

# TPG

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Flaming Gorge National Recreation Area contains 207,363 acres of land and water, almost equally divided between Utah and Wyoming. The area was given the name "Flaming Gorge" by John Wesley Powell during his 1869 expedition down the Green River, due to the spectacular red sandstone cliffs that surround this part of the river. The Flaming Gorge reservoir was created by the 1964 construction of the Flaming Gorge Dam across the Green River. The nearly flat-lying shale and ledge-forming sandstones are of Late Cretaceous age (Mancos Shale capped by Mesa Verde Group sandstones). Photo by Clyde Dabbs, CPG-09865.

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# The Grapevine Hill Fault: A New Local Fault Discovered During Preliminary Geotechnical Exploration for Route Construction, US 50, Osage Co., Missouri

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## Abstract

During the winter of 2010 and through the summer of 2011, a preliminary engineering soil survey was conducted for the relocation of Route U.S. 50 in Osage County, Missouri. This 6.2 – mile survey of the geology and soils precedes construction and upgrade for two additional lanes for U.S. 50 as well as relocates the road to a less curved alignment, enabling higher speeds for motorists. In conjunction with this survey, four resistivity traverses were conducted to investigate the efficacy of using this geophysical method for planning the number and spacing of borings on the subject route. Faculty-supervised students from Missouri University of Science and Technology (MS&T, formerly the University of Missouri-Rolla) completed the resistivity traverses, which were post-processed and interpreted by faculty of MS&T.

One major resistivity anomaly was identified during these traverses on a ridge known as Grapevine Hill. This feature was investigated by drilling three rock cores at the location of, and on either side of the identified anomaly. The locations of these borings were chosen due to their proximity to a planned bridge for a county road connector. Originally this anomaly was thought to be a filled-sink deposit. Instead, the identification of a 20-foot offset in a key bed of the Jefferson City Formation from one side of the anomaly to the opposite side identified the feature as a fault. Comparison of the processed resistivity profile to another profile from a known faulted area confirmed this interpretation. The feature seems to fit within the areal geologic framework, but was previously unknown.

The existence of this fault has now been verified during construction in early 2013.

## Introduction

Prior to route construction in Missouri, the Missouri Department of Transportation (MoDOT) relies upon geologists to deliver a wide range of expertise in order to fulfill our mission of providing a world-class transportation experience to the citizens of the state. At the District level the primary focus is on delivering a preliminary engineering soil survey to the Design Division of MoDOT for use in preparation of final roadway design. Local quarries and other sources of high-grade aggregate are identified. Samples are obtained for

laboratory testing in the District and at the MoDOT Central Office Materials Laboratory where they may be approved for a wide variety of pavement, precast, and structural products. Auger and rotary wash borings are conducted on the subject route alignment and soil and rock samples are also taken. These samples are sent to the Central Laboratory for testing to establish ranges of expected characteristics for soils that may be encountered, and rock is tested for strength.

Geologic features are also examined on and along the subject route. Karst may be investigated, and paleokarst features may be identified. Any abandoned underground mines (as well as active mines) are also identified by location, and characterized for their influence on the upcoming project. Necessary studies of slope stability of cut slopes, and settlement studies of embankments are also initiated through the Central Office. Preliminary foundation soundings are conducted to aid in bridge investigations. Finally, it should be mentioned that all drilling and excavation activities conducted are subject to utility location and clearances through the Missouri One Call System. This public utility-funded service marks the location of underground utilities so that the utilities are not damaged during excavation. “Call Before You Dig!”

The Central Office Geologist is responsible for examining, sometimes editing, and approving all preliminary engineering soil surveys. This is in addition to final soundings for structures and special investigations of slope stability and settlement conducted by traveling crews on a weekly basis out of the Central Office. All logs and correspondence are subject to internal peer review and quality control procedures to insure the best possible products given to Departmental designers and consultant forces.

