Electrical Resistivitiy Imaging (ERI) beneath Sinkholes and Suspect Sinks: Implications for Karst Risk Assessment in Clark County, Ohio

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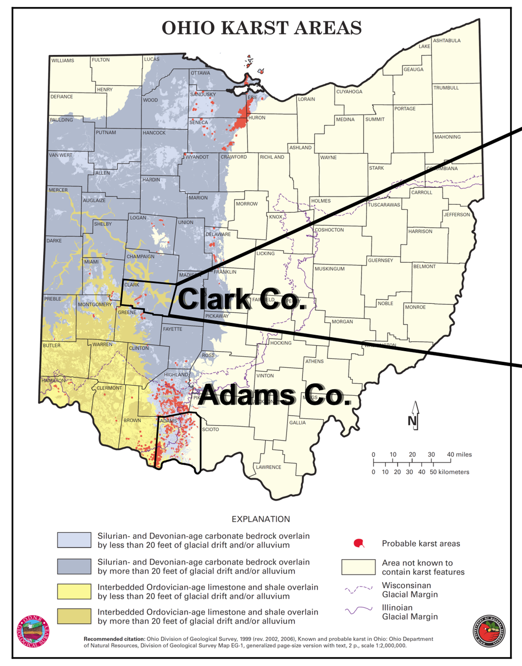
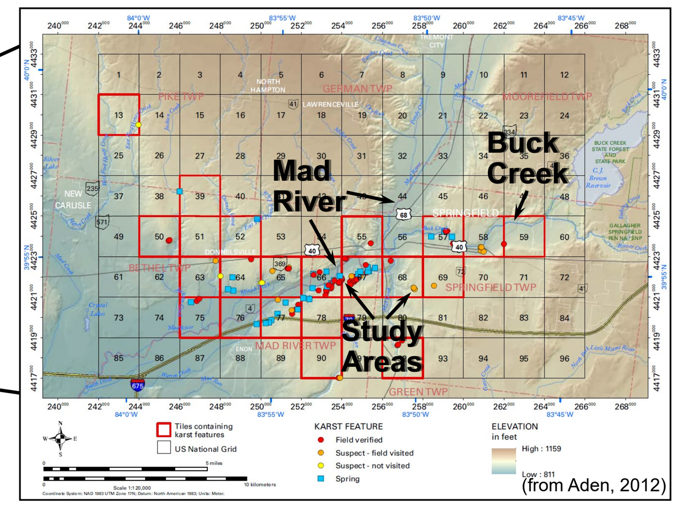
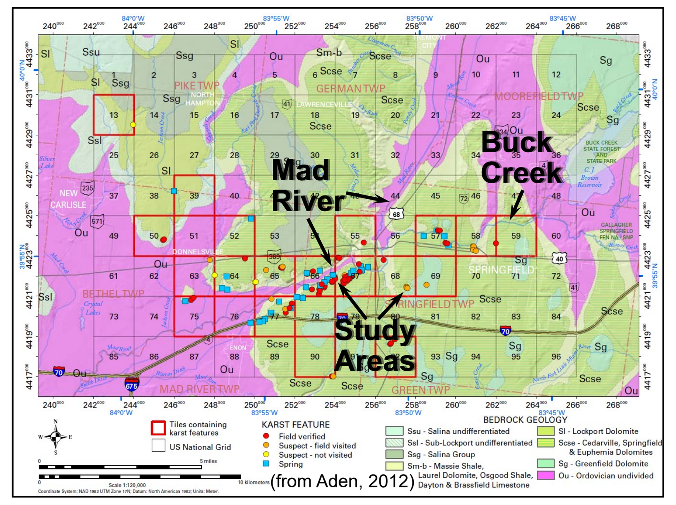
Study Areas

The study areas are ***underlain by middle Silurian dolostones*** (the Cedarville, Springfield, and Euphemia Dolomites) ***overlain by glacial till and outwash***, typically decimeters to a few tens of meters thick. Most karst occurs where till and outwash are less than ~8 m thick (Aden, 2012).







