

The Grapevine Hill Fault - A New Fault Discovered During Preliminary Geotechnical Exploration For Route Construction

Route US 50, Osage County
Missouri



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Missouri Department of Transportation



Mission of the Missouri Department of Transportation (MoDOT)



Our mission is to provide a world-class transportation experience that delights our customers and promotes a prosperous Missouri.

Roles of the Geologist in Our Transportation Organization

- Perform Preliminary Route Engineering Soil Survey
- Provide Expertise at the District Level For a Wide Range of Geologic Problems, Including:
 - Aggregate source characterization/approval after testing
 - Utility Location and Clearance for Drilling Activities
 - Landslide/rockfall characterization/identification
 - Karst investigation
 - Abandoned underground mine investigation
 - Studies of slope stability and settlement of embankments

MoDOT Job No. J5P0951B

Route U.S. 50, Osage Co.

- My initial area of responsibility entailed the preliminary engineering soil survey.
- No District Geologist in Central District of MoDOT – after reorganization the responsibility for that position came to me *de facto*.
- Not only would I have to fulfill the District responsibilities, but the Central Office responsibilities as well.

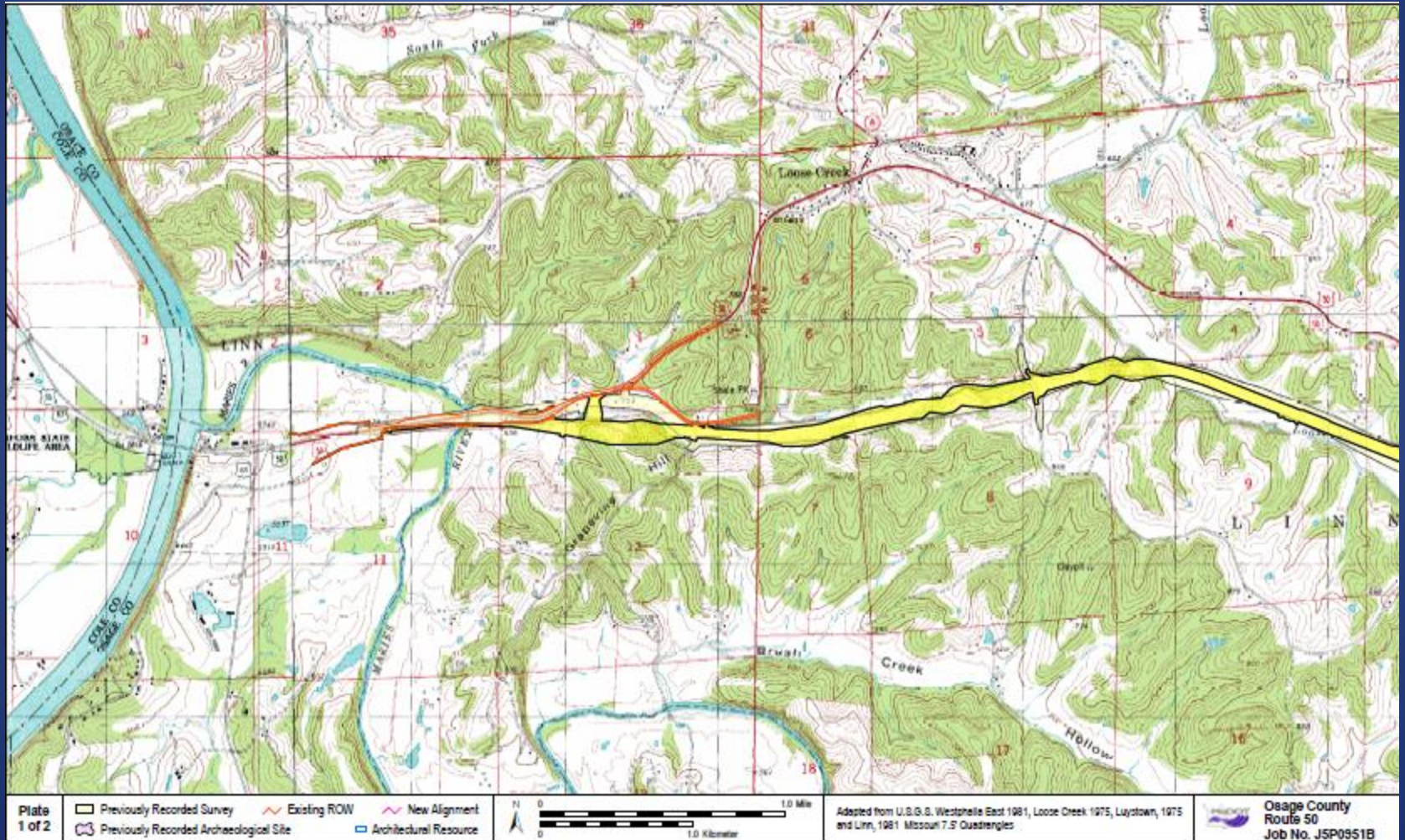
MoDOT Job No. J5P0951B

Route U.S. 50, Osage Co.

