



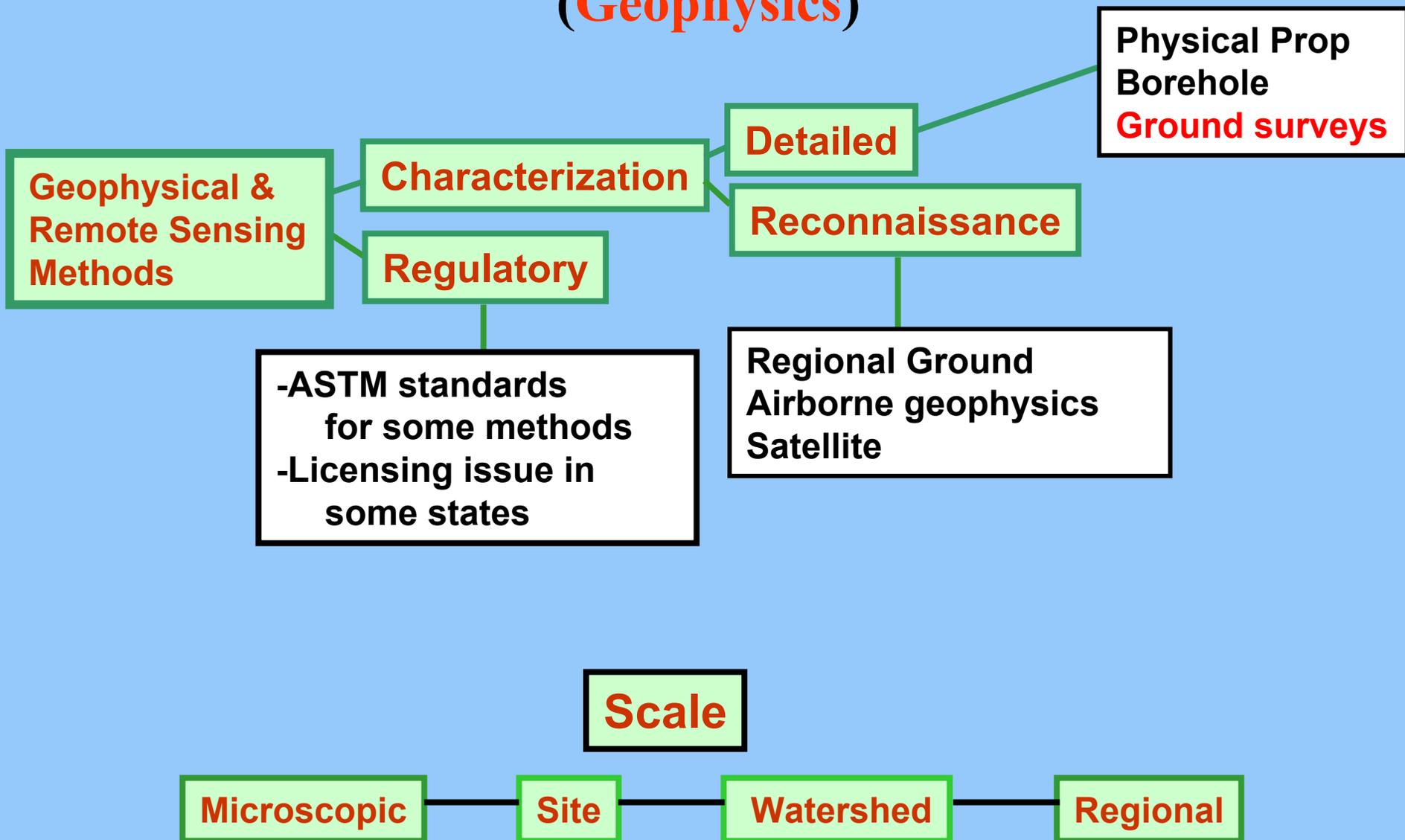
Geophysical Applications Mine Waste Piles

Bruce D. Smith, USGS

bsmith@usgs.gov

**Billings Symposium / ASMR Annual Meeting
Assessing the Toxicity Potential
of Mine-Waste Piles Workshop
June 1, 2003**

Flow Chart for Ranking and Prioritization (Geophysics)



Many applications for Geophysics



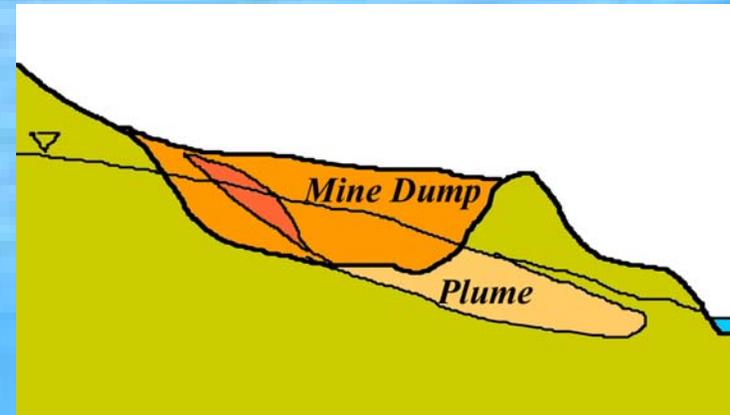
"Never, ever, think outside the box."

Why Geophysics????