Above. Map of ***Ohio*** showing locations of ***known and probable karst features***, bedrock geology, and glacial boundaries. The study areas are located in Clark County and a comparative study was conducted in Adams County (see below).
Top right. Karst features of Clark County plotted on a base map of ***surface topography***. Karst features tend to be associated with the major drainages in the area of the Mad River and Buck Creek.
Bottom right. Karst features of Clark County plotted on a base map of ***bedrock geology***. Karst features tend to be associated with lower and middle Silurian dolostones.

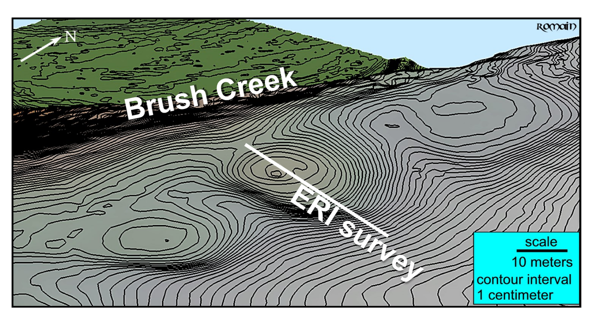
Examples of Karst & Karst-related Features in Clark County

Solution void (cave) within the Cedarville Dolomite. Also note fractures (arrowed) along which the void has developed.

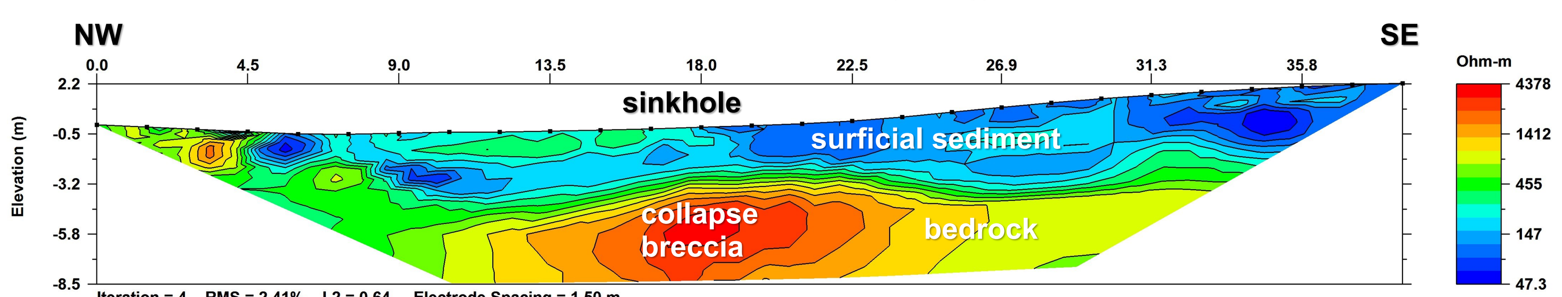
Sinkhole apparently due to collapse into a subsurface void comparable to that to the left (from Aden, 2012).

Solution-enlarged fracture (joint), common within the Cedarville Dolomite, filled with sediment. Such fractures are often associated with cover-collapse sinkholes.

Adams County ERI Survey



Zaleha and Romain (2014) conducted a prior study that examined suspect ***sinkholes in Adams County***, Ohio (see Ohio Karst Areas map above for location). ***Left. Topographic map of*** the area showing the three ***depressions*** examined. The map was constructed from LiDAR data. ***Below.*** Example of ***ERI results*** which show an anomaly in the bedrock beneath one depression indicating that it is likely a ***collapse sinkhole***. Bedrock is the Peebles Dolomite, equivalent to the Cedarville Dolomite that underlies the study areas in Clark County. Development of the initial void that resulted in sinkhole formation was likely related to the evolution of Brush Creek and its associated subsurface hydrology.



