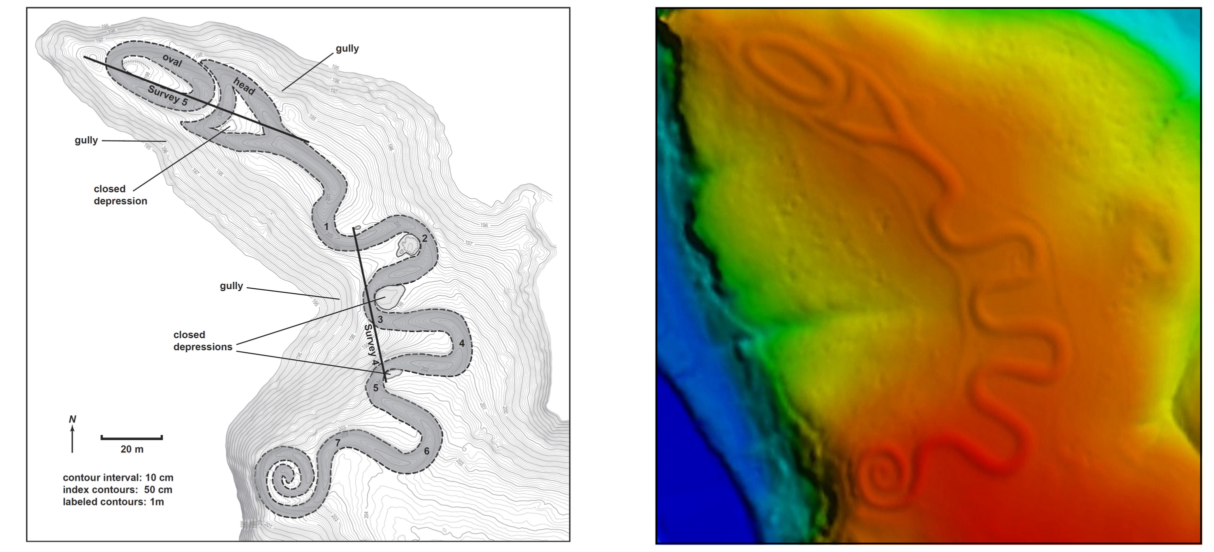


ERGI Survey 3 showing the southwest & middle depressions, electrodes, and cable. Insets show the ERGI instrument and an electrode attached to a stake. Resistivity surveys were conducted with a Super Sting R1 IP resistivity meter and an array of 28 electrodes. All surveys employed a dipole-dipole array.

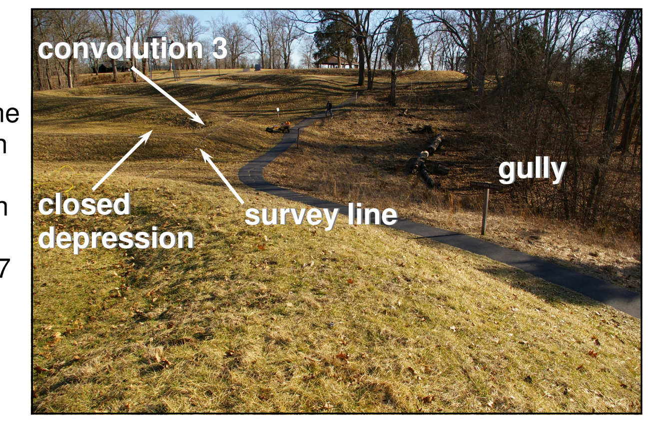


Topographic map of the study area showing the three depressions. The map was constructed from LiDAR data.

