PROFITS AND PITFALLS OF USING GEOPHYSICAL METHODS FOR ABANDONED MINE MAPPING

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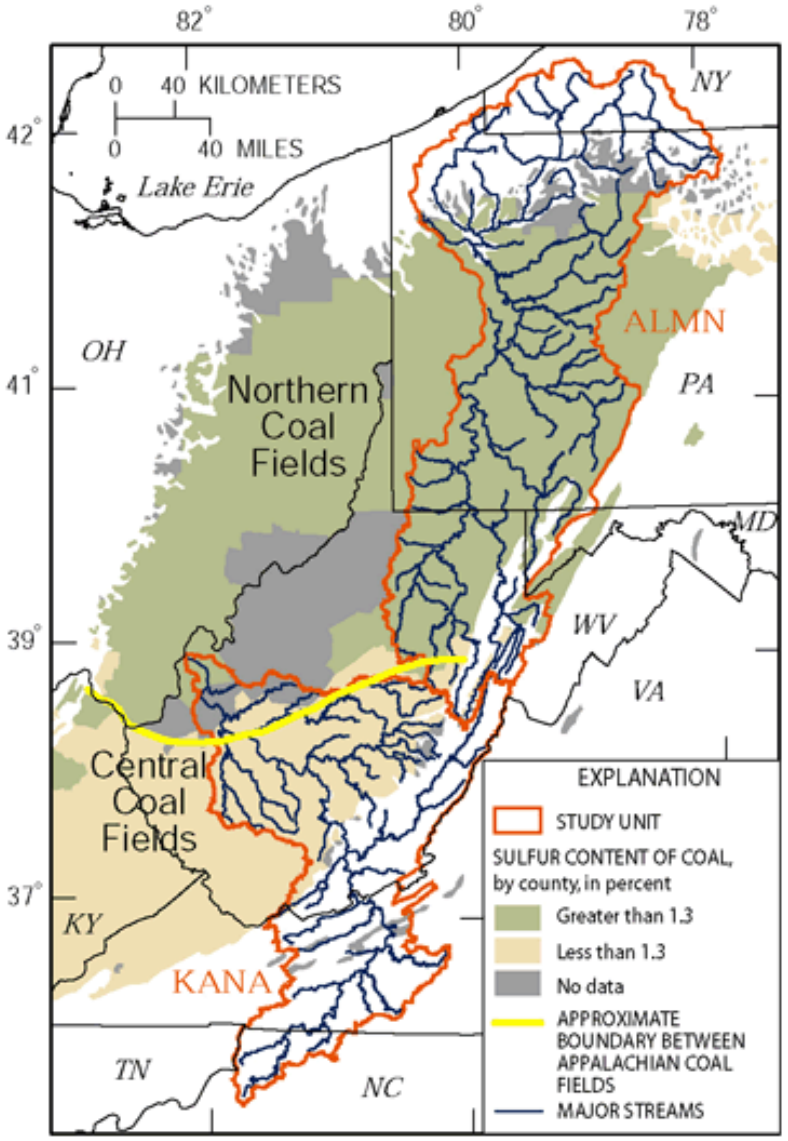
Abandoned mines are ubiquitous across the landscape of western Pennsylvania, West Virginia and Ohio.

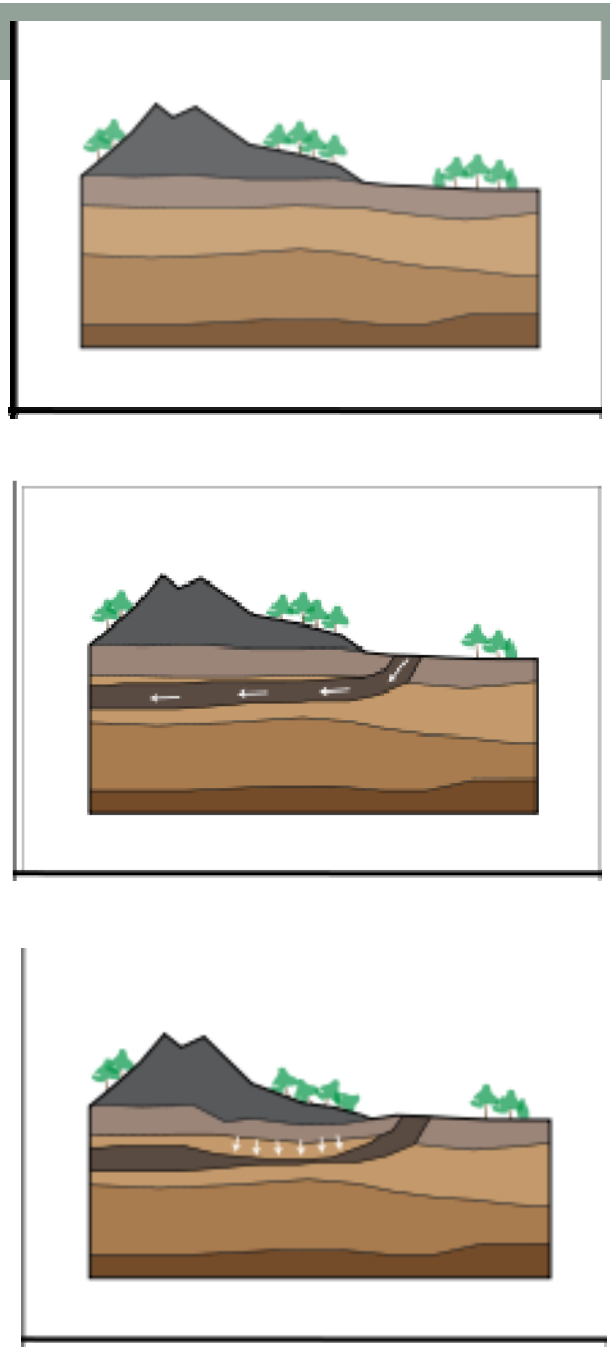
- prompting more extensive deep site investigations



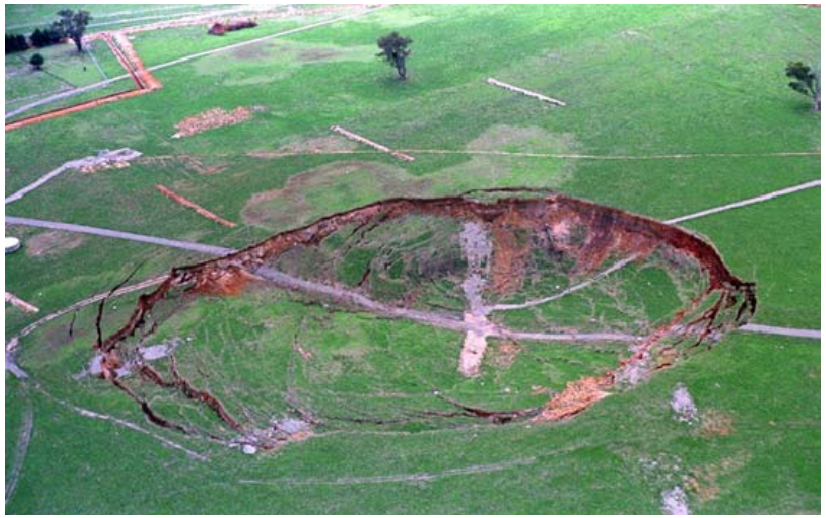
Paybins, K.S., Messinger, Terence, Eychaner, J.H., Chambers, D.B., and Kozar, M.D., 2000, Water
Quality in the Kanawha–New River Basin West Virginia, Virginia, and North Carolina, 1996–98:
U.S. Geological Survey Circular 1204, 32 p., on-line at http://pubs.water.usgs.gov/circ1204/

How do the voids form?