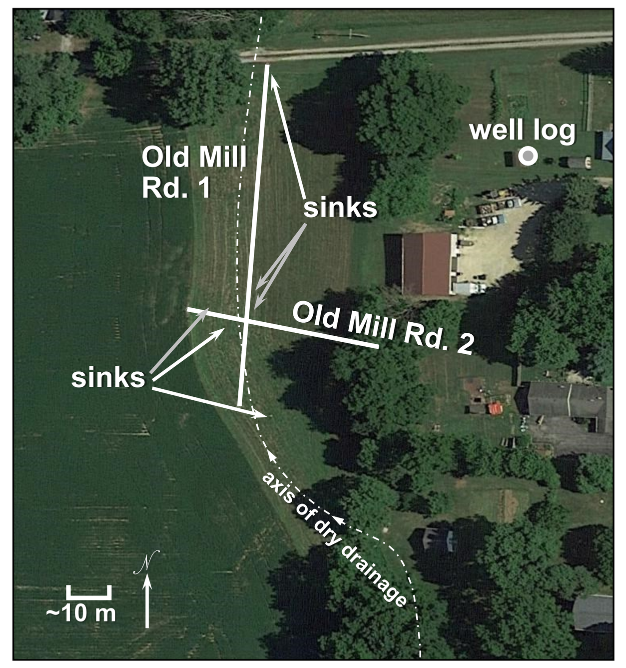
Abstract

Karst features (sinkholes, subsurface voids, solution-enlarged fractures, and springs) occur in Silurian carbonates (mostly dolostones) of west- and south-central Ohio. The Division of Geological Survey of Ohio published a report identifying known and suspect karst features associated with these carbonates in a 24 km x 16 km area covering most of Clark Co., Ohio. Potential sinkholes were identified on a DEM generated from LiDAR data. Most were then examined in the field. The study also included locations of voids in cliff faces and springs. Results were presented as maps and aerial images showing the locations of features. Karst features were classified as field verified (59 features), suspect - field visited (17), suspect - not visited (4), and spring (32). We examined a site with 3 field verified sinks and a site with 3 suspect - field visited sinks using electrical resistivity imaging (ERI) to evaluate processes associated with their formation. The study areas are underlain by middle Silurian dolostones overlain by glacial till and outwash. Interpretations of ERI profiles were informed by nearby well logs.

The 3 field verified sinks are ~1 m wide and dm's deep. In the 2 ERI surveys conducted (78 m & 50 m long, both 12 m depth), bedrock (resistivities, ρ's, of ~700-3300 Ωm) is readily differentiated from overlying sediment (ρ's of ~20-300 Ωm). The sinks occur in a dry drainage controlled by bedrock topography. No anomalies indicative of bedrock collapse are present beneath the sinks, suggesting that they formed by subsurface erosion and collapse of sediment associated with solution-enlarged fractures, similar to those apparent in outcrops. The 3 suspect sinks are ~10 m wide and ~1 m deep. The 2 ERI surveys conducted (each 81 m long, 17 m depth) imaged discontinuous gravel lenses (ρ's of 200-500 Ωm) and sand, silt, & clay (ρ's of 10-100 Ωm), but did not intercept bedrock, consistent with nearby well logs. The depressions likely are not sinkholes, but rather cultural features, as this site appears disrupted on historical aerial imagery.