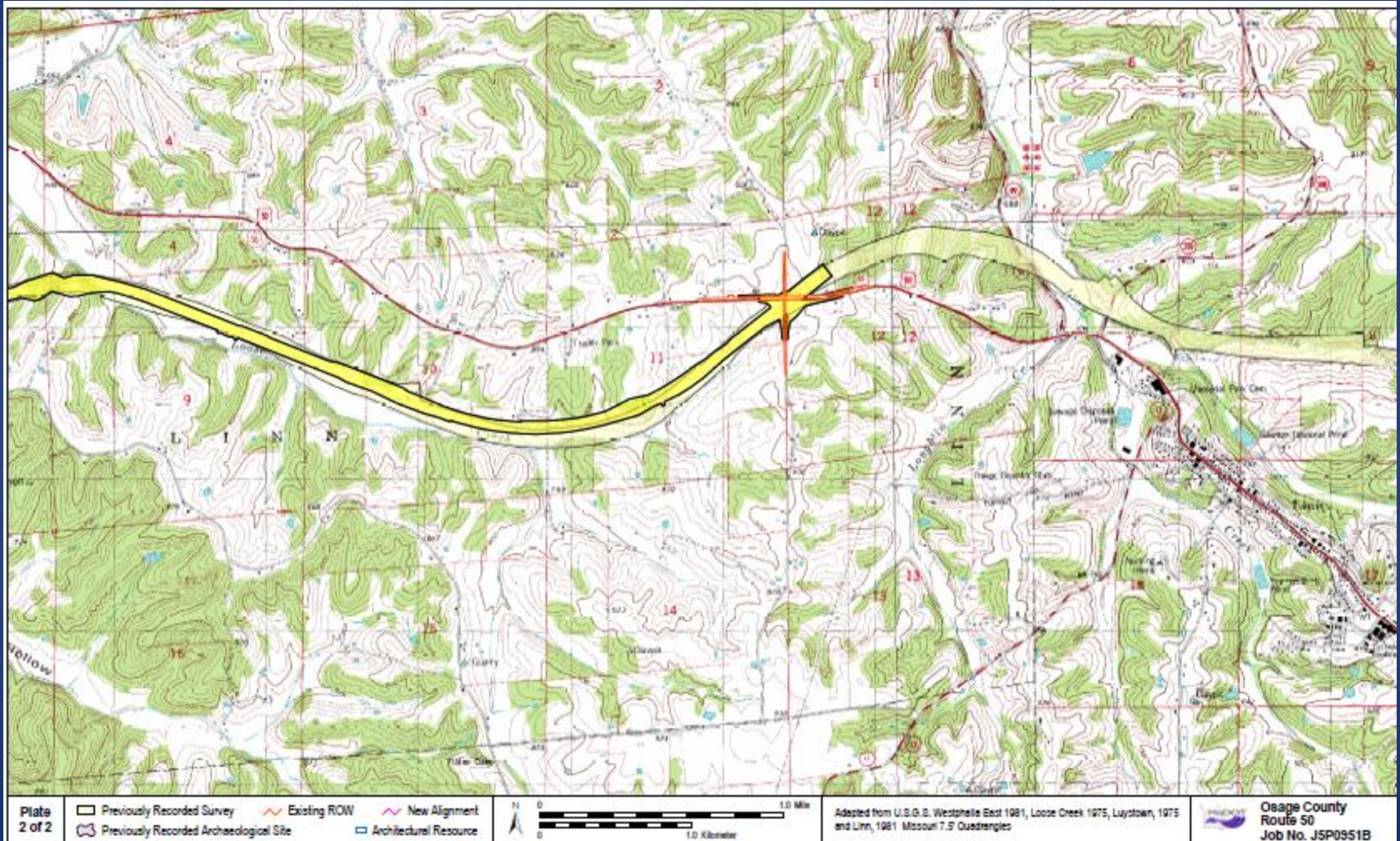
- 6.2 mile upgrade AND relocation of US 50.
- Bridges over the Maries River and Loose Creek
- Several multiple-barrel box culverts
- Terrain ranging from river bottom to ridge summits.
- Several landowners were against the project and potentially hostile.

THESE FACTORS COMBINED FOR A VERY TOUGH SURVEY, WITH HUNDREDS OF BORINGS AND A SIX-MONTH WINDOW TO COMPLETE THE SURVEY.