- Historic coal seams were mined out, resulting in an open tunnel.
- The tunnel was held in place with pillars, or retreat mined.
- Over time the lack of adequate support below the overhead rock, results in cave-ins of the tunnel, and eventually, subsidence on the surface.



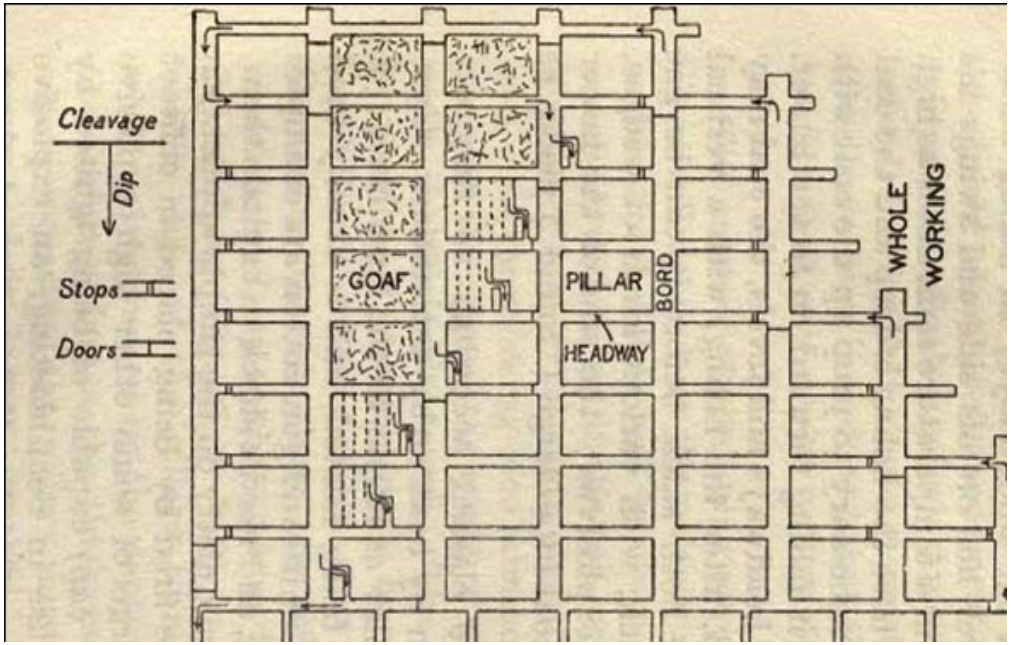
Mine Subsidence



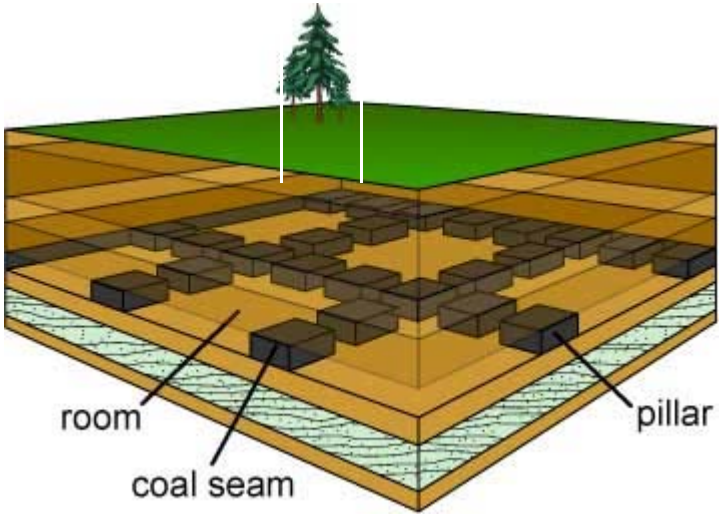
"Elura" by Rolinator - http://en.wikipedia.org/wiki/Image:Elura.png. Licensed under Public Domain via Wikimedia Commons – https://commons.wikimedia.org/wiki/File:Elura.png#/media/File:Elura.png

Photos courtesy of PA DEP: http://www.dep.state.pa.us/msi homeowners/damage.html#picbase

Detailed information of subsurface conditions is crucial for the management of existing subsidence problems and to avoid the development of potential subsidence.



http://www.wveha.org/history/Mechanization



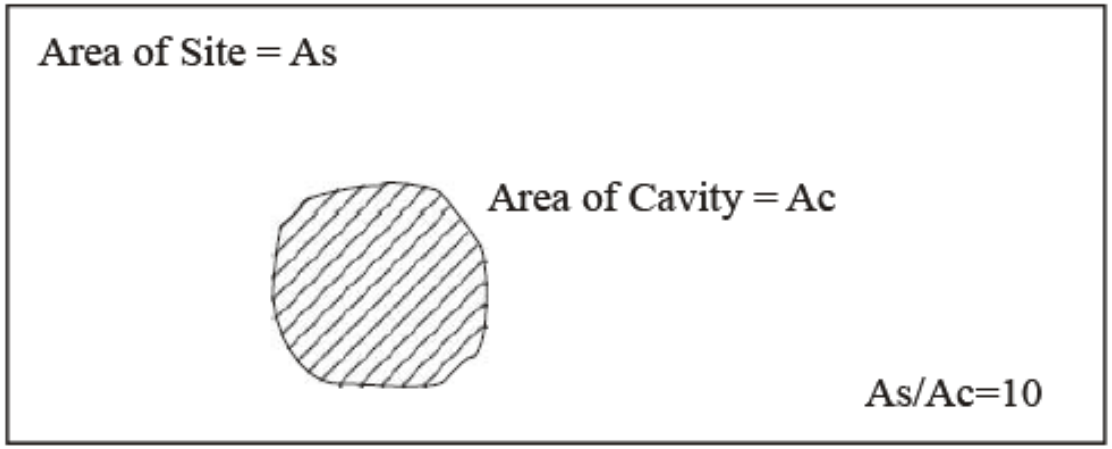
http://www.gg.uwyo.edu/content/lecture/energy/fossil_fuels/coal/production/underground/methods/room-pillar/retreat.asp?type=ss&callNumber=14276&color=993300&unit=

Geophysical data often improves the results of geotechnical studies, whether by connecting the data between boreholes or by guiding engineers with the placement of additional borings.

Why use geophysics?

- Non-destructive
  - Ideal for populated areas and sensitive areas (e.g., environmental and archaeological)
- Efficient
  - Evaluation of large areas in short time
- Cost Effective
  - Can reduce or eliminate invasive tests
- Comprehensive
  - Combining non-invasive/invasive or multiple non-invasive methods leads to greater confidence

Cost Effective and Efficient



Number of Borings required to provide a given probability of detection

Probability of Detection	As/AC=10	As/AC=100	AS/AC=1000
100	16	160	1600
98	13	130	1300
90	10	100	1000
75	8	80	800
50	5	50	500
40	4	40	400

Benson, R., Yuhr, L., and Kaufmann R., 2004, Some Considerations for Selection and Successful Application of Surface Geophysical Methods, Proceedings of Highway Geophysics Symposium.

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Traditional Exploration

- Point values
- Inefficient for large volumes of soil/rock
- Invasive
- Very precise data

Geophysics

- “Continuous” sampling
- Efficient for large volumes of soil/rock
- Non-invasive
- Ambiguous data

Best when used in combination.

Ground truthing is essential!