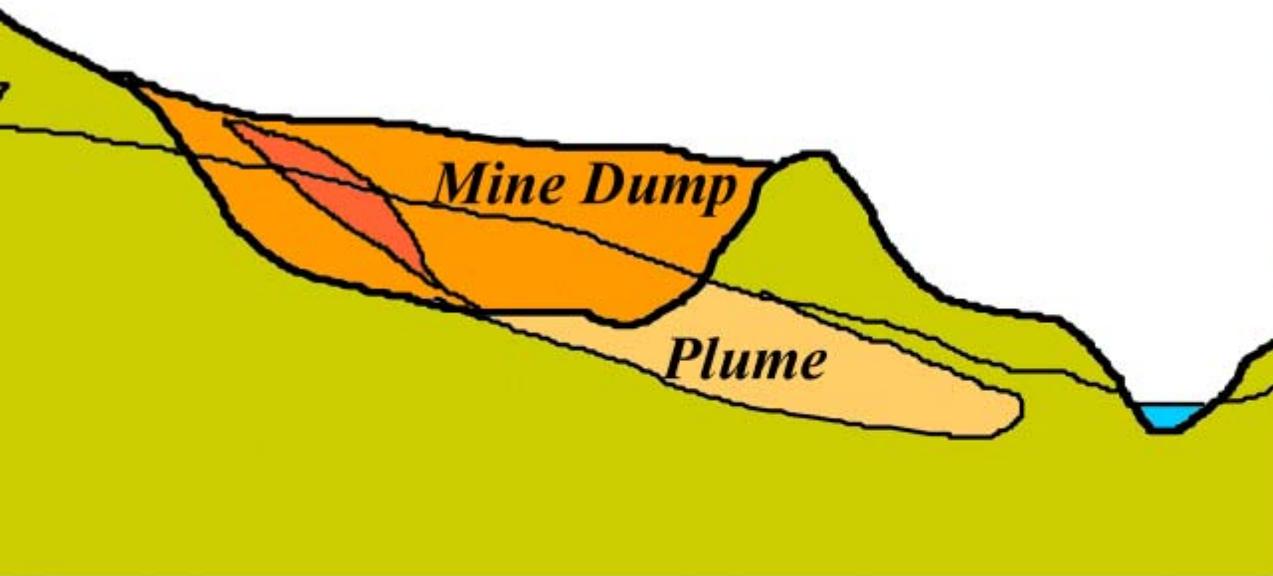
- **Non invasive (usually)**
- **Rapid surface and subsurface mapping information**
- **Money: Survey costs can be high but savings can be great**
- **Airborne no access problems (PRP issues) and large areas**

What's the Objective

- **Physical property mapping (conductivity)**
- **Trends and hot spots (anomalies)**
- **Analysis of subsurface (below the obvious)**



Features



- Within Dump
 - Size and depth
 - Water table
 - Concentrations
- Outside Dump
 - Existence and location of plumes

Geophysical Methods

- **Remote Sensing**

- **Airborne**

- **Ground**

Remote Sensing

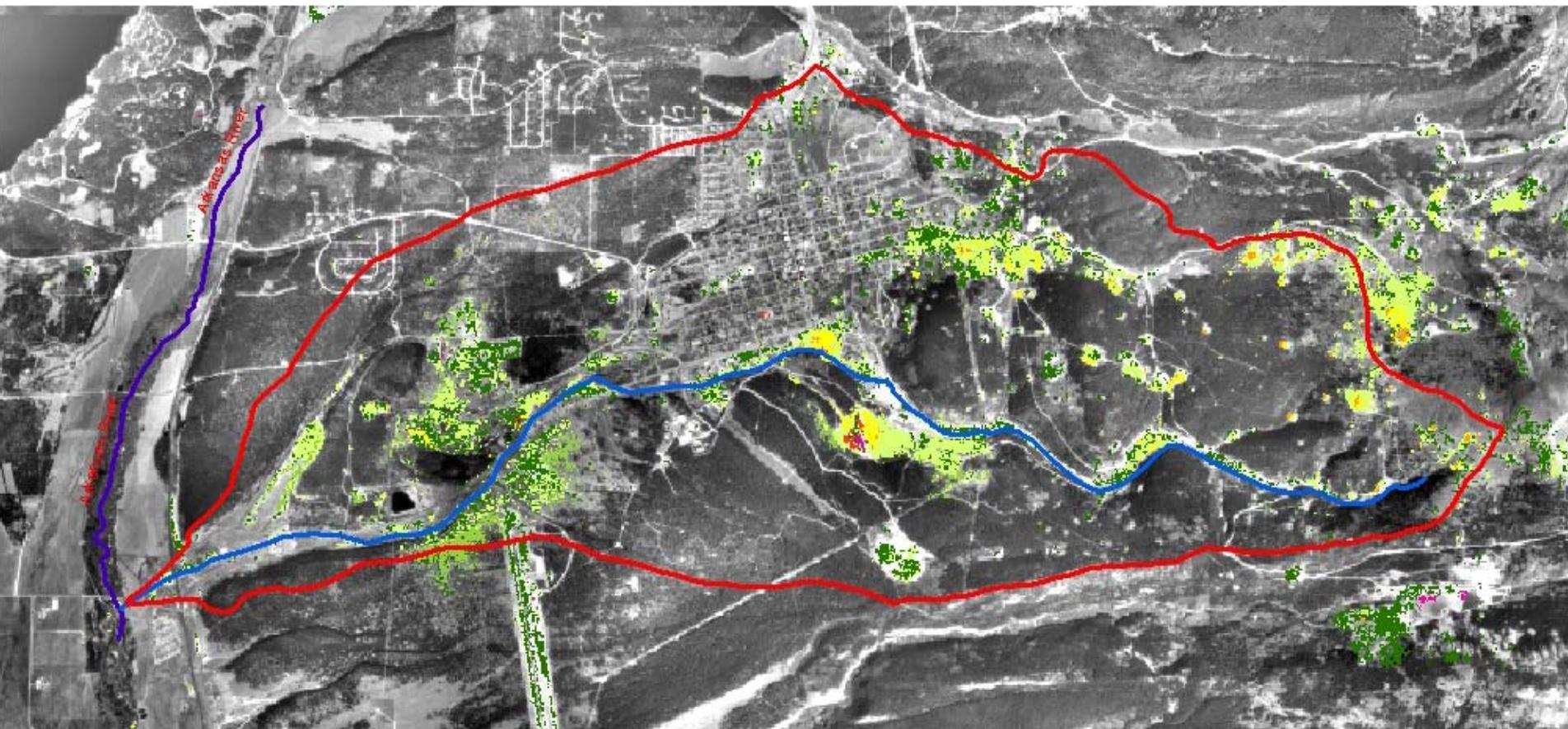
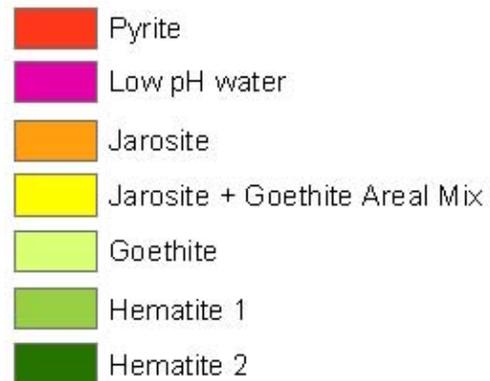
- **Linear feature mapping using a variety of satellite data such as LandSat and Thematic mapper**
- **Mapping areas of alteration (limonite mapping)**
- **Surface mineral and chemical mapping high and low altitude AVIRIS**