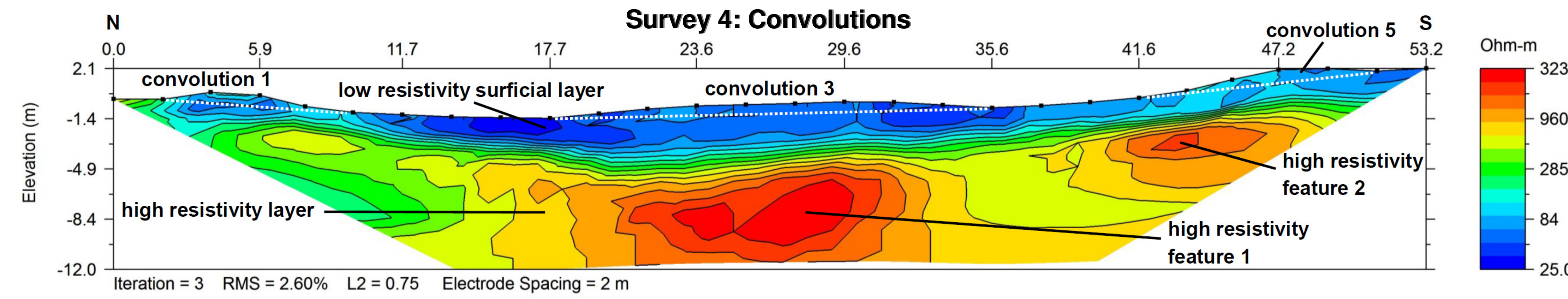
Serpent Mound Subsurface



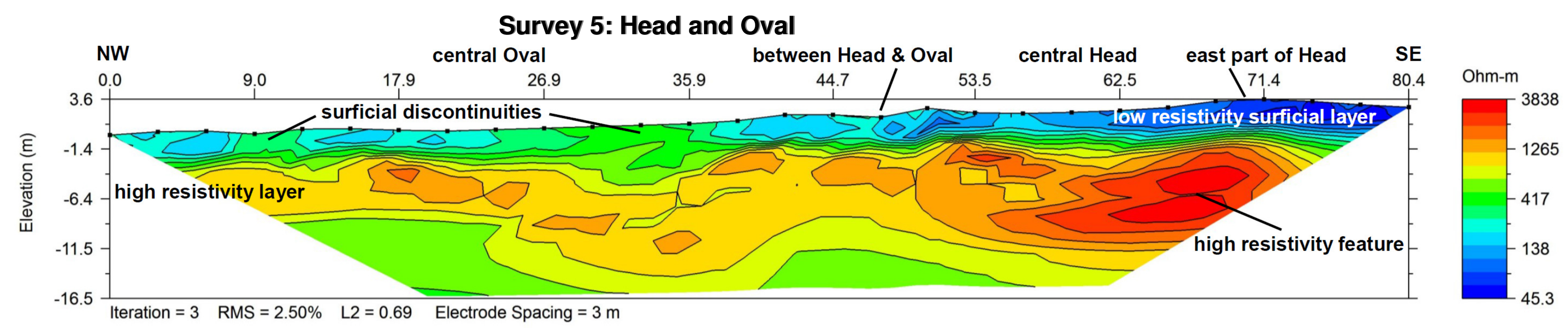
Left. Topographic map of the Serpent Mound ridge showing the footprint of Serpent Mound (convolutions numbered), locations of the ERGI surveys (bold lines), and gullies & closed depressions. Base map with Serpent Mound footprint courtesy of G.W. Monaghan & E.W. Herrmann, and was constructed from LiDAR data. **Right.** LiDAR image of the Serpent Mound ridge.



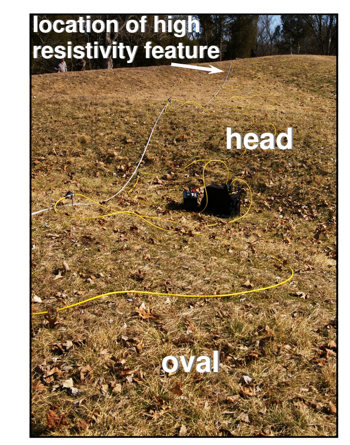
ERGI Survey 4 showing convolution 3 & the closed depression in relation to the gully. Convolution 1 in foreground, convolutions 5 & 7 in background. View is looking southeast.