Location of the Survey – Map 1



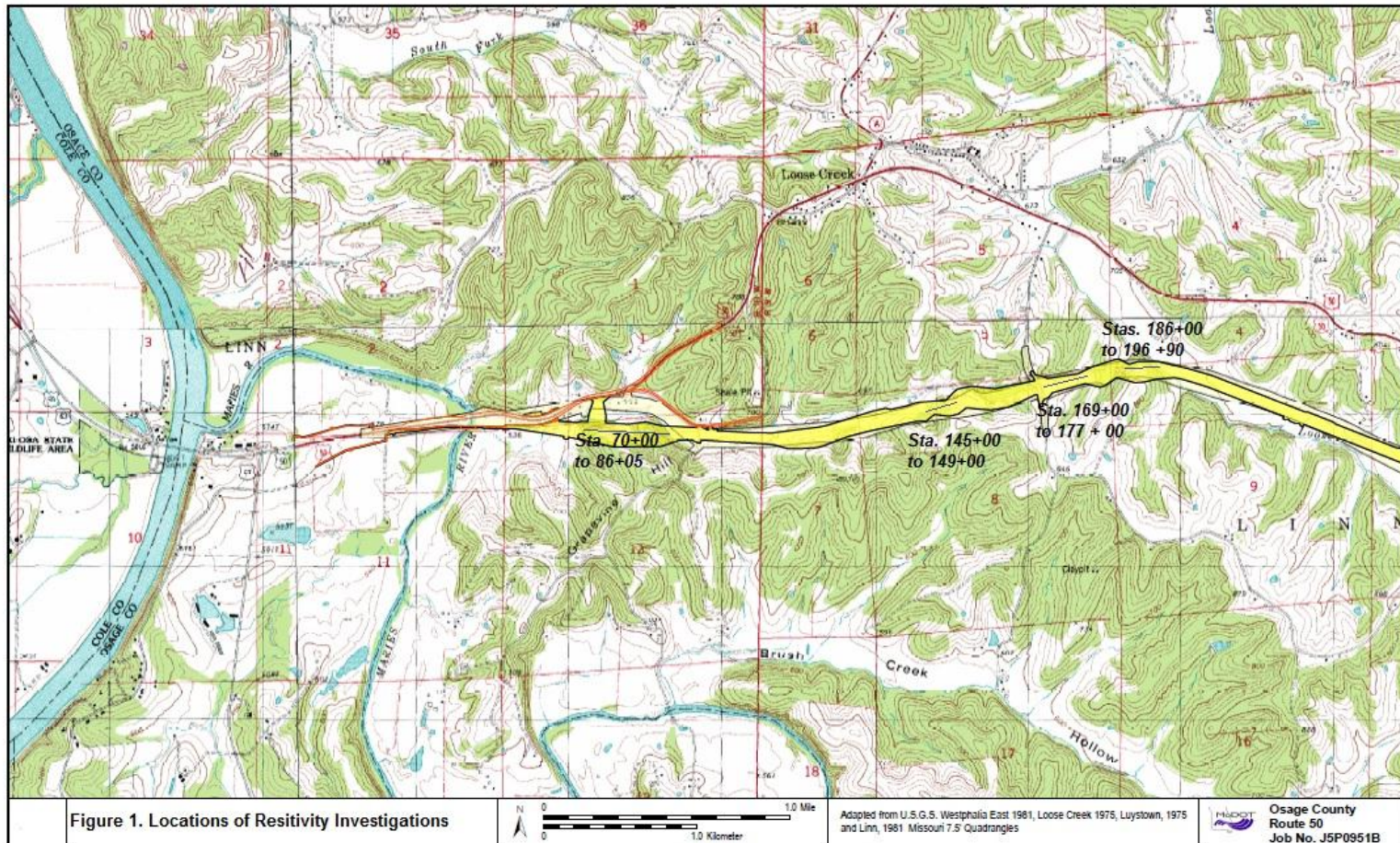
Location of the Survey – Map 2



Potential for Research

- Electrical resistivity in advance of drilling was thought to perhaps provide a way to identify areas that might be of concern during construction and 'target' these areas for further drilling to investigate those areas more completely.
- Hoped to potentially speed the soil survey process, and require fewer borings overall.

Locations Chosen for Resistivity Surveying



Local Stratigraphy

- Shallow soil overlies dolomite, chert, and argillaceous dolomite of the Jefferson City Formation (L. Ord. -Ibexian) in the majority of the survey area.

It is difficult to determine vertical location in this formation except for key beds of “Quarry Ledge” and “Maries County Oolite” – informally named units of which the latter isn’t persistent statewide.



“Maries County Oolite” - Base of the Jefferson City



Rare Jefferson City Fossils

Archeoscyphia annulata, a lithistid sponge thought to be a late link between sponges and archeocyathids



Calathium sp., a type of receptaculitid green alga but not hermatypic.



Rare Jefferson City fossils -Gastropods



Lecanospira sp.



Gastropod coquina preserved as chert consisting of *Ophileta* sp. , *Hormotoma* sp. , and *Ceratopea keithi*.

A final word on the rarity of fossils in the Jefferson City in the area

- Osage County is immediately to the south and east of Cole County, which is the type section area for the Jefferson City formation, characterized by tidalite sediments and migrating island facies.
- The fauna found in the area existed in a hypersaline environment, and are thus dwarfs. Larger representatives of these species occur to the south.

Local Stratigraphy

- Eastern mile of the project is underlain by sandstone and dolomite of the Roubidoux Formation (L. Ord.-Ibexian)
 - Characterized by two persistent key beds, the 'ledge sandstone' and a layer of mound-forming digitate stromatolites that are persistent throughout Missouri.