**AVIRIS image
reclassified to 7 minerals
(Swayze et al., 2000)**



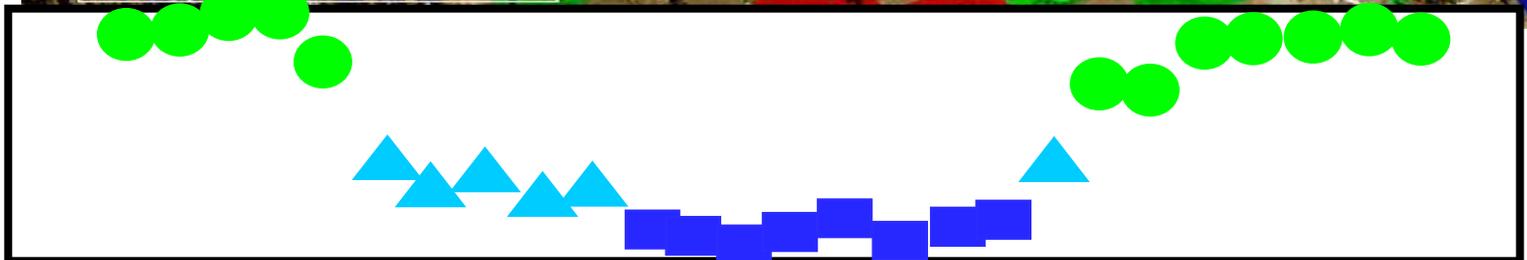
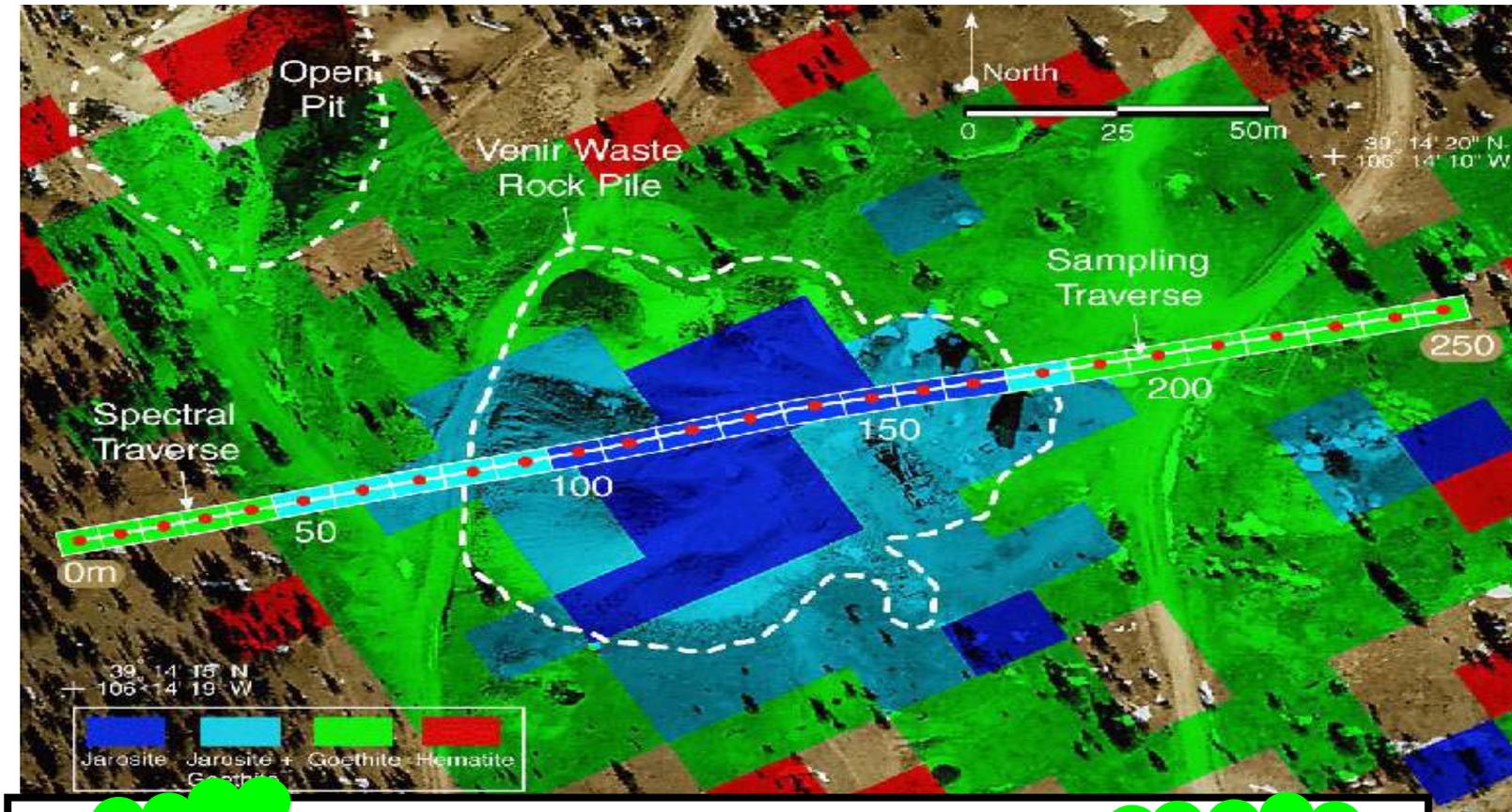
**ACIDIC
High Leachability**