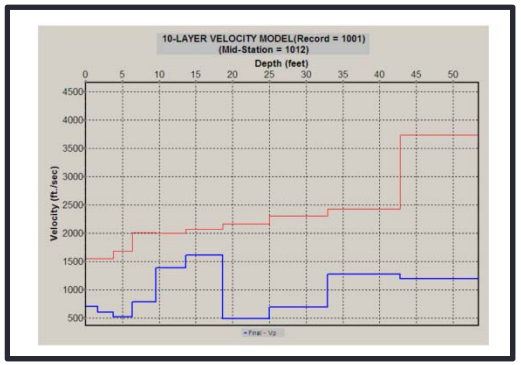
Mapping Historic Underground Coal Mines

Geophysical Techniques:

- Electrical Imaging
  - Most common: affordable, depth and resolution
  - Provides the most information
- Seismic Reflection
  - Less common: expense is a balance depth and resolution
- Gravity
  - Not frequently used: expensive and low resolution
  - Works well in culturally noisy environment

Geophysical Survey Design

- Depth versus Resolution
  - Target depth
  - Survey objectives
- Limitations of geophysical techniques
- Rock properties
  - Successful geophysical surveys require a measurable contrast

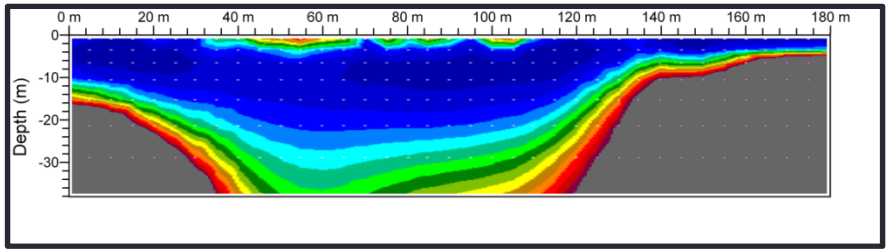


Electrical Resistivity

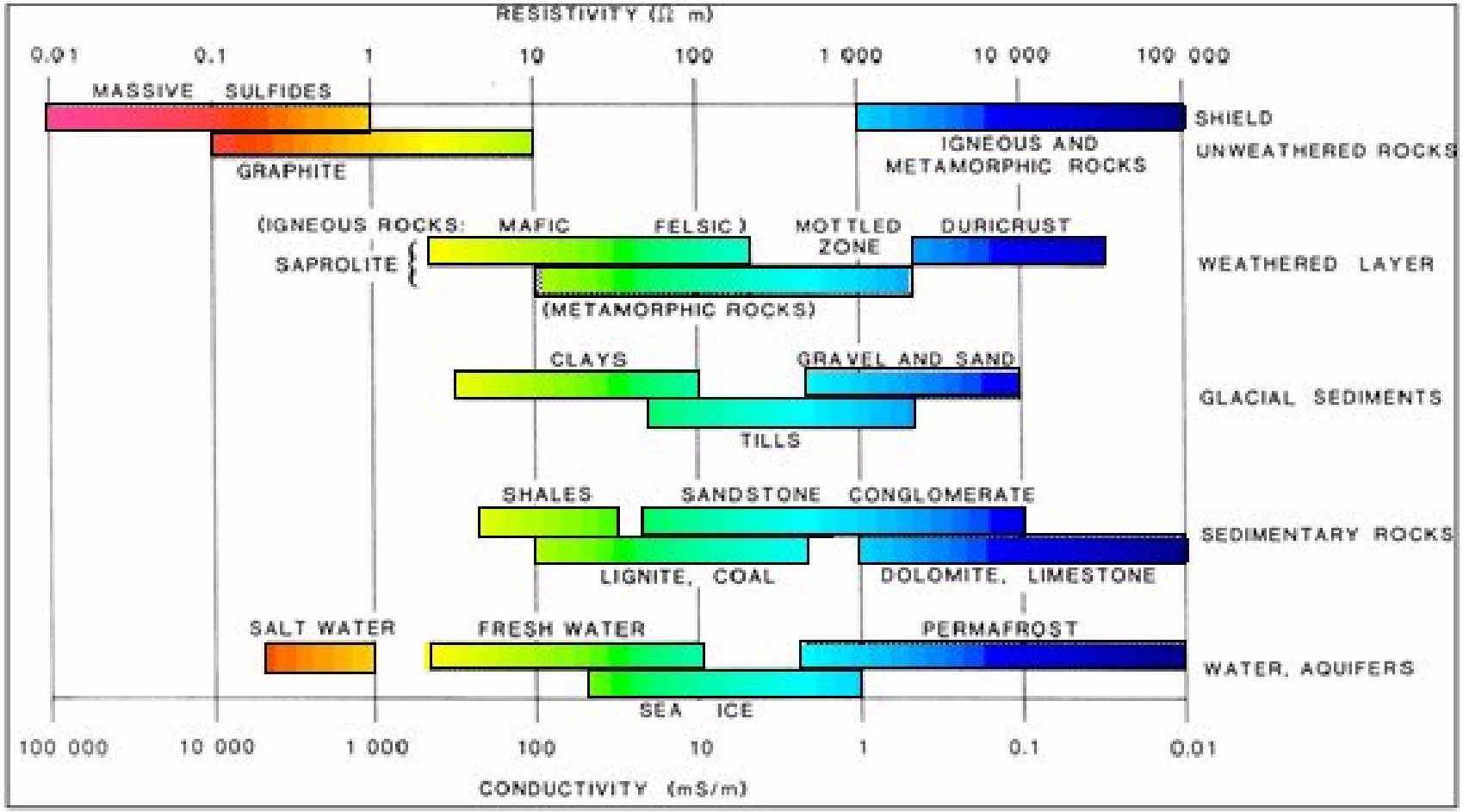
- Resistivity is:
  - The governing relationship between current density and electrical potential gradient
  - Measure of material's resistance to current flow
  - Reciprocal of conductivity
  - An intrinsic property of materials

Electrical Resistivity

- Properties that affect resistivity of soil or rock include:
  - Porosity
  - Water content
  - Composition (clay mineral and metal content)
  - Salinity
  - Grain size distribution



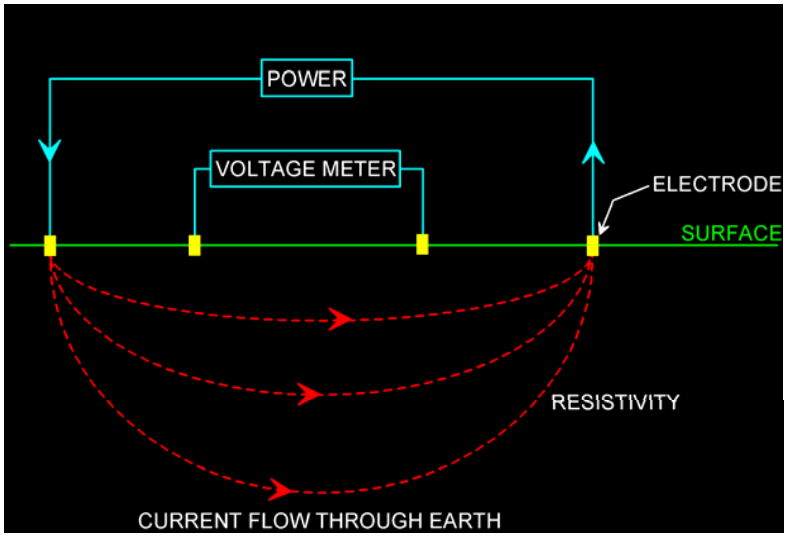
Electrical Resistivity



(Palacky, 1987)