Roubidoux Formation stromatolites



This regionally persistent layer has been found at the Westphalia reference section in Maries County, outcrops along US 54 near Eldon, Missouri in Miller County, and as far away as El Paso, Texas, where it appears in the Kindblade Formation according to Jim Loch, one of my colleagues.

Structural Complications

- Paleosolution features – “filled sink” deposits
 - Difficult to identify where covered with soil.
 - Potential for reactivation (!) – ex. Rainbow Sink, Jefferson City, 1977.
- High-angle faulting with displacement of up to 50 feet – at the time, thought to occur only north of the survey area.

Structural Complications

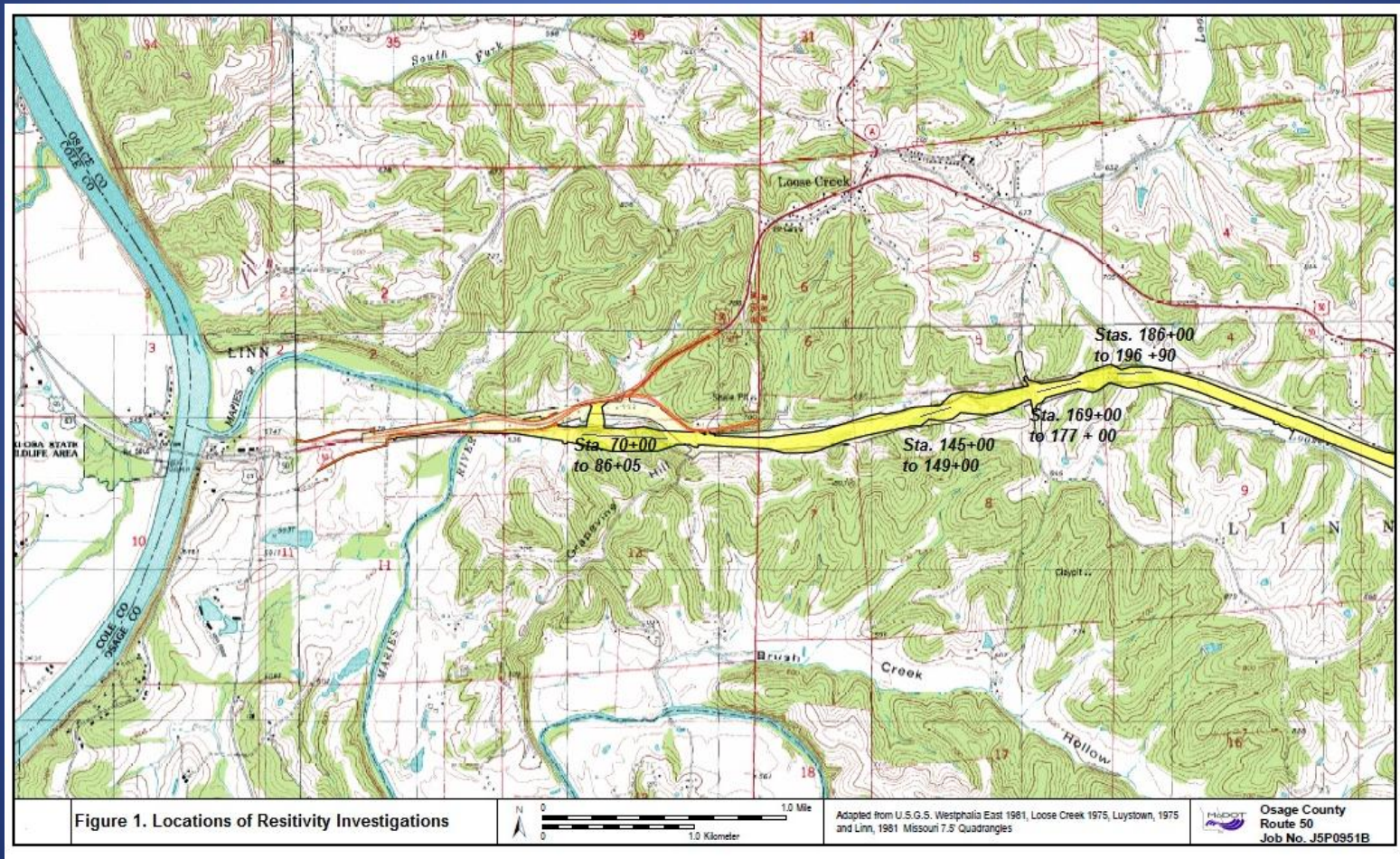
“Filled-sink” structures are known to occur in the survey area. Some are mined for refractory clay. This particular sink occurs on Grapevine Hill, and is unique in that it possesses quaquaversal bedding dipping towards the center.