**NEUTRAL
Low Leachability**



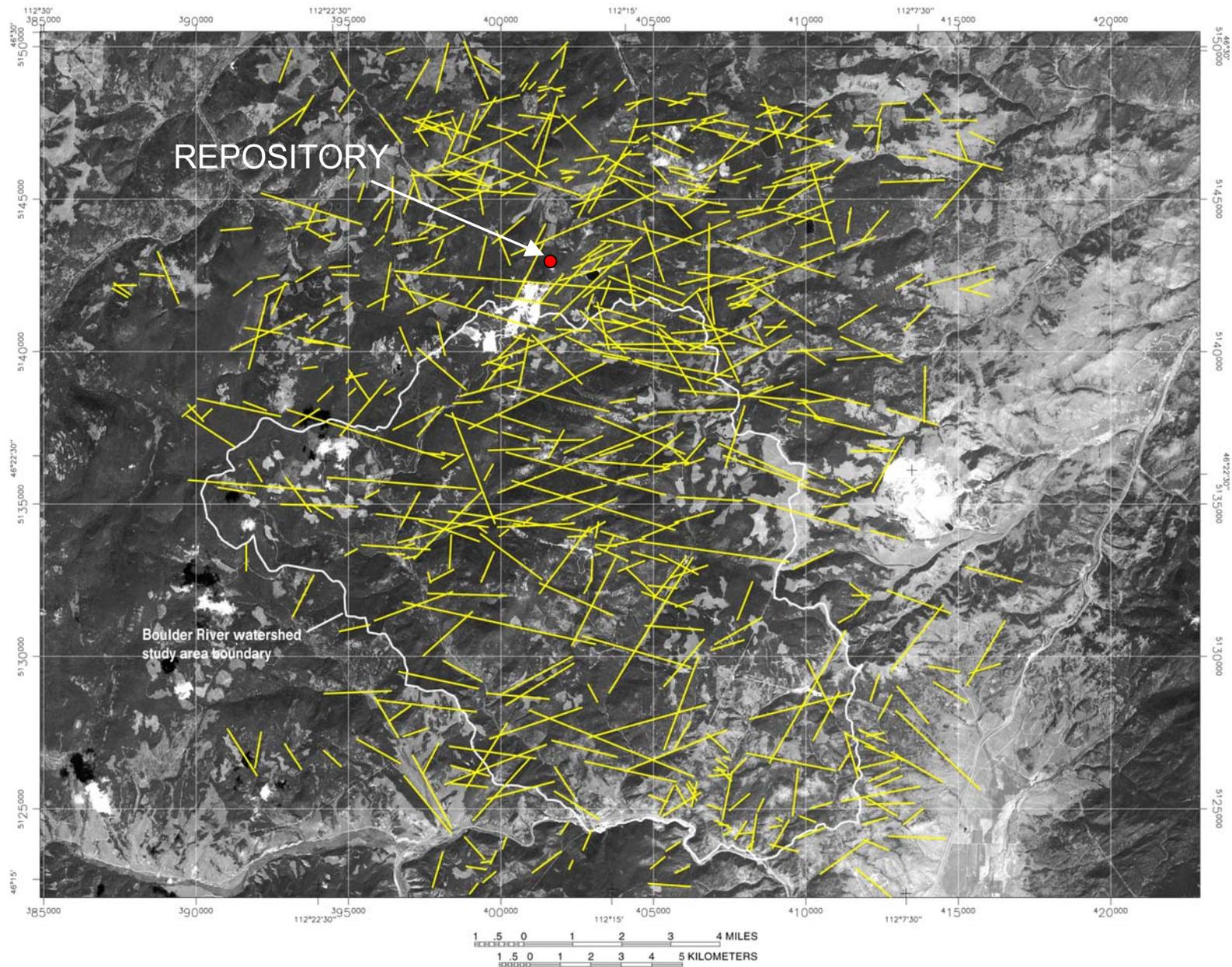
AVIRIS Leadville

Imaging Spectroscopy (AVIRIS)