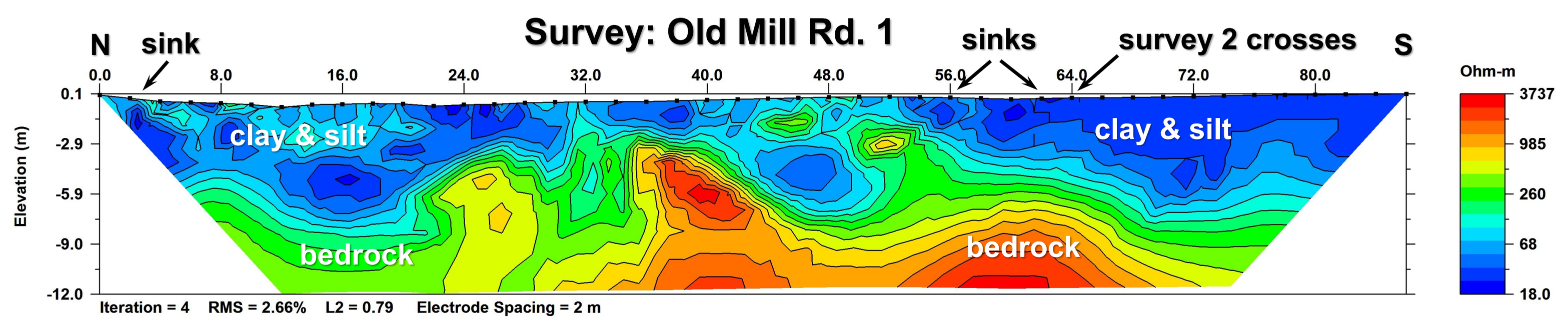
This study shows that ERI is an effective tool for evaluating depressions when used with well logs and surface examination. Results suggest that the karst risk associated with collapse sinkholes in the area may be minimal and that other suspect depressions may not be sinks and warrant further evaluation.

Field Verified Sinkholes: Old Mill Road Site



Aerial photo of the Old Mill Road site showing locations of ***ERI surveys***, ***sinkholes***, axis of the ***dry drainage*** and a nearby ***well log***. Sinks identified in the Division of Geological Survey report are shown with white arrows. Sinks that developed since the report was published are shown with gray arrows. Image from Google Earth.

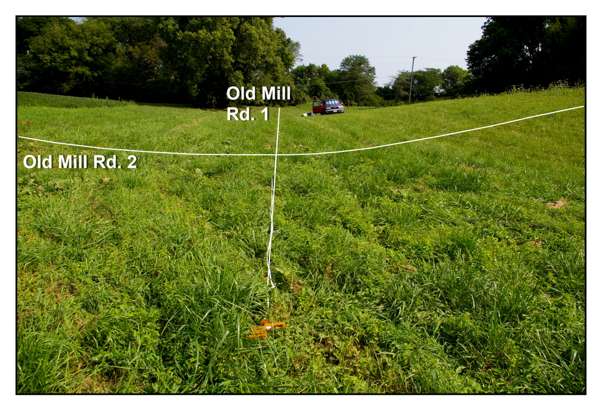
Examples of sinkholes at the Old Mill Road site. Sinkholes are typically ~1 m across, decimeters deep, and floored by sediment.



In this ***ERI survey***, bedrock (the Cedarville Dolomite) is readily differentiated from the overlying sediment. Relief on the bedrock surface of decimeters to a few meters is apparent. No anomalies indicative of bedrock collapse are present beneath the sinks, suggesting that they formed by subsurface erosion and collapse of sediment associated with solution-enlarged fractures, similar to those apparent in outcrops.

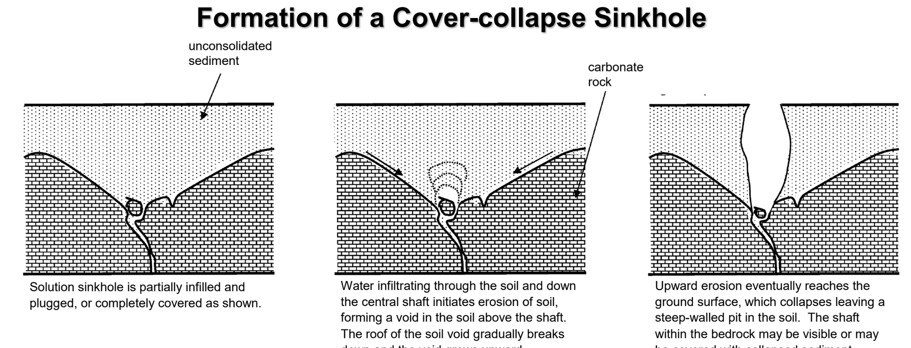
Surface expression of a ***solution-enlarged fracture***. Subsurface erosion and collapse of sediment into similar fractures (see process in figure below) is the likely mechanism for the formation of the sinks at the Old Mill Rd. site.