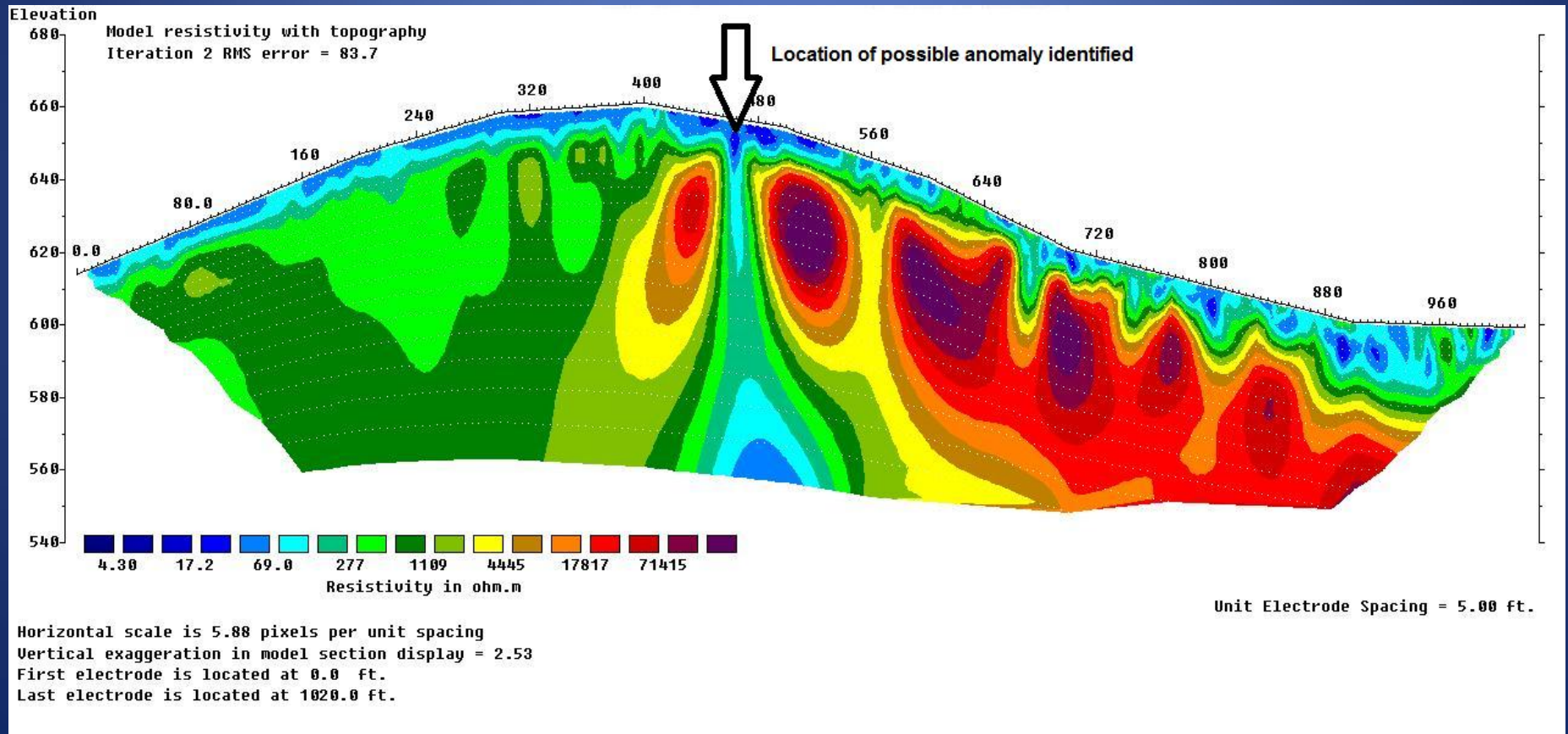
Resistivity Investigation

- Conducted by faculty-supervised students from the Missouri University of Science and Technology (MS&T, formerly the University of Missouri-Rolla)
- 4 lines chosen and surveyed using a SuperSting Resistivity meter; data processed by Dr. Neil Anderson of MS&T.

Locations of individual traverses



Grapevine Hill Traverse Locates possible anomaly



Grapevine Hill was the most important location

- Adjacent bridge would possibly be affected by any negative rock feature.
- Approximately eighty feet of cut adjacent to two lanes of highway would be exposed.
 - Depending upon the feature, rockfall could be disastrous at this location, requiring expensive mitigation or redesign of the roadway.

Possible Interpretations (Multiple Working Hypotheses)

1. The anomaly may be interpreted as a 'filled-sink' structure
 - favored since filled-sink already found on Grapevine Hill.
2. The anomaly may be interpreted as another structural feature.
 - Thus, the first task was to prove or disprove the first hypothesis so that it could be validated or rejected.*

Three holes were continuously cored to 10' below planned ditch line.



Core holes selected to 'bracket' the feature, and drill in its center.

- Determine the possible extent and influence of the feature.
- Drilling in the center of the anomaly could identify a sandstone 'cap' prevalent in nearly all of the known filled-sinks regionally.
 - Sandstone caprock in Osage, Cole Counties is Pennsylvanian in age
 - caprock may be underlain by refractory clays of the Cheltenham Formation.