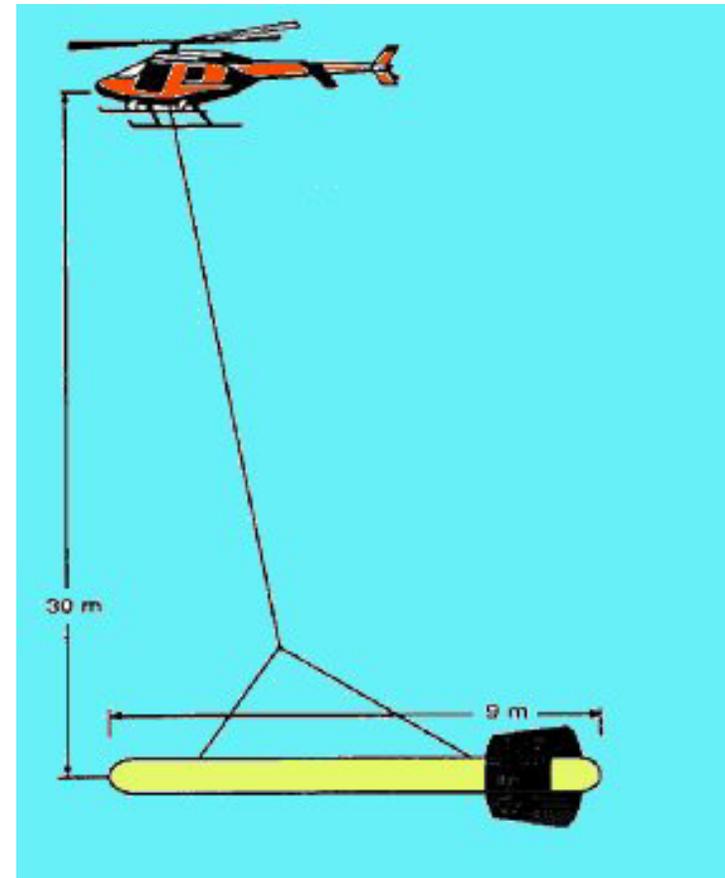
Linear Feature Mapping

Boulder Watershed, MT

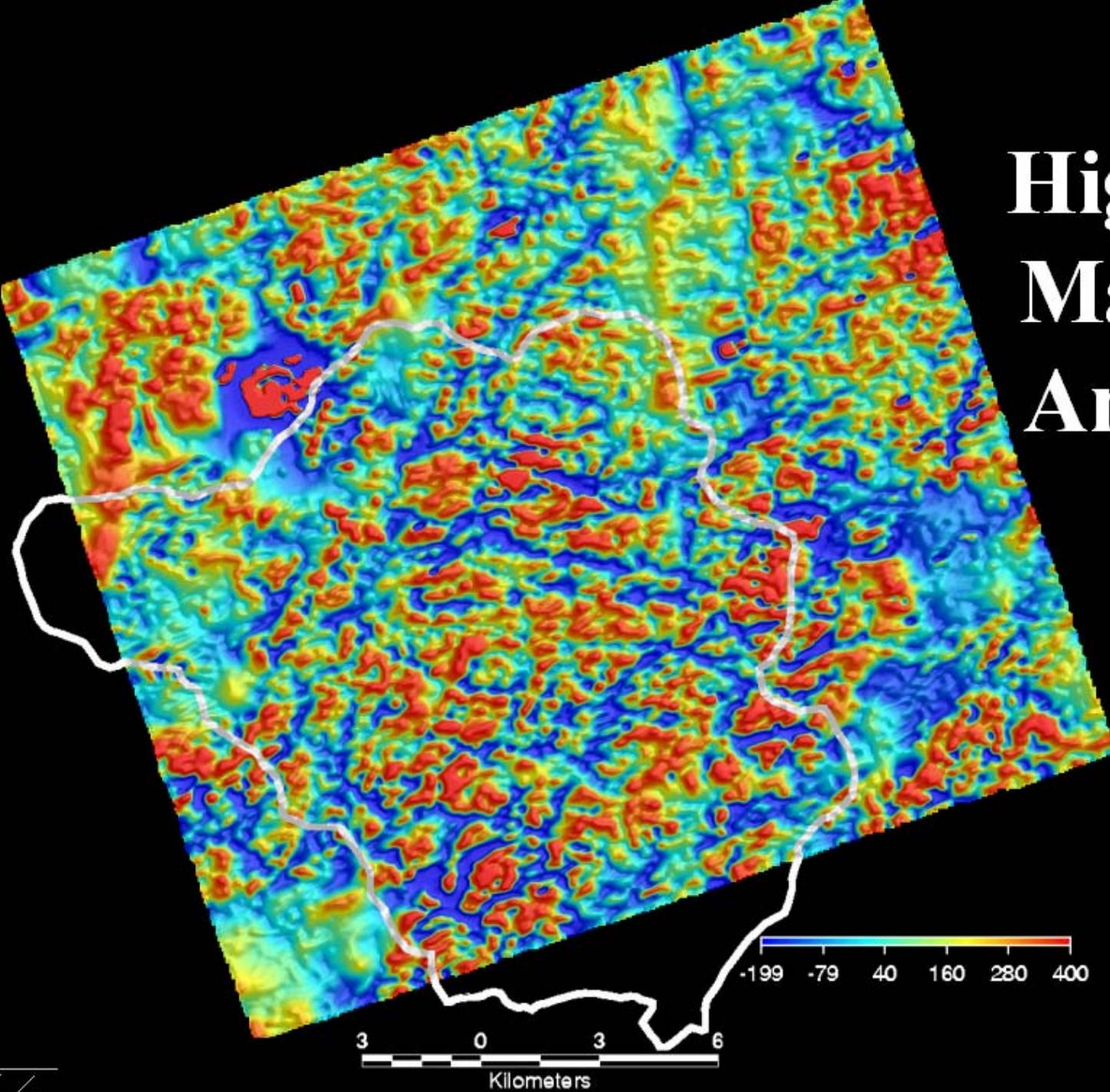


Airborne Geophysical Surveys

- Radiometrics
- Total field magnetics
 - Magnetization
- Electromagnetics
 - Subsurface conductivity