The ***Old Mill Road site*** showing approximate locations of the ERI surveys. View to the south-southeast looking up the dry drainage.

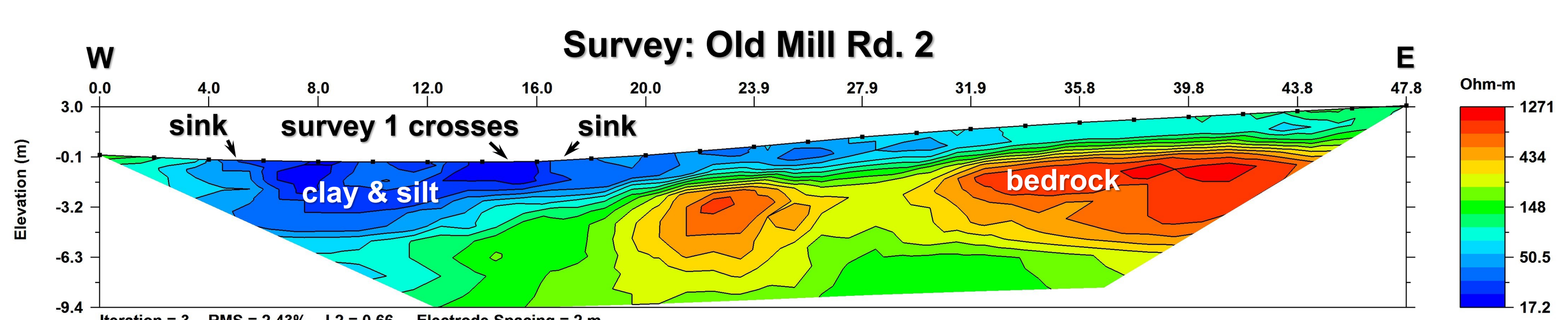


The ***Old Mill Road site*** showing approximate locations of ERI surveys. View is to the north looking down the dry drainage and corresponds with that of the ERI figure below.

Formation of a Cover-collapse Sinkhole

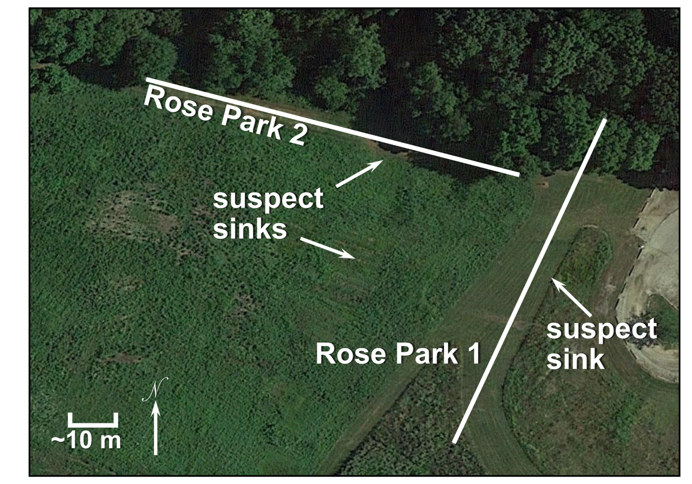


Sinkholes at the Old Mill Road site are likely ***cover-collapse sinkholes***, formed by the above process (from Zhou et al., 2002), associated with subsurface water flow confined by bedrock topography of the dry drainage.

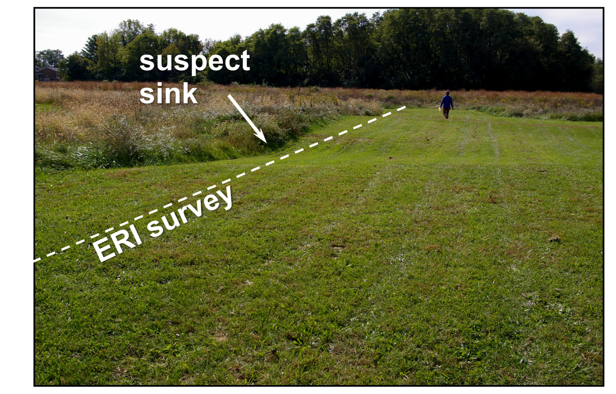


In this ***ERI survey***, bedrock (the Cedarville Dolomite) is readily differentiated from the overlying sediment. Depth to bedrock on the ERI survey is consistent with that recorded on nearby well logs. The dry drainage is clearly controlled by bedrock topography. As in Survey 1, no anomalies indicative of bedrock collapse are present beneath the sinks, suggesting that they are cover-collapse sinkholes formed by the process outlined above.

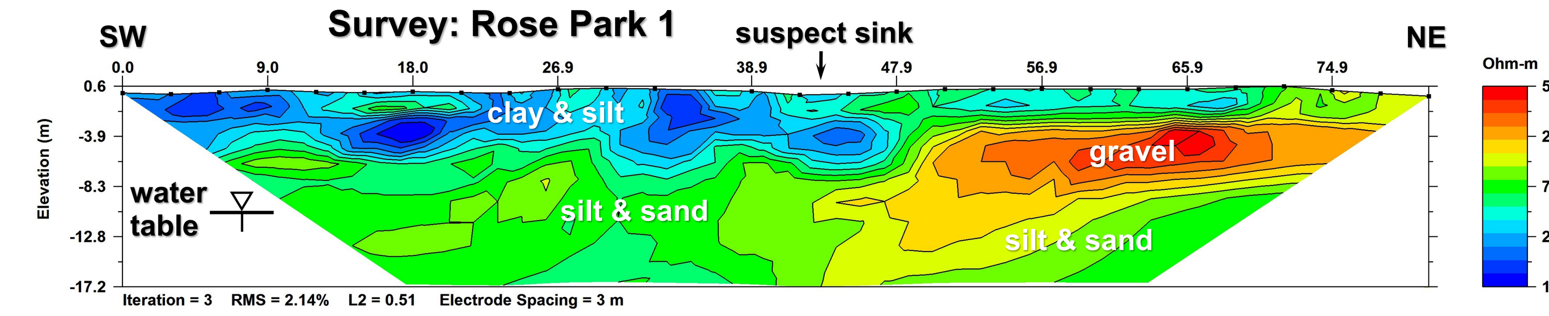
Suspect Sinkholes - Field Visited: Rose Park Site



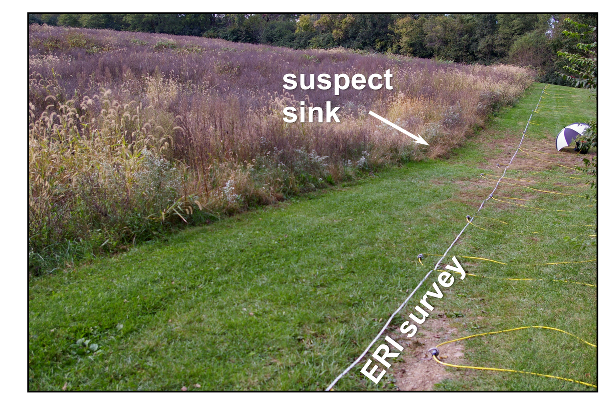
Aerial photo of the Rose Park site showing locations of ***ERI surveys*** and ***suspect sinkholes***.