What did we find?

- There was NO filled-sink structure.
 - ALL of the borings did not encounter any type of sandstone or refractory clay.
 - There was none of the brecciation normal associated with a filled-sink deposit.
- Had to be a structural feature.
 - BUT WHAT?
 - Returned to the core to reexamine and plot key beds on a cross-section.

Tabulating the results -

<u>Station</u>	<u>Offset</u>	<u>Drillers' Hole No.</u>	<u>Surface Elevation</u>	<u>Elevation Rock Encountered</u>	<u>Top of 'Lower Mudstone'</u>	<u>Base of 'Lower Mudstone'</u>	<u>Top of 'Quarry Ledge'</u>	<u>Base of 'Quarry Ledge'</u>
74 +00	C/L EBL	O-10-13	661.7	655.3	598.2	597.0	575.9	553.9
74 +70	C/L EBL	O-10-14	662.8	653.1	603.0	602.4	582.4	562.4
75 +00	C/L EBL	O-10-15	664.7	655.3	605.8	605.2	582.5	564.3

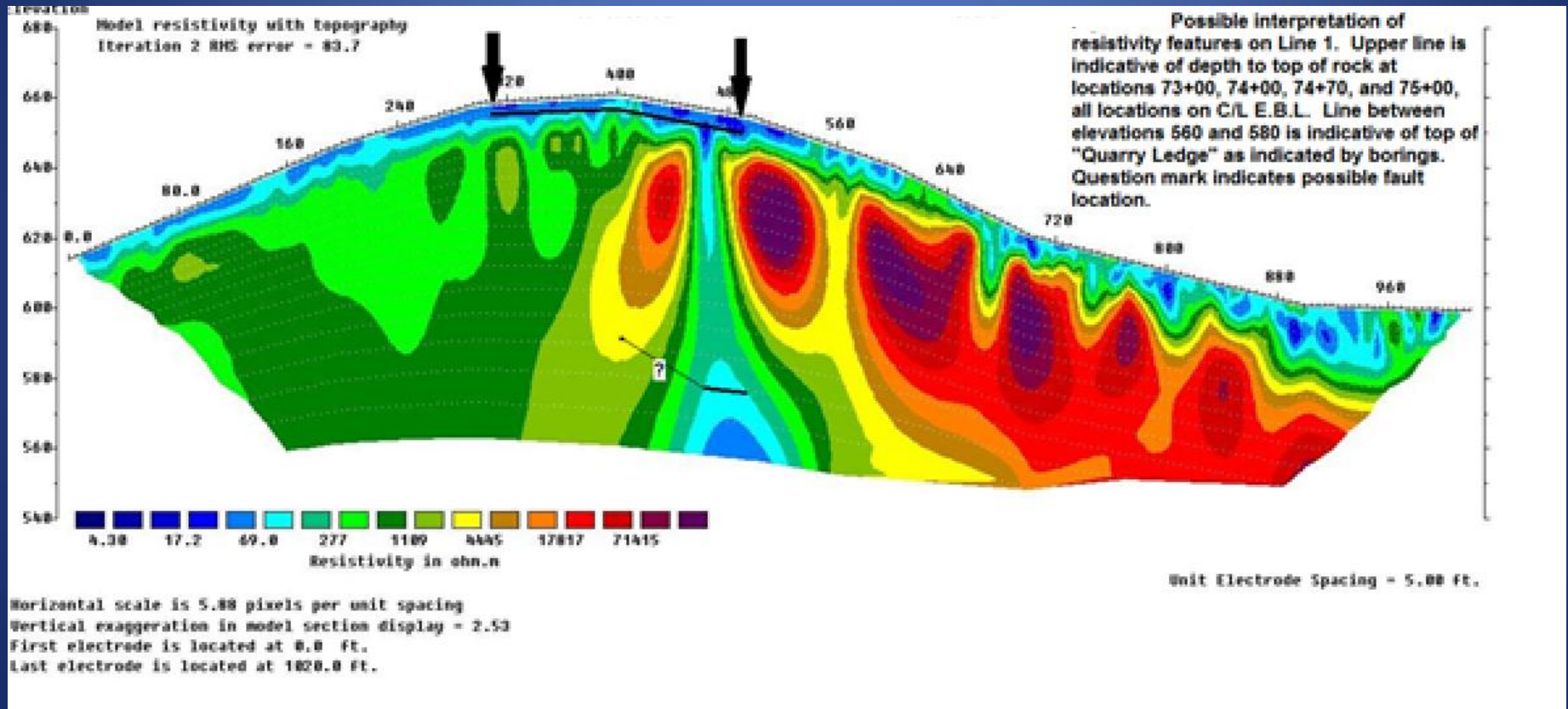


Surface elevation and depth to rock are within comparable limits.

What's this? A 10-FOOT DIFFERENCE?



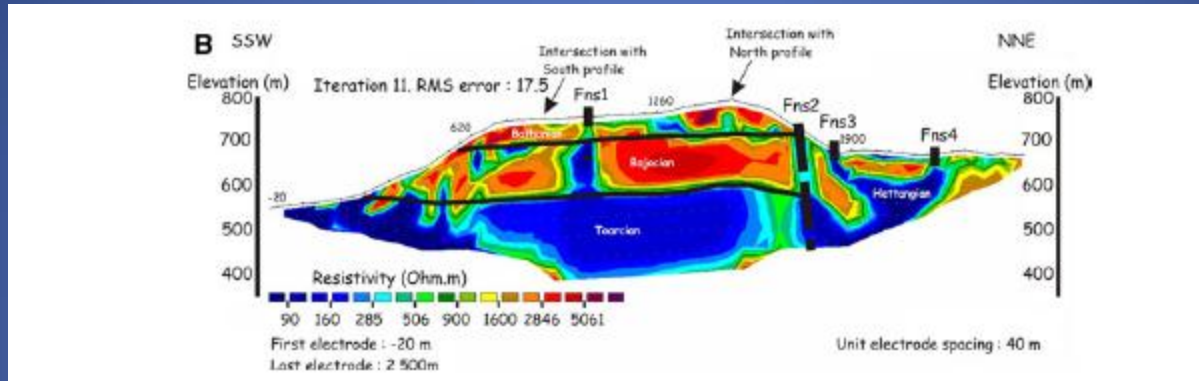
The Interpretation



Strike and dip of the rock units is nearly level.

- If it's *faulted*, then let's look at that geophysical plot again.
- Let's also look for work others have done in the identification of faults using resistivity in carbonate terrain.
 - We KNOW that resistivity has been used successfully in Missouri for karst, perhaps we can demonstrate that it can be successfully used to identify faults.

Literature Search for Electrical Resistivity Used for Carbonates



French government used resistivity at Tournemire nuclear research tunnel facility and were able to identify faults in mixed carbonate and argillaceous rocks at even greater depth – C.Gelis et al., 2010, in Pure Appl. Geophys.

“Trust, but VERIFY.”

- Does the data exhibited truly represent a fault? (Could be a small monocline)
- Direct observation of the fault trace on the ground and on the cut face would be the best evidence.
- Construction on this project began in November 2012 with groundbreaking, grubbing, and excavation – a special provision was inserted so that the fault could be verified visually so that its impact could be determined and mitigated if necessary.

VERIFIED!

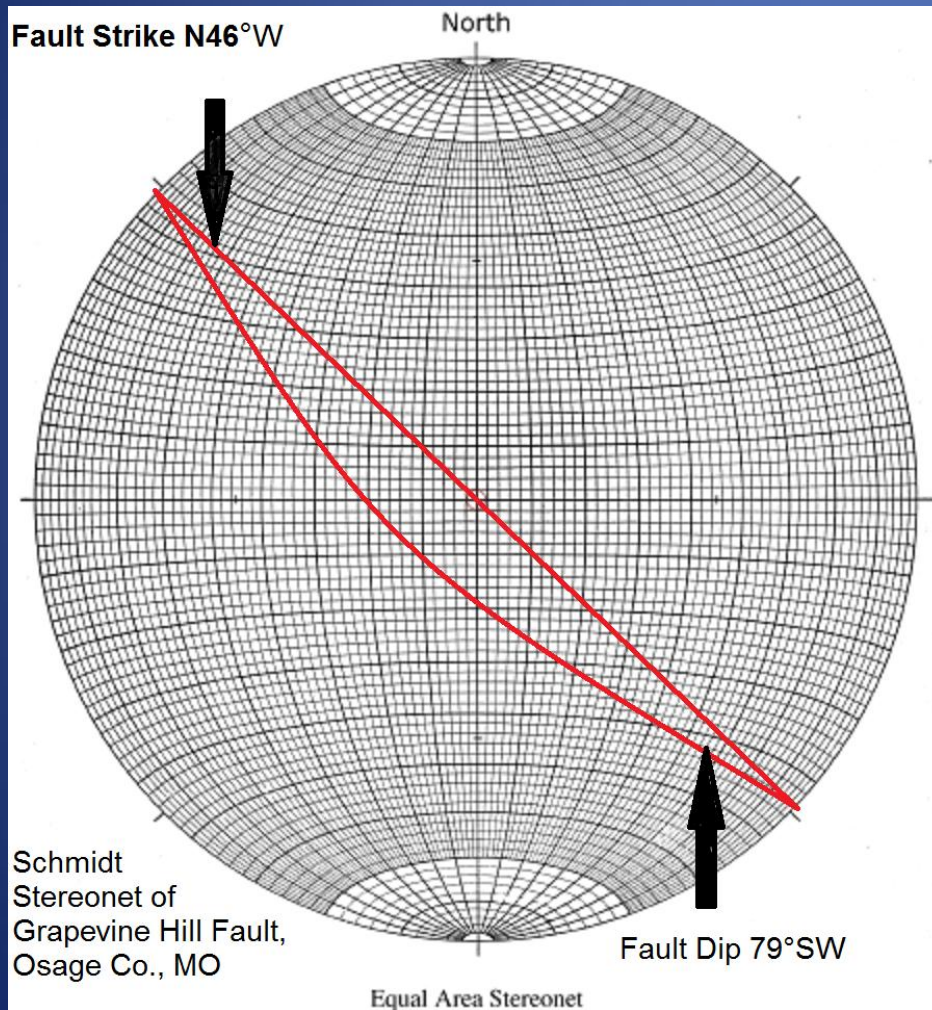


Drilling the feature
in 2010



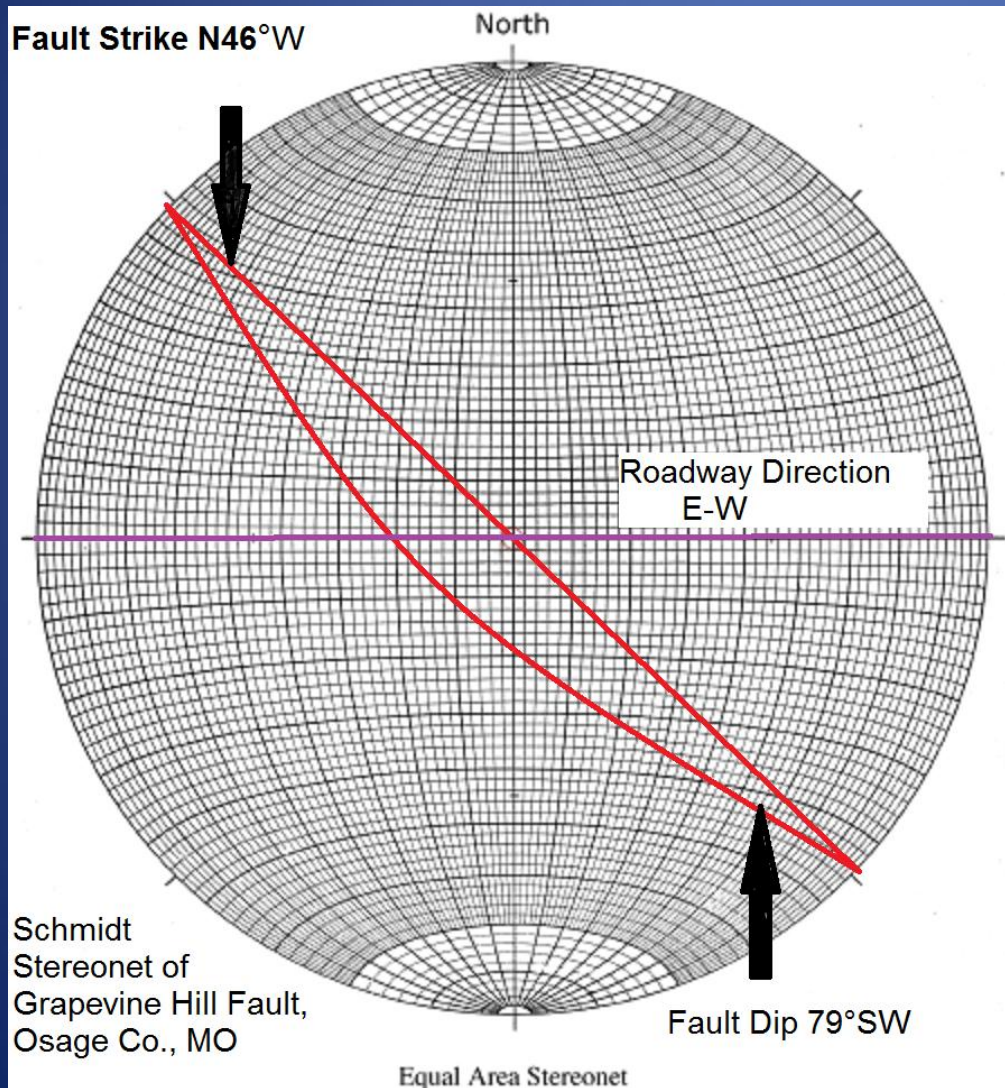
The Grapevine Hill Fault
Exposed during construction 2013

Equal-Area Stereonet Projection



Next step:
Plot the fault on a stereo net, and compare it to the cut face to determine if the fault represents a problem for the safety of the roadway.

Analysis indicates no problem.



- The dip of the fault doesn't 'daylight' to the north where the cut is, so we anticipate few problems, if any.

Results

1. Electrical resistivity proved to be useful in identification of potential problem-causing structural features in Missouri dolomite bedrock.
2. Grapevine Hill in eastern Osage County was found to possess a previously unmapped structural feature, which we propose the name of “Grapevine Hill Fault”.

Acknowledgements

- Dr. Neil Anderson and Dr. Norbert Maerz of Missouri University of Science and Technology, Rolla, Missouri.
- Mike Fritz (ret'd) and Kevin McLain of the Missouri Department of Transportation's Geotechnical Section who I consider to be friends as well as colleagues.