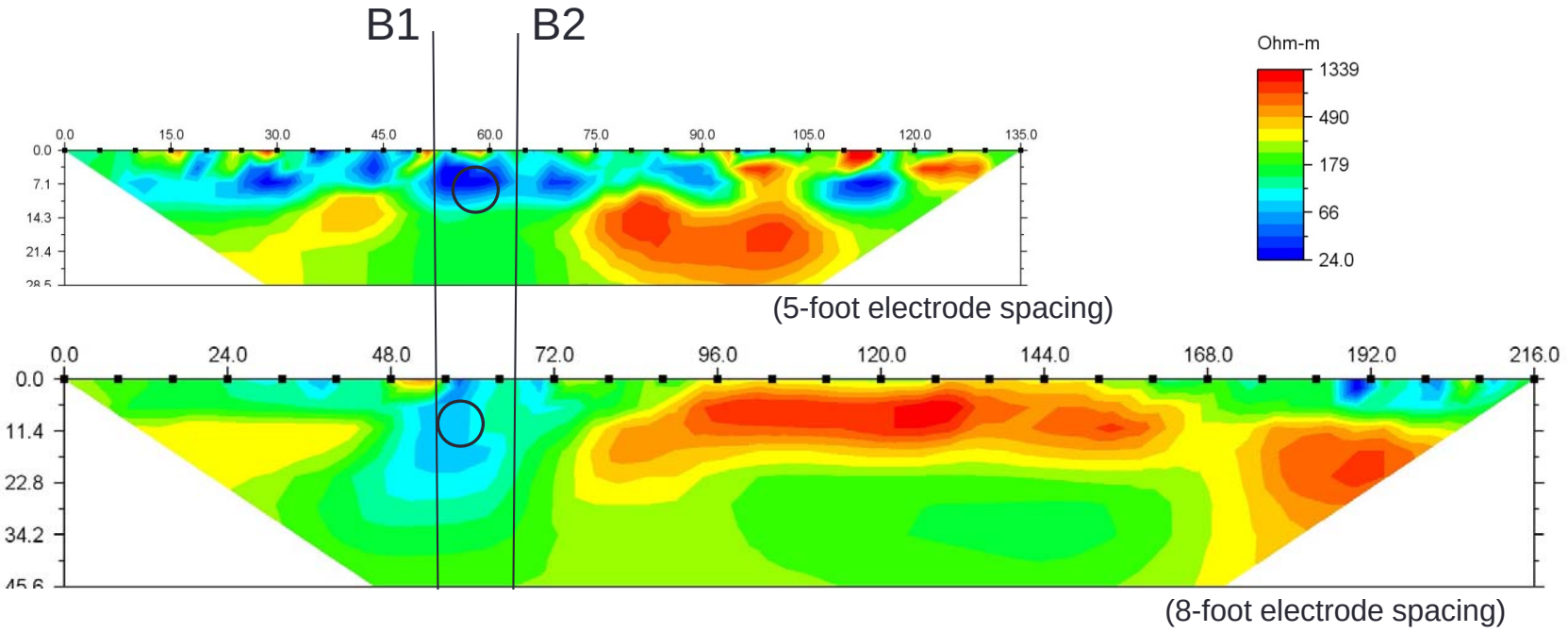
Electrical Resistivity

- Four metal probes are placed in the ground (G)
- Current (I) is induced between paired electrodes (c_1 and c_2)
- Potential difference (ΔV) is measured between paired voltmeter electrodes (p_1 and p_2)
- Apparent resistivity (ρ_a) is calculated



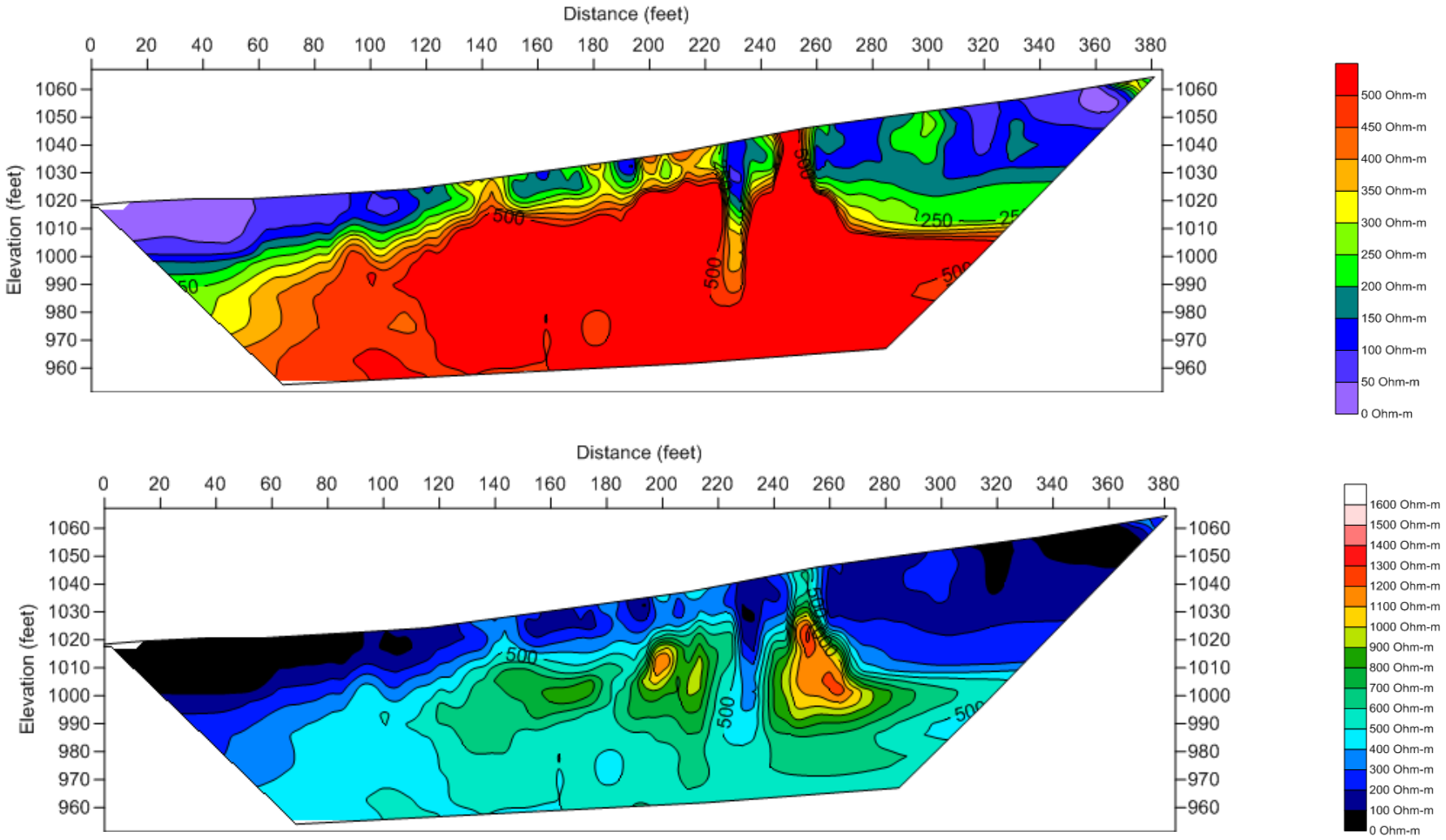
Resolution - Electrode Spacing

Electrode configuration dictates depth of penetration and data resolution.