High Pass Magnetic Anomaly



Unaltered Butte Granite

Acid Neutralizing Minerals

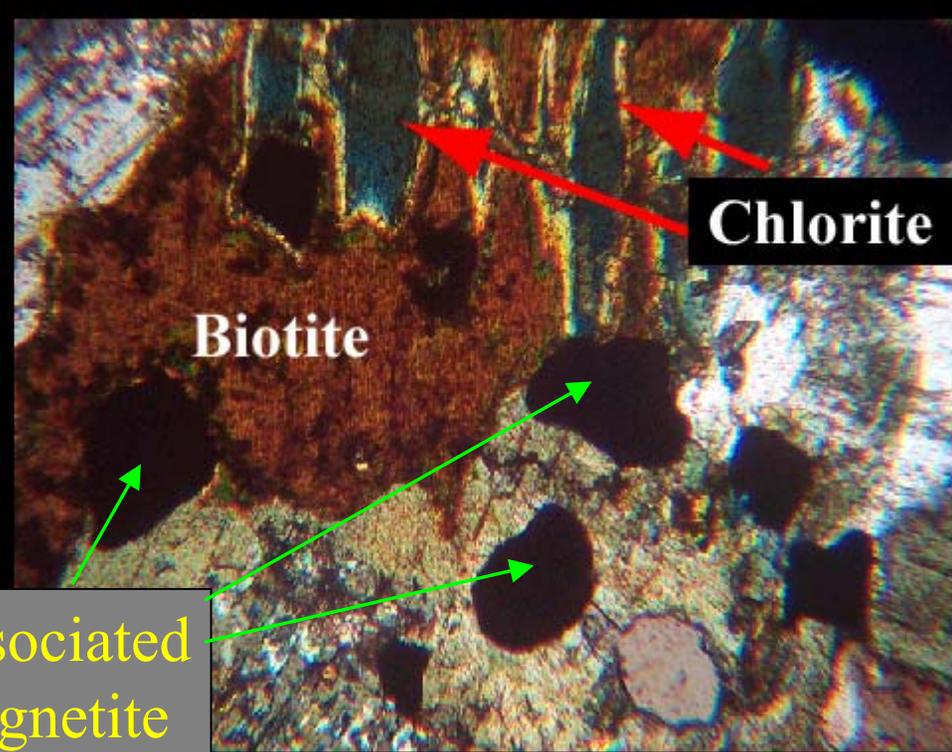
Chlorite

Biotite

Hornblende

Plagioclase

Calcite



Chlorite

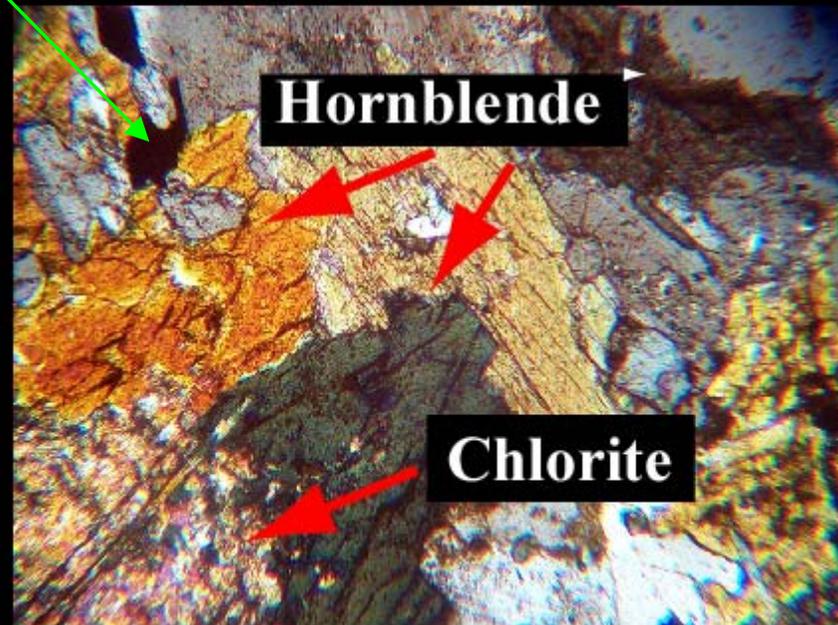
Biotite

Associated
Magnetite

Plagioclase

Biotite

500 μ



Hornblende

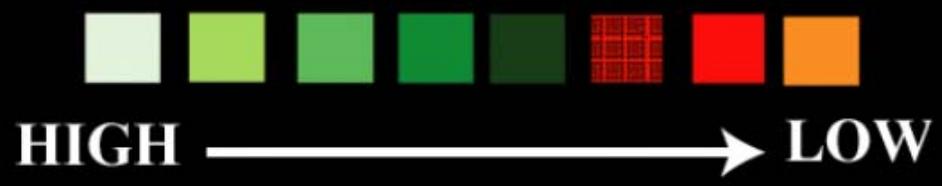
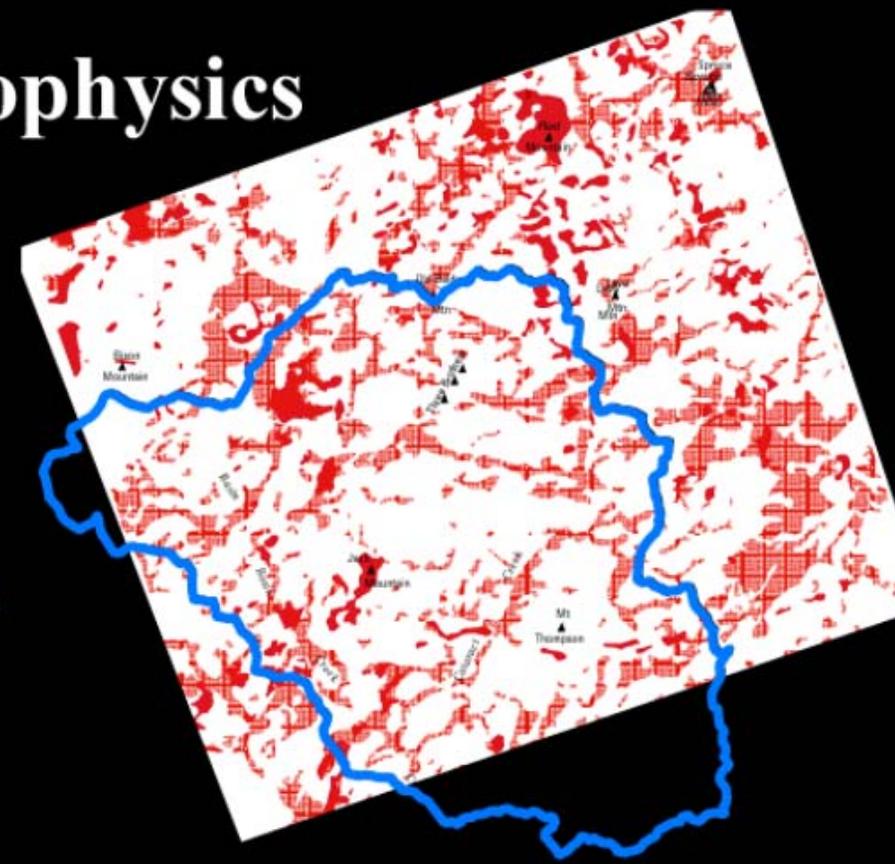
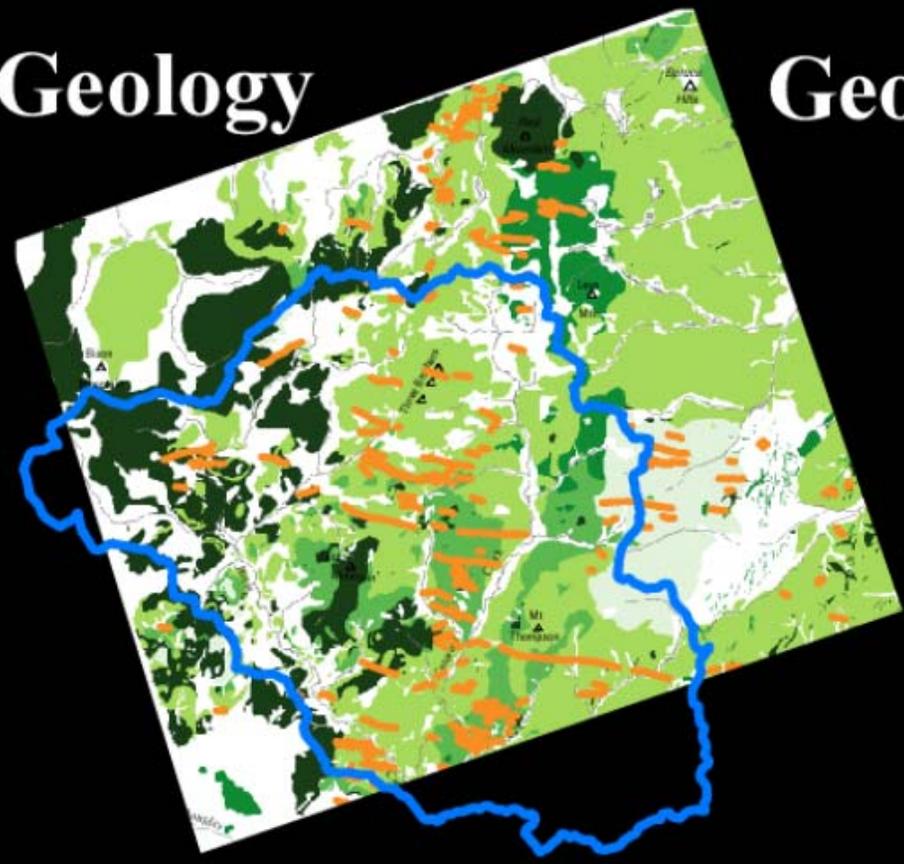
Chlorite

Associated
Magnetite

Relative Acid-Neutralizing Potential

Geology

Geophysics



Geoelectrical Methods

CONTACTING

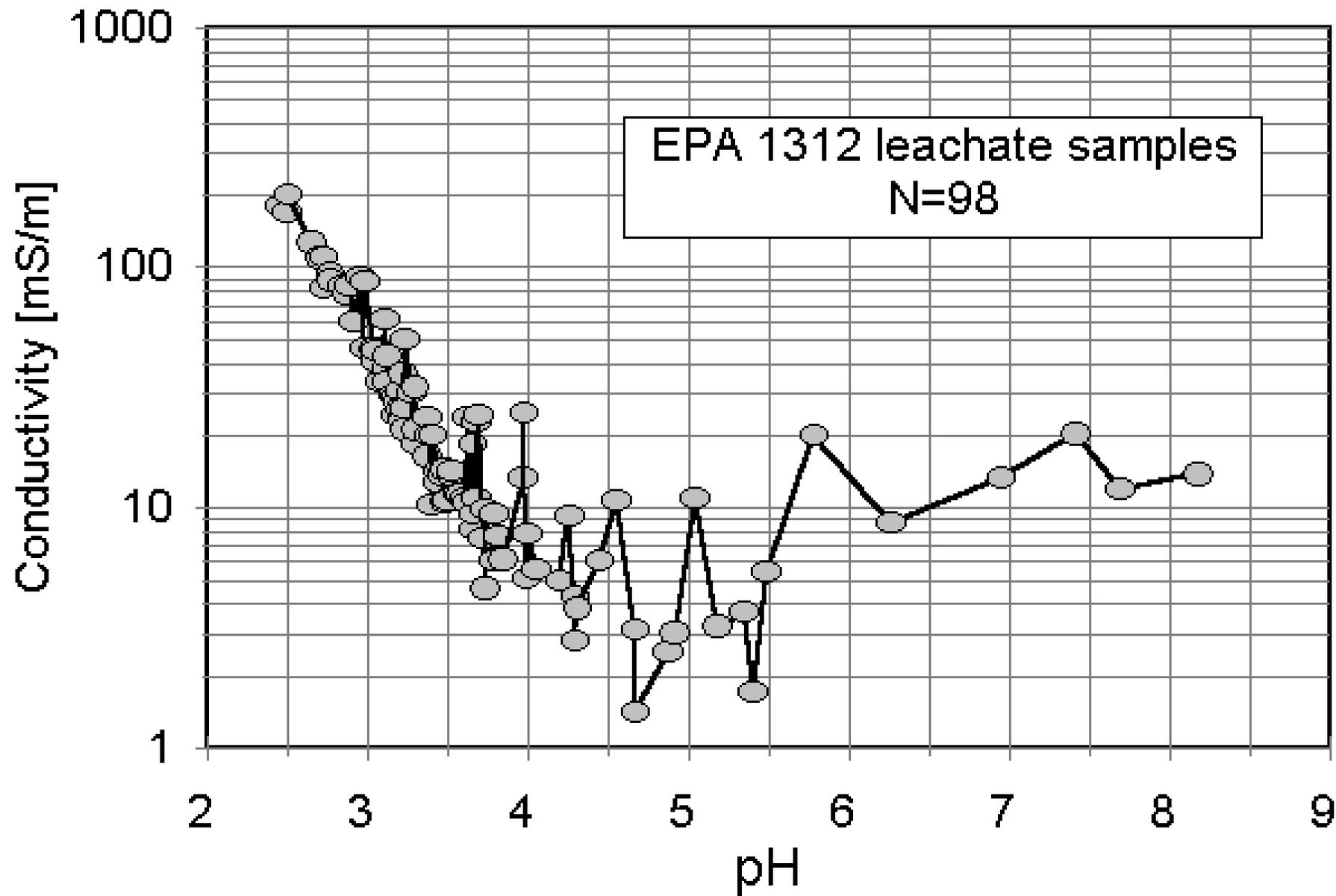
- DC (direct current resistivity)
- IP (induced polarization)

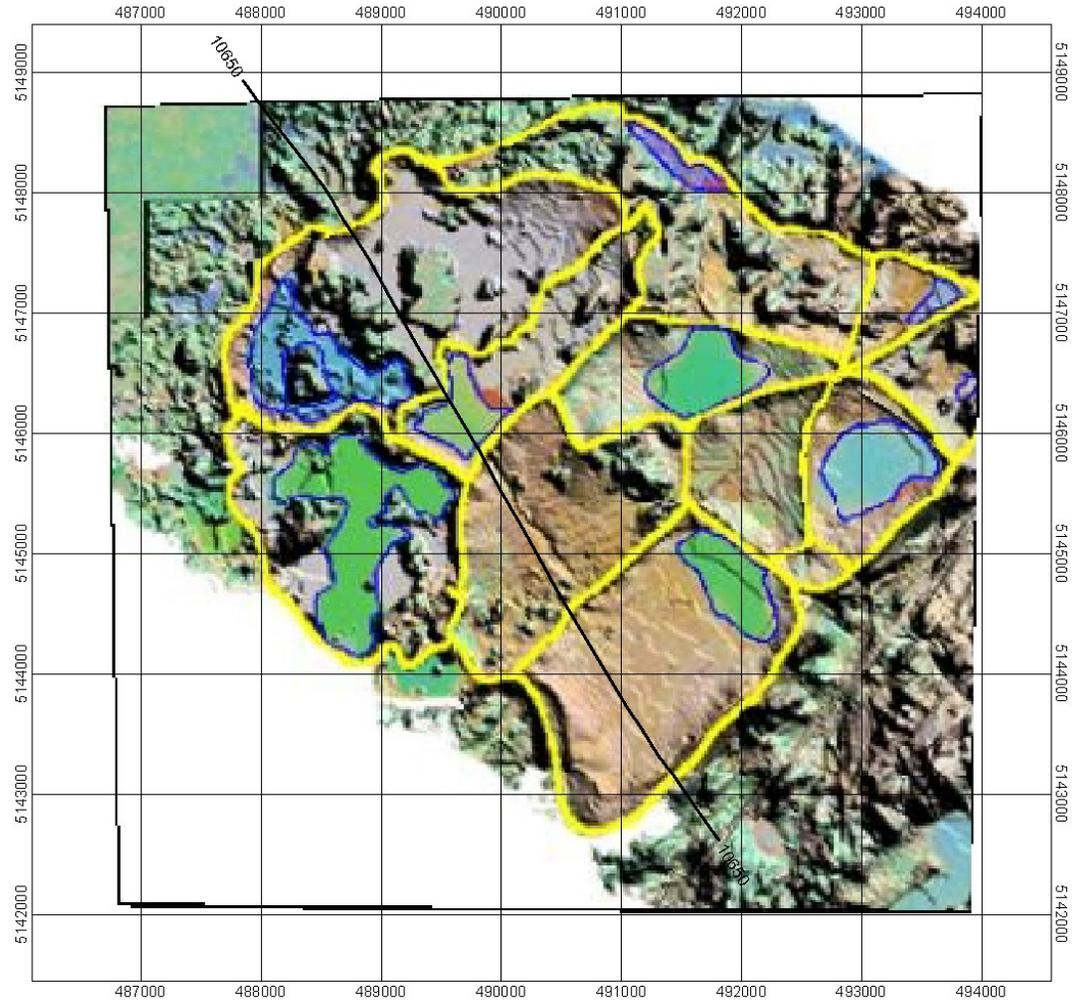
INDUCTION

- **EM (frequency domain electromagnetics)**
- TEM (time domain electromagnetics)
- CSAMT (CS audiomagnetotellurics)

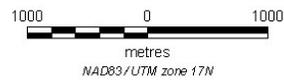
NATURAL FIELDS

- SP (spontaneous polarization)
- AMT/MT

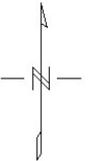




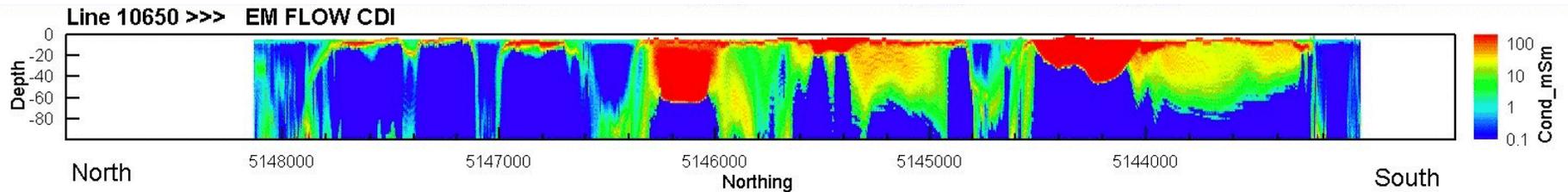
Condor Consulting, Inc.



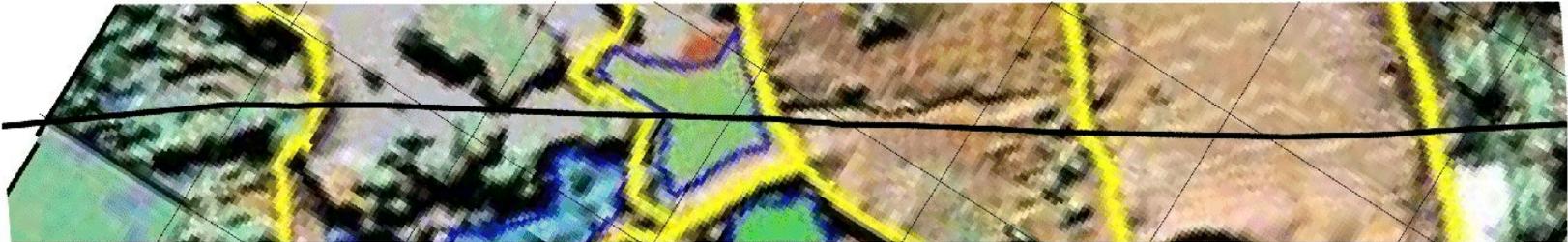
Copper Cliff Tailings Area
Location of Flight Line 10650



Conductivity Depth Section