## Route 50 Relocation in Osage County

The scope of the planned project involves a 6.2 mile upgrade of Route U.S. 50 to four lanes and relocation to avoid excessive curvature, as the ‘old’ Route 50 follows the ridge line from the town of Loose Creek to the outskirts of the Osage County seat of Linn, Missouri. Bridges over the Maries River and Loose Creek were planned, as well as several concrete box culverts with multiple inlets. Terrain ranges from river bottom at the Maries River to ridge lines near the town of Linn, with an overall relief of approximately 350 feet. Approximately six months

were required to complete the survey, which left no possibility of route relocation if adverse conditions had been found.

At the suggestion of the transportation project manager, the area was split in half so that the project could be expedited. Exploratory drilling and sampling would proceed on the first half of the project after utilities had been cleared with Missouri One-Call. During short periods of inclement weather, the first half's data would be correlated and shared with the Central District design staff, and requests would be made to clear utilities for the second half of the program. This arrangement worked well enough that requests for individual final bridge soundings arrived shortly after completion of the survey, and were completed ahead of schedule. Coordination continues at this time in as part of the overall Departmental effort to complete projects with smooth surfaces, make them safer, and deliver them to the public sooner.

## Bedrock Geology of the Route Corridor

Bedrock formations of the area consist of the Lower Ordovician (Ibexian) Jefferson City and underlying Roubidoux Formations. These formations consist primarily of dolomite but also possess layers of arkosic sandstone, illitic quartz siltstone and ubiquitous chert. There are few marker beds within these formations, but several are notable nonetheless. A unit of burrowed dolomitic mudstone known informally as the "Quarry Ledge" occurs in the lower third of the Jefferson City Formation. Blocks from this unit were extensively used in the past as building stone in the Jefferson City and Rolla areas, thus the name. It possesses a dark gray mottled appearance, and burrows of *Skolithos* occur throughout the ledge, which ranges in thickness from 15 feet in Osage County to 25 feet in other areas of Missouri.

The base of the Jefferson City Formation is delineated in a number of ways, all used within Missouri. One definition used extensively in field mapping is to define the base of the Jefferson City formation as being twenty-five feet under the base of the "Quarry Ledge" (Thompson, 2007). This method is very expedient as the 'Quarry Ledge' is a normally erosion-resistant unit as compared to other parts of the Jefferson City. A second definition is the use of a horizon of oolitic dolomite, known as the 'Maries County Oolite' or 'Buhrstone' to define the formation's base where it is visible. Both methods have been used successfully in Osage County for delimiting the base of the formation.

The Roubidoux Formation encountered within the corridor area is from the upper part of the formation, including two diagnostic key beds, the informally-named "Ledge Sandstone" and a thick prominent horizon of large, merged, digitate stromatolites.

Fossils are sparse in the two formations, the most common being gastropods including *Ceratopea*, *Lecanospira*, *Ophileta*, *Hormotoma*, and *Orospira*. The lithistid sponge *Archeosyphia annulata* is occasionally found, as are extremely rare pygidia of *Jeffersonia trilobites*. The receptaculid green alga *Calathium* is occasionally found preserved in chert. None of these fossils were present in sufficient numbers to enable correlation by paleontologic methods. Lithologic methods of correlation proved to be sufficient for the task, since only a local area was involved.

Possible structural features included paleosolution or 'filled-sink' structures, which result from the infill of paleokarst on

an unconformable surface. High-angle faulting is also known from Cole County to the northeast of the route corridor. Paleosolution features may be difficult to identify where covered with soil. Some have the potential for reactivation in the Central Missouri area, where one reactivated sink collapsed, endangering a housing development in the Rainbow Drive area of Jefferson City in 1977.

An initial reconnaissance of the route area revealed one filled sink on a secondary ridge of Grapevine Hill approximately 200 feet from the planned right-of-way. It would be unaffected by construction, but provided one clue to the presence of these structures in the area. This particular sink exhibited quaquaversal bedding, further indicative of its mode of origin, and is depicted in Figure 1.



Figure 1. Filled sink on secondary ridge of Grapevine Hill, exhibiting quaquaversal bedding of sandstone infill, with beds dipping between 15 and 20 degrees towards a common center.

## Geophysical Survey Using Resistivity

Geophysical methods of investigation offer a fast and effective means of investigating shallow subsurface conditions for the purpose of site characterization. In highway and transportation engineering geology they may be used to characterize anthropogenic or natural land subsidence, to locate potential obstacles to construction, and to determine moisture characteristics of subsurface materials. Resistivity characterization is one geophysical method that is used by many geologists for its effectiveness and simplicity. It also may be used in a variety of ground conditions.

Missouri University of Science and Technology students under Drs. Norbert Maerz and Neil Anderson were tasked with obtaining resistivity data at four locations along the future alignment of Route 50 as part of a research project to determine if resistivity methods could be used in conjunction with a program of targeted drilling to determine potential problem areas in advance of drilling. The locations that were targeted are shown in Figure 2.

All four of the survey lines appeared to have good general agreement with the subsurface geology, especially with the depth to rock and the location of zones of fractured and weak rock as could be determined with subsequent post-processing.

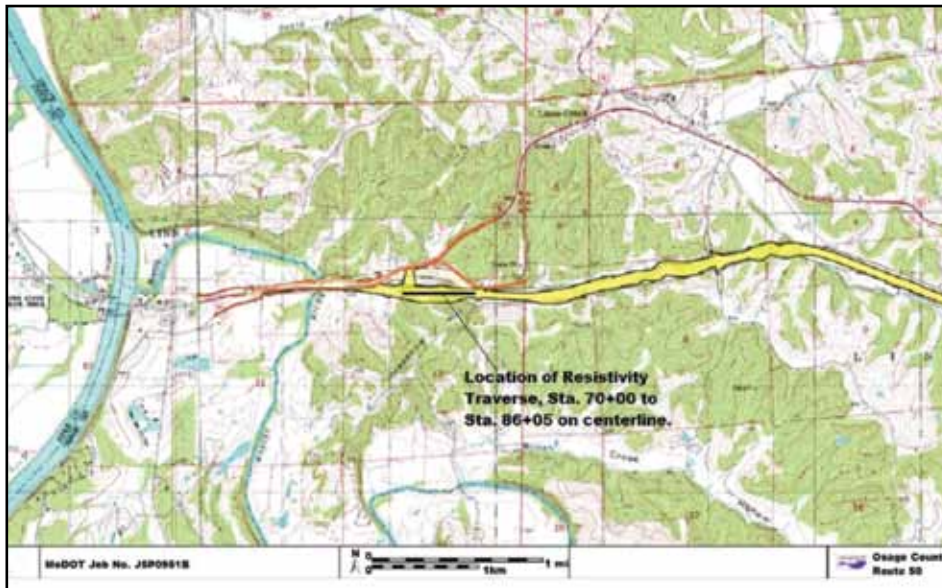


Figure 2. Location of resistivity traverse conducted on Grapevine Hill for Osage County Route 50 preliminary engineering soil survey and research project. Topography from USGS Loose Creek 1981, Westphalia East 1975, Luystown 1975 and Linn 1981 7.5' quadrangle maps.

Particular attention was given to the survey line that was laid out on Grapevine Hill. This ridge can be thought of as a secondary ridge that has remained as an erosional remnant of the 'gooseneck' at the confluence of Loose Creek and the Maries River. This location also would be the site of the largest major cut on the project, reaching a planned height of 80 feet, and serving as the south end pier position for a four-pier bridge for an outer road and state letter highway connector. This traverse extended from Station 70 + 00 to Station 86 + 05 along the roadway alignment centerline. An adverse structural feature might negatively affect not only the competence of the planned rock cut, but the bridge end if the feature were underneath.

The post-processed result of part of this resistivity traverse is shown in Figure 3.