Survey 4 ERGI profile. High resistivity feature 1 is possibly a collapse breccia associated with sinkhole formation, a small void, or subsurface weathered bedrock. The feature is consistent with the scenario of Herrmann et al. that a portion of convolution 3 may have undergone erosion or damage in association with sinkhole subsidence or sub-Mound drainage associated with the closed depression. The white dotted lines demarcate the approximate pre-Mound topography.

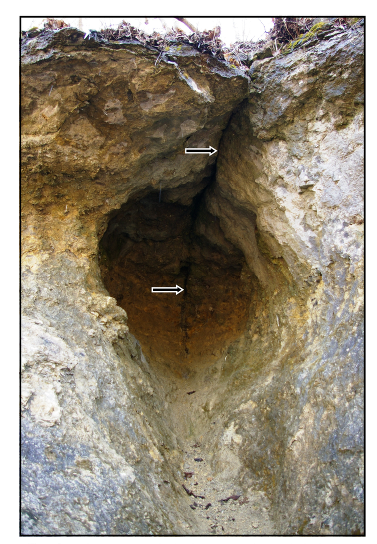


Survey 5 ERGI profile. The high resistivity feature may represent weathered rock or a small void associated with subsurface drainage toward gullies on either side of the ridge. Survey 5 does not indicate the existence of a large cave or cavern system beneath the head-oval area as purported by some people.



ERGI Survey 5 showing a portion of the oval, head, and location overlying the high resistivity feature. View is looking southeast. The ERGI instrument, cable, and tape measure also are shown.

Comparative Features



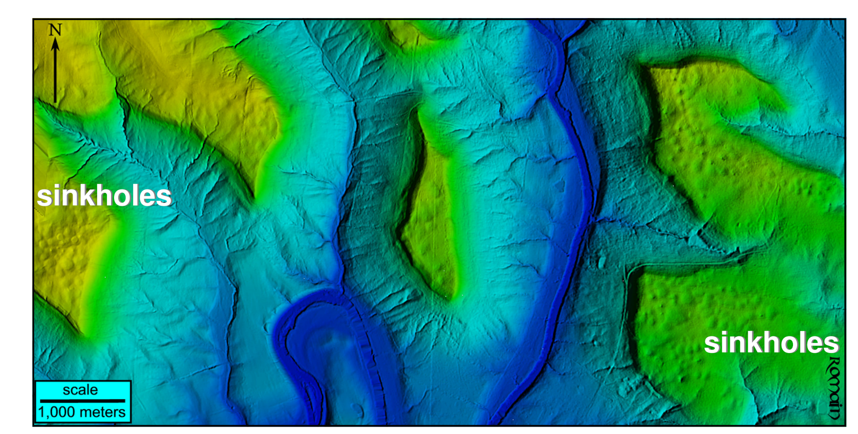
Solution void (cave) within the west face of the Serpent Mound ridge. The void is ~2 m high & ~1.5 m wide. Also note fracture (arrowed) along which the void has developed.

The Springfield Dolomite is stratigraphically equivalent to the Peebles Dolomite which underlies the study area.

Solution void (cave) within the Springfield Dolomite. Also note fractures (arrowed) along which the void has developed. The outcrop is in Springfield, Ohio.

Numerous small voids within the Springfield Dolomite. The scale and elongate (parallel to bedding) nature of the voids are comparable to some high resistivity features evident in the ERGI profiles. The outcrop is in Springfield, Ohio.

Downwarped strata in the Springfield Dolomite attributable to collapse into a void. The outcrop is near Springfield, Ohio.



LiDAR image showing sinkholes approximately 1 km south-southeast of the study area. The sinkholes are located on small plateaus similar to that of the study area. The scales of these sinkholes are comparable to the depressions examined in this study.