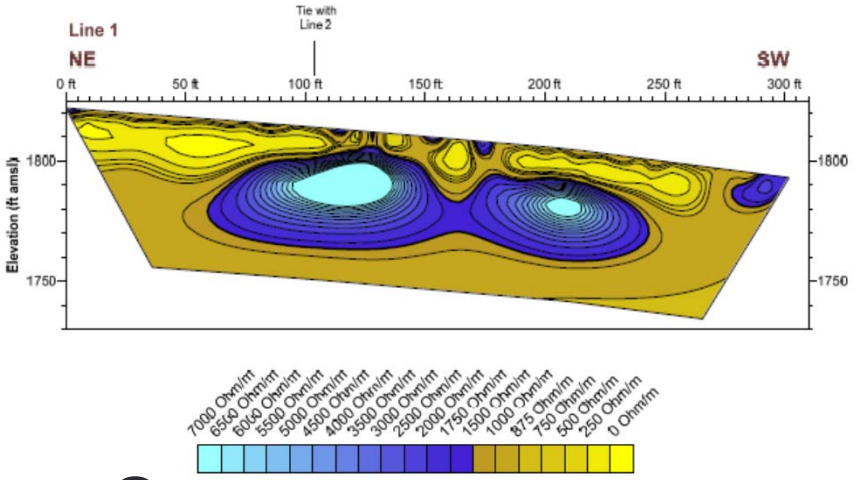
Same line acquired using different electrode spacings

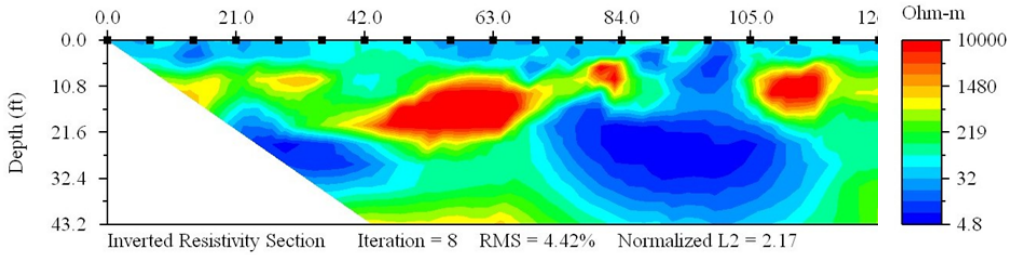
Color Scales and Interpretation



Electrical Imaging for Coal Mine Mapping

EI is an optimal technique for mapping voids

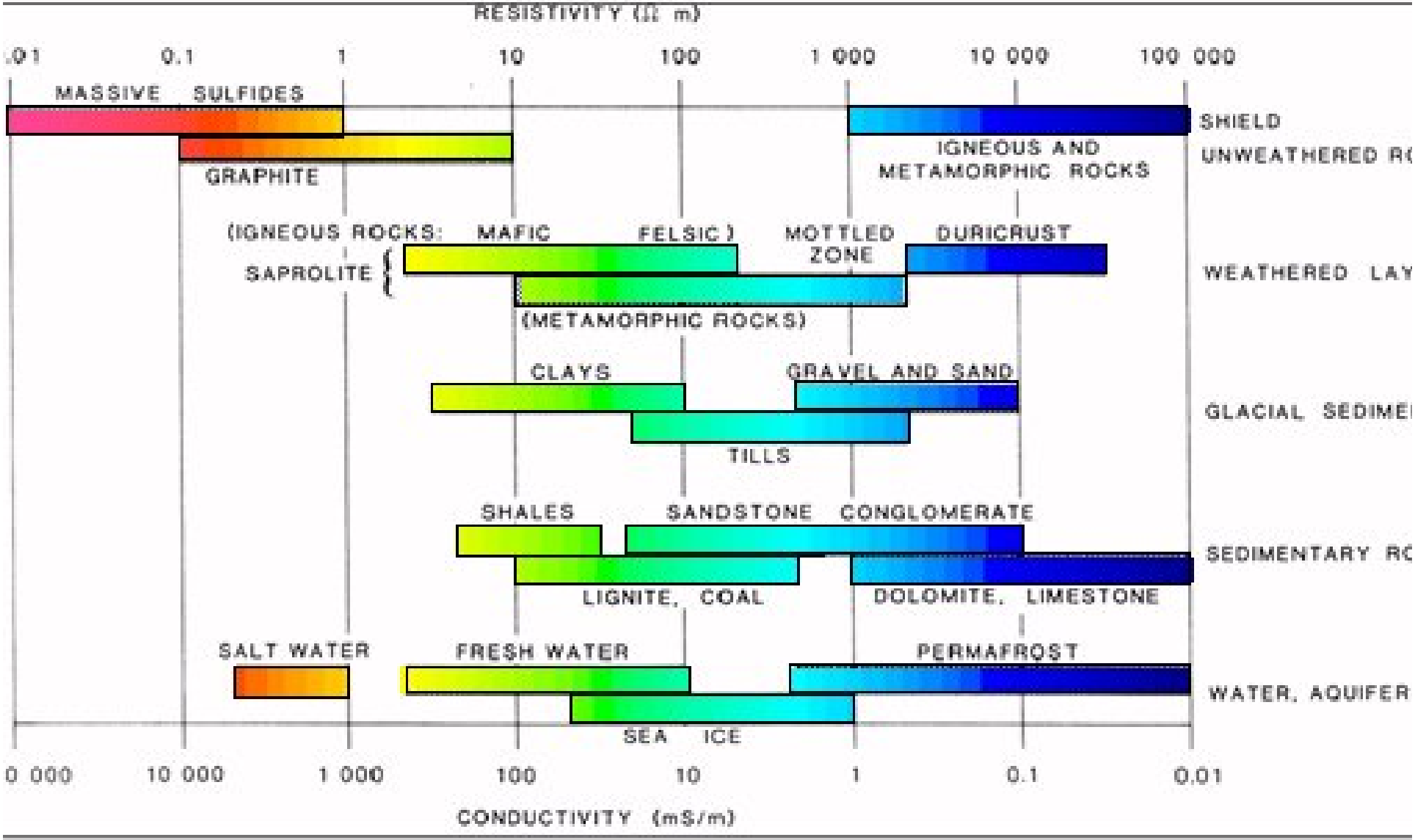




Open voids are highly resistive

Clay filled voids are highly conductive

What if there is no Electrical *Contrast?*



Clay filled void

4.8

CASE STUDIES

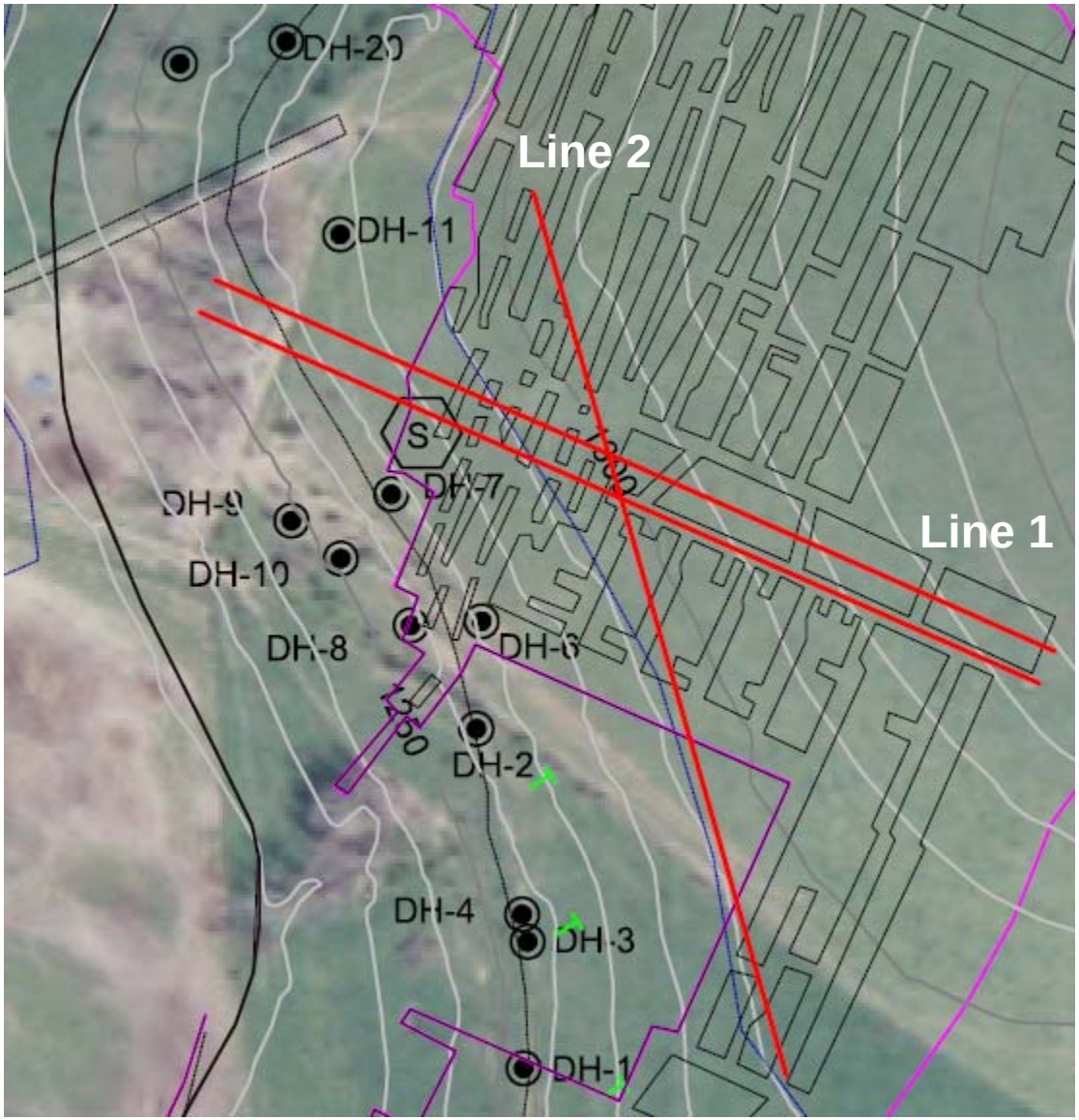
- Pre-Construction – Avoidance
- Existing Structures - Repair