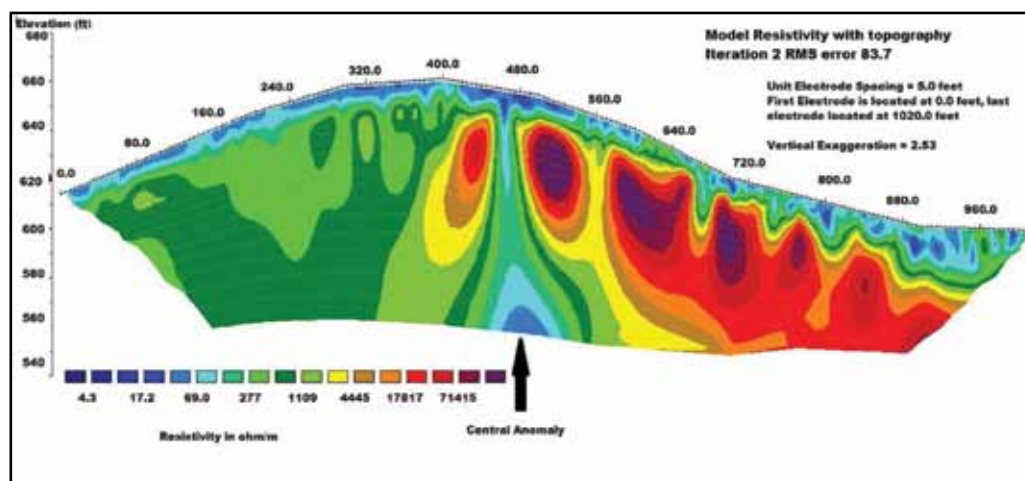


Figure 3. Post-processed resistivity tomogram illustrating shallow bedrock depth. Darker colors to right of tomogram indicate higher resistivity since measurements were taken during drought and on a sunny north-facing slope. Lowest resistivity is at surface and at central anomaly found at Station 74 + 70.

An anomalous feature was found at this location that originally was thought to be a paleokarst feature, or 'filled-sink' structure, since they are common structural features in the area. Such structures formed on an erosional surface in the Pennsylvanian period and also during the Mississippian period in Missouri. The anomaly was 200 feet away from the bridge, but its effect on the surrounding strata was unknown. In the event that a filled-sink structure was not found, it would have to be interpreted with additional cores.

## Drilling Program for Grapevine Hill

Discussions on-site led to a decision to drill into the feature, expecting to find a Pennsylvanian sandstone deposit or a large detached block of limestone from the Mississippian period that would be present in a typical Missouri paleokarst feature. Instead, the upper part of the first core recovered highly fractured rock. Furthermore, the core was from the Jefferson City Formation, already known to be present from outcrops further downslope. Thus, a different structural feature was present which would have to be interpreted with the aid of further drilling.

Since the adjacent planned bridge might still be affected by the unknown anomalous feature, two additional cores were procured, with continuous recovery to a point ten feet below the planned ditch line for the road. Logs of the core were prepared, and all core was photographed. A ten-foot difference in elevation was noticed between one core and an adjacent core, using the key "Quarry Ledge" bed as a datum. These results were then plotted on a copy of the initial resistivity tomogram, shown as Figure 4.

All core drill holes were completed with an Acker XLT geotechnical drill rig with an NW-D4 wireline coring setup. No drilling fluid additives other than water were used to aid completion.

The recognition of minor faults in the Jefferson City area (Cole and Osage Counties) with throw of 10 to 20 feet is not without precedent. A new bridge over Route U.S. 54 for Missouri Route 179 was completed over the top of the White Church or City Limits Fault. This fault may continue southeasterly and cross Route 63 to the north of this area; it is common knowledge that the White Church/City Limits fault crosses Missouri Route B south of Jefferson City adjacent to the

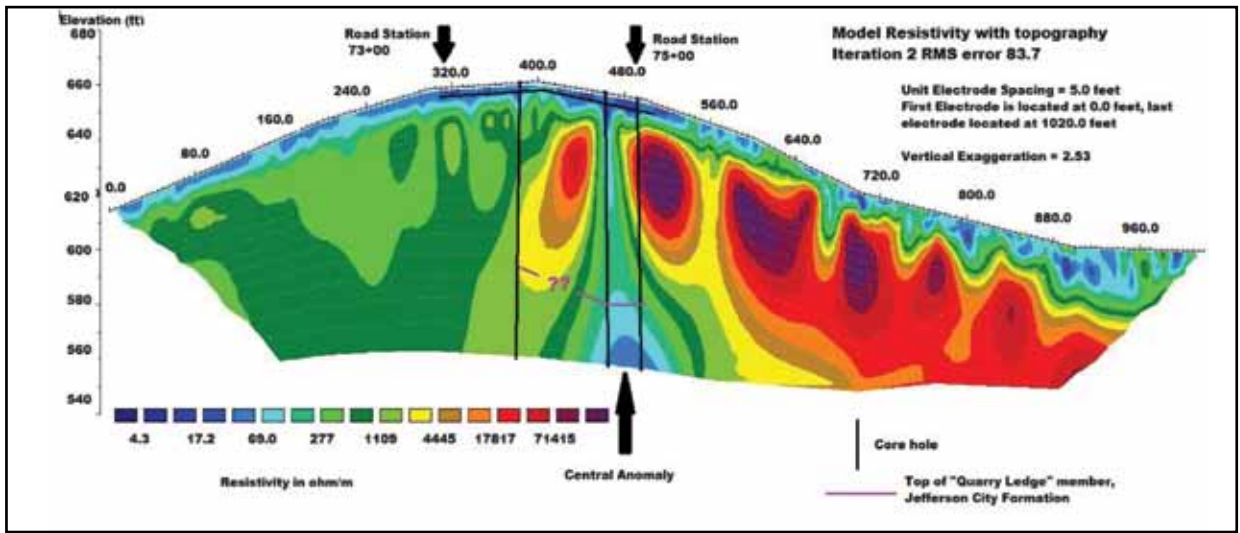


Figure 4. Initial interpretation of resistivity tomogram correlated with drilling and identification of key bed in Jefferson City Formation. Arrows indicate rock line as found between elevations 560 and 580 on Grapevine Hill, between Stations 73 + 00 and 75+00. Lower line across anomalous feature indicates elevation of top of ‘Quarry Ledge’ key bed.

Moreau River. Our office has previously used resistivity methods for the successful characterization of underground voids associated with karst terrain, this would mark the first time that resistivity would identify a structural feature in the right-of-way in Missouri, though such features have been identified successfully elsewhere (Gelis, *et al.*, 2010), and at greater depth.

### Verification of the Interpretation

Verification of the interpretation of this feature as a fault relied on actual construction taking place for the project. Groundbreaking, clearing the alignment of trees and brush, and excavation of Grapevine Hill for the planned highway began in November of 2012 and is ongoing. To insure public safety, a special provision was inserted in the contract requiring the presence of a geologist after excavation began so that the fault zone area could be verified visually and its potential impact could be determined and mitigated if necessary.

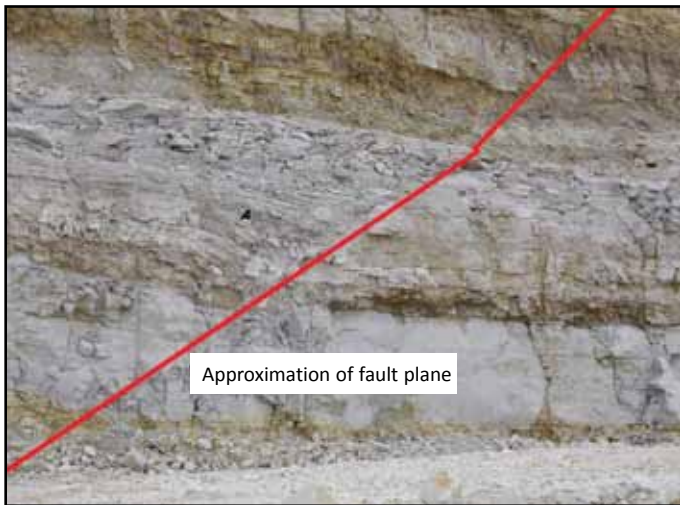


Figure 5. The Grapevine Hill Fault. Slight drag folding at ‘A’ adds evidence to interpretation of feature as fault.

### Conclusion

The use of electrical resistivity in civil construction projects is rapidly becoming a valuable tool in the characterization of the subsurface for geotechnical investigation, such as in Ohio and reported by Sheets (2002) The use of experienced professionals in processing the data for interpretation is important to achieve optimum results.

In February and March 2013, a major part of the cut for Grapevine Hill was complete. A field visit to the site verified the fault’s existence, and subsidiary minor features were noted in relation to the highway alignment. The Grapevine Hill fault is shown in Figure 5. One beneficial feature that was noted was that joint/fracture faces dipped into and away from the highway, rather than daylighting in the cut face, as can be seen in Figure 6.

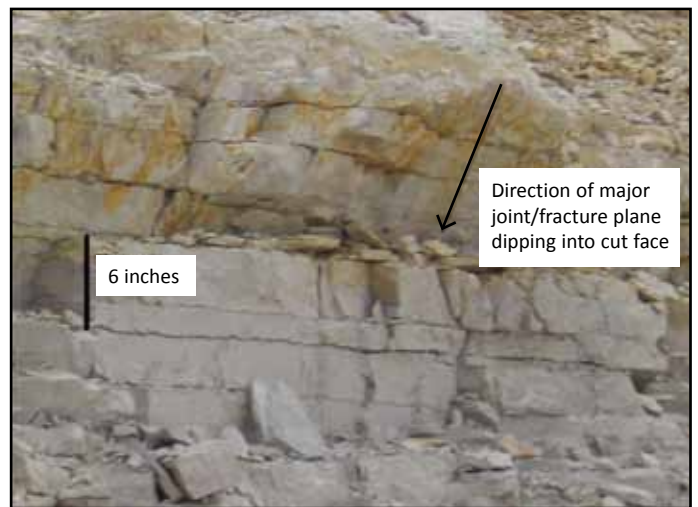


Figure 6. Grapevine Hill detail of major joint/fracture. Rock is thin-to-medium-bedded finely crystalline dolomite which is largely featureless, colloquially known as “cotton rock”.

## Acknowledgements

Thanks are due to Geotechnical Director Kevin McLain of MoDOT and former Geotechnical Director (retired) Mike Fritz, now with GeoEngineers for providing the time and encouragement to write this paper. Special thanks are due to Drs Norbert Maerz and Neil Anderson of the Missouri University of Science and Technology for providing excellent students to participate in this project, and for post-processing facilities and expertise. Also, thanks are due to AIPG Associate Editors and reviewers Dale Rezabek, Vic Ridgeley, and U Kar Winn for their reviews which helped clarify the intent of this article.

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**Reviewed by AIPG Associate Editors Vic Ridgley, CPG-05138, U Kar Winn, CPG-11219, and Dale Rezabek, CPG-09285.**

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## AIPG History



The Louisiana Section will be hosting the AIPG annual meeting in Baton Rouge next year. (1998). Louisiana Section's Booth had many visitors. Ron Alexander, Conrad Kuharic, and Jon Price were just a few that checked out the tabasco sauce and cajun spices that were being given away.

Alaska Field trip during the 1999 Annual Meeting in Girdwood, Alaska.

## AIPG History



Bobby Timmons and Gary Mitchell. Gary marched into the 1995 Awards Banquet to the sounds of bagpipes.