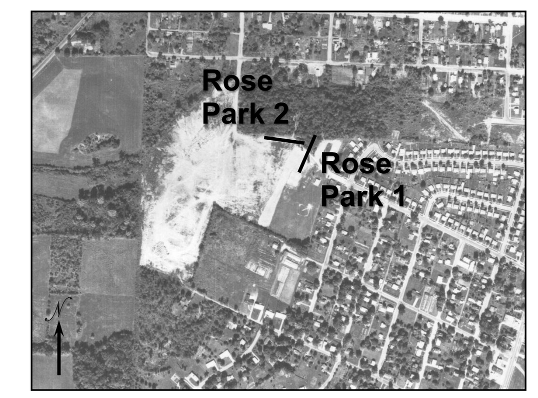
The site of ***Survey: Rose Park 1*** showing location of survey line and suspect sink. View is to the south.



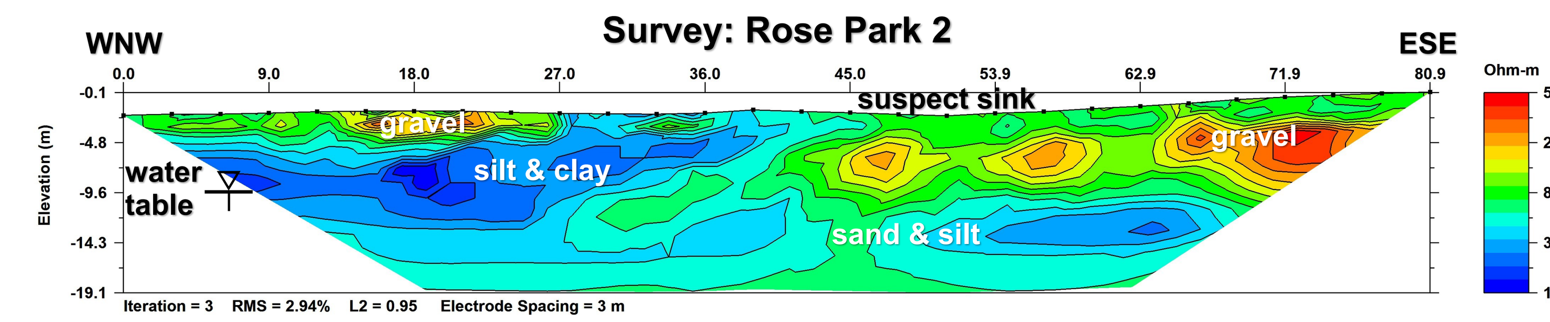
Bedrock was not intercepted in this survey, consistent with nearby well logs which indicate depth-to-bedrock in this area ≥18 m. Most karst features in Clark County occur where depth-to-bedrock is ≤8 m. It is unlikely that the ***suspect sink*** is related to any bedrock feature and, hence, is ***not a sinkhole***. The depression does correspond with a change in the underlying sediment and may be the result of differential compaction or, more likely, a cultural feature (see historical aerial photo, below-right). Depth of water table is from a nearby well log.



The site of ***Survey: Rose Park 2*** showing location of survey line and suspect sink. View is to the west.



1968 aerial photo of the Rose Park site. The site is on the margin of an urban area and appears disrupted, suggesting that the suspect sinks are cultural features (e.g., decomposed, buried trash pits, such as plant debris; excavations) rather than sinkholes.



As in Survey 1, ***bedrock was not intercepted***. The depression does correspond with a slight change in the underlying sediment and may be the result of differential compaction between two gravel lenses or, more likely, a cultural feature (see historical aerial photo, above-right). Depth of water table is from a nearby well log.

Conclusions

This and other studies have shown that ERI is an effective tool for evaluating karst and karst-related features, particularly when used in conjunction with well logs and surface examination. The small sinkholes at the Old Mill Road site are likely cover-collapse sinkholes associated with solution-enlarged fractures in the bedrock. The three suspect sinks at the Rose Park site do not appear to be sinkholes, but rather cultural features. The remaining 18 suspect sinkholes identified by the Division of Geological Survey warrant further evaluation. Our preliminary results suggest that the karst risk in Clark County may be somewhat overestimated and that the risk associated with collapse sinkholes may be minimal.

References Cited

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