Case Study

- Fayette County, PA
- Existing mine

Objective:

Attempt to delineate room and pillar structure



- Performed 3 electrical resistivity profiles

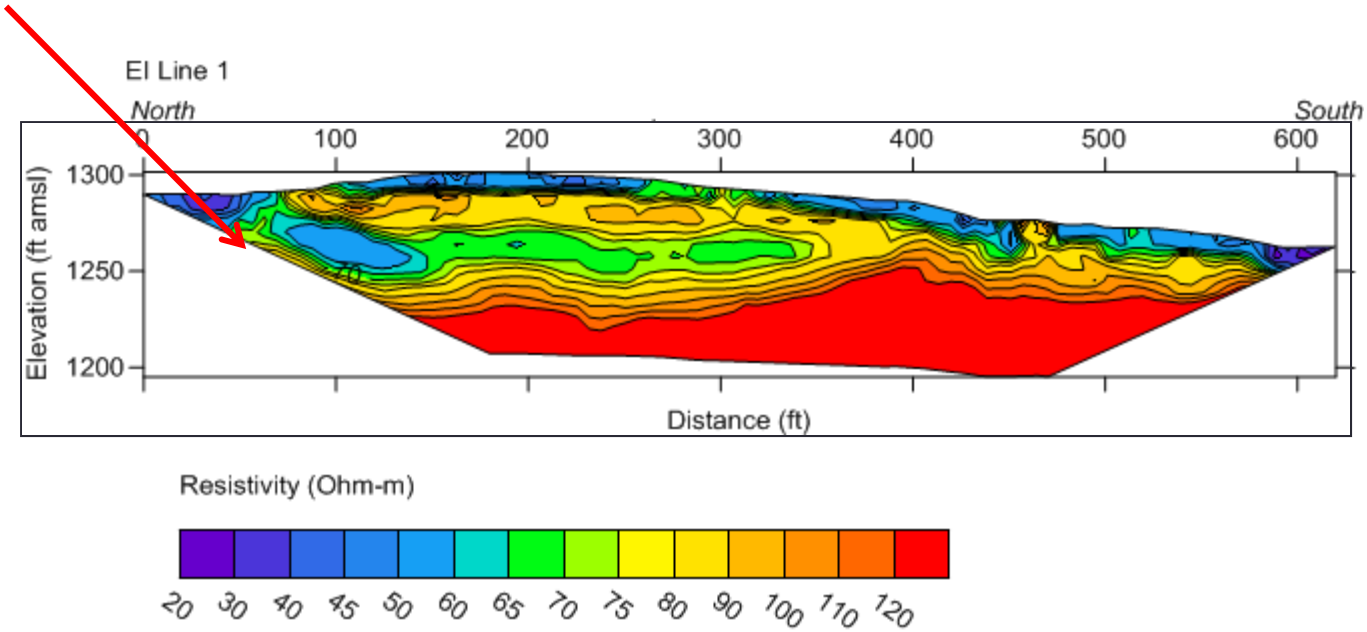
- Site was a sloped hill on a farm

- Line placement was an issue

- No structures present

Line 1

Mine structure and elevation according to the available map

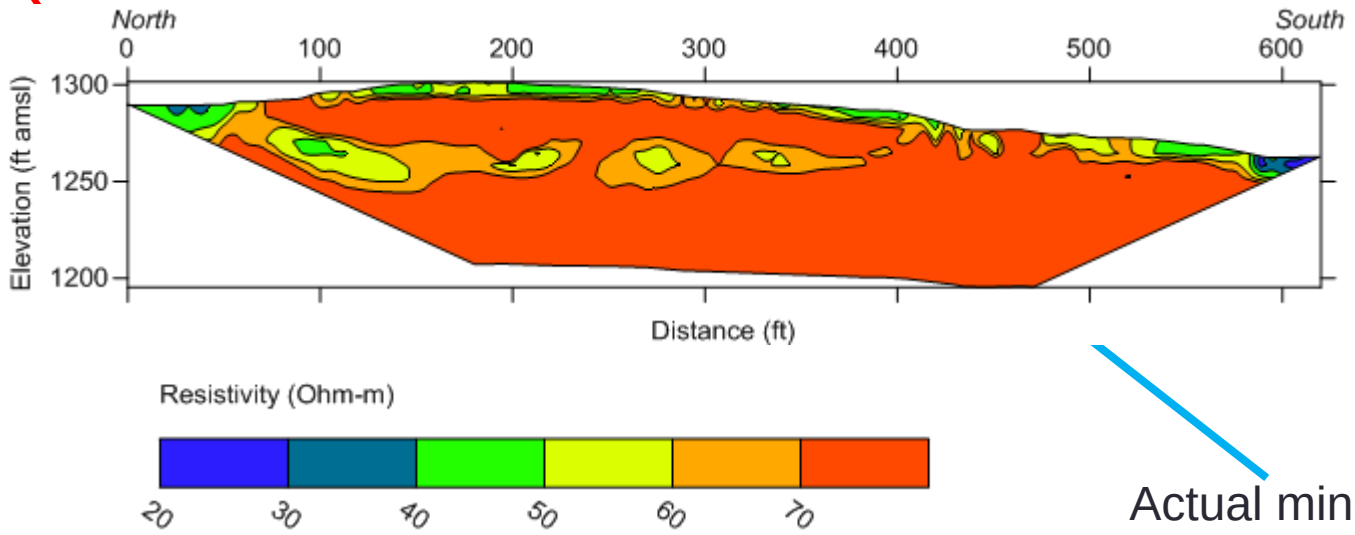


Clay or water filled mine void set in resistive rock

Line 2

Room
Pillar

Mine structure and elevation according to the available map

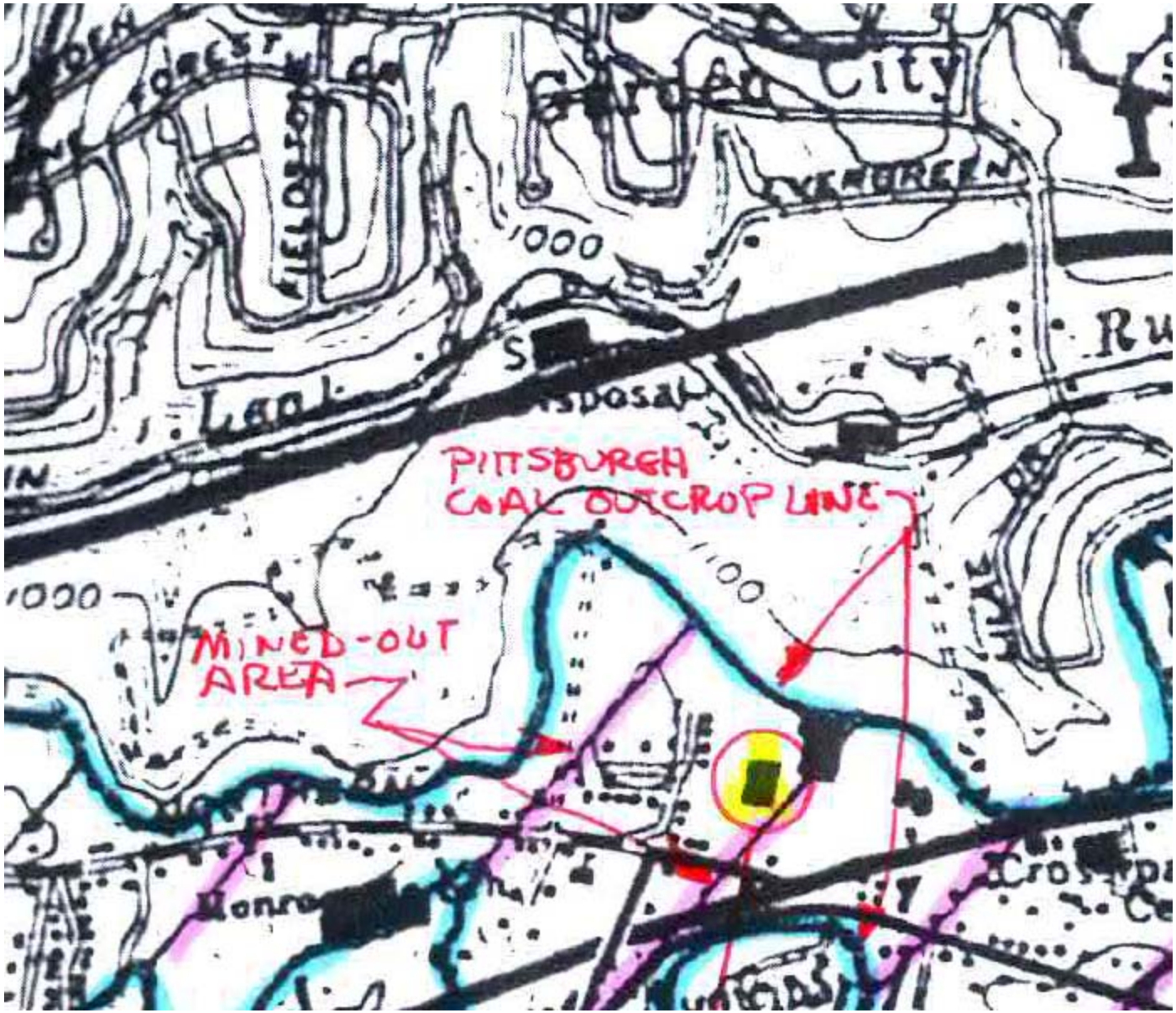


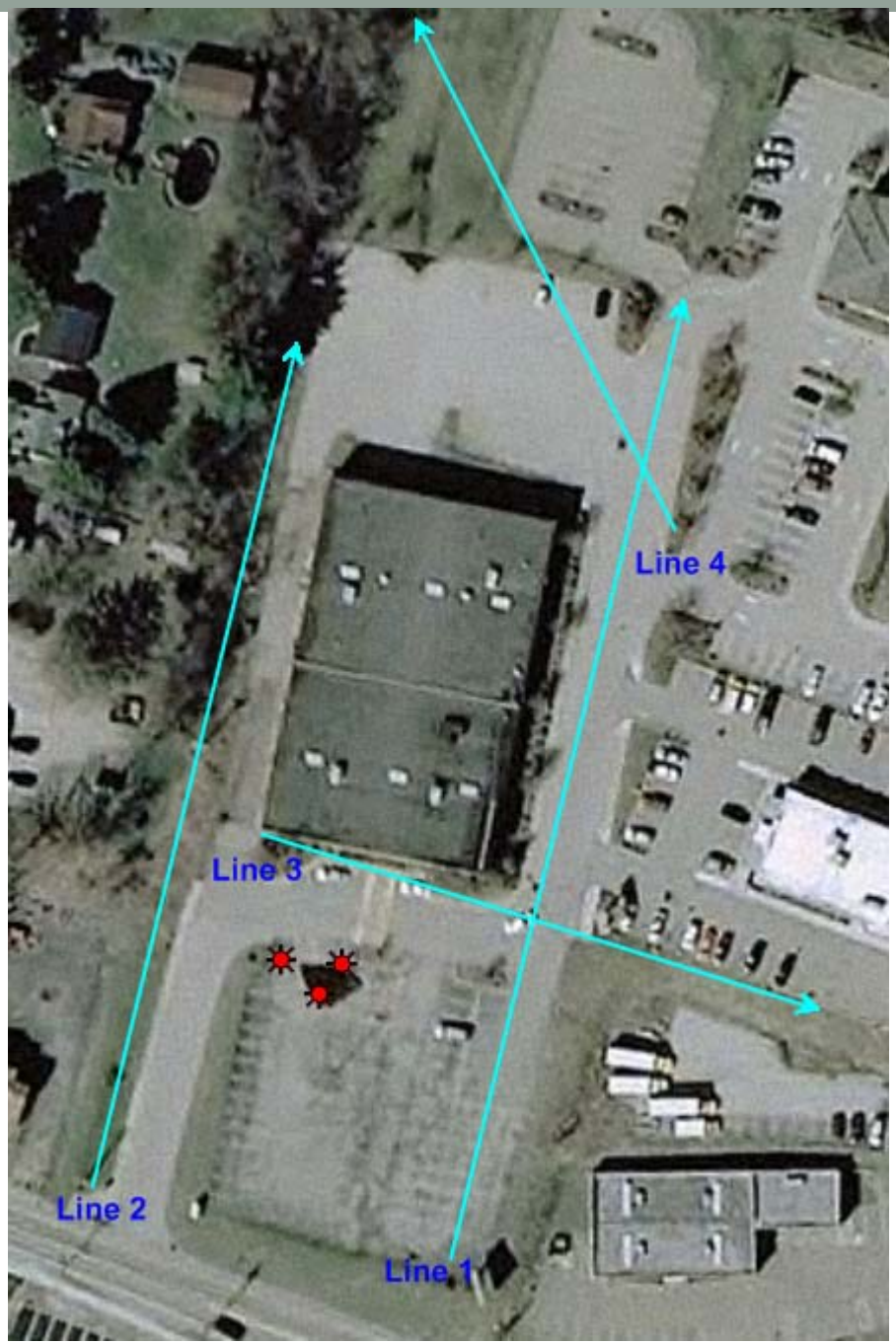
Actual mine elevation

Clay or water filled mine void set in resistive rock

CASE STUDY

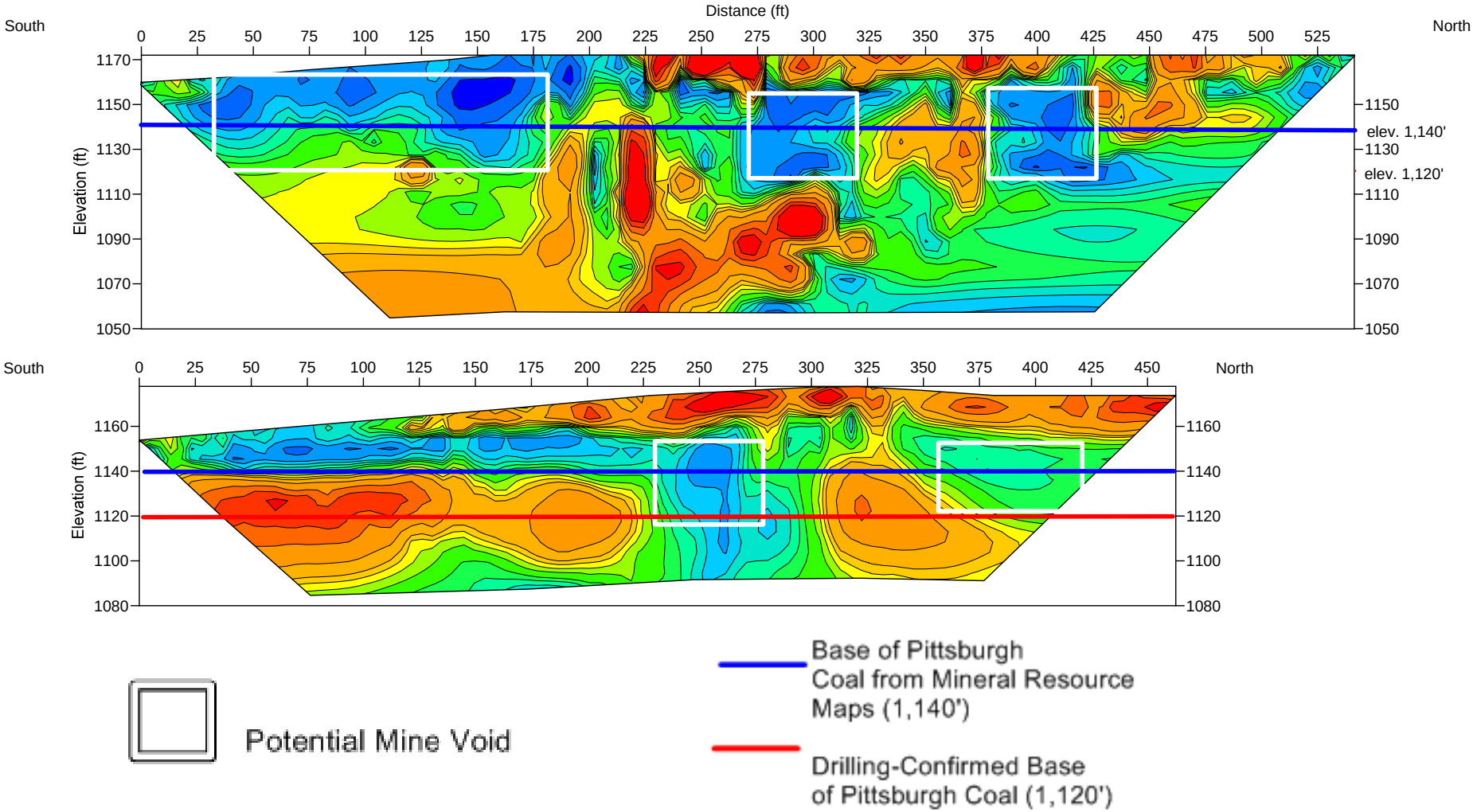
- Existing retail site
- Obvious damage to structure
- Overlies documented mining of Pittsburgh coal


PITTSBURGH
COAL OUTCROP LINE
MINED-OUT
AREA

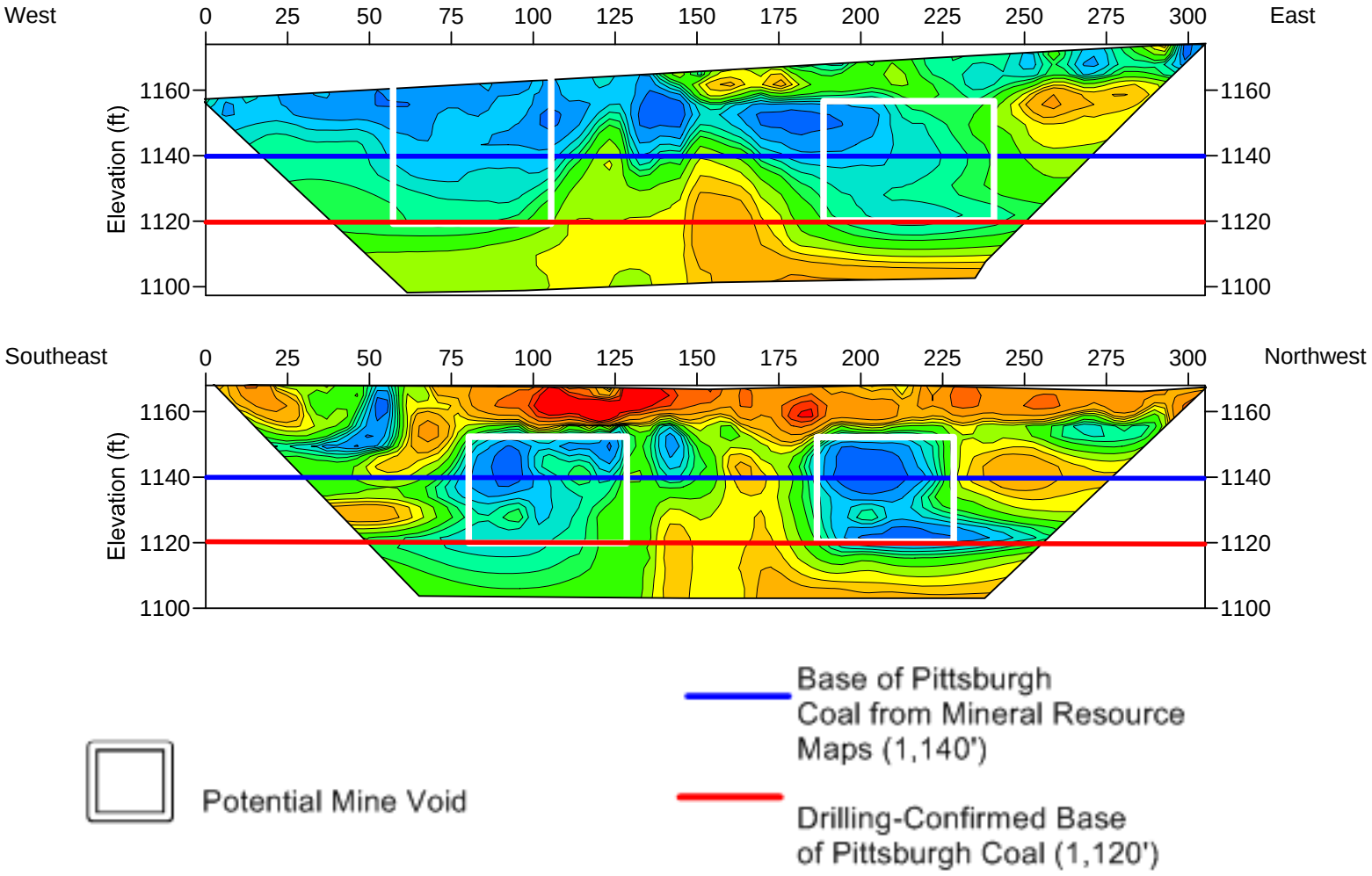


- Acquired 4 EI lines designed to look deep while maintaining high resolution
  - Long lines with tight electrode spacing
- Developed area introduced additional challenges
  - Asphalt parking lot
  - Subsurface utilities

Electrical Resistivity Data



Electrical Resistivity Data



(Over-) Interpretation

EI Line

Location of Potential Mine Void

Approximate boring location (Fagan, 2009)

Inferred In-Place Coal Map

Conclusions

- When geophysical surveys are properly designed to map the target of interest, geophysical surveys can be a very effective way to map abandoned coal mines

- Users need to keep in mind that geophysics is interpretative, and dig deeper into interpretations and their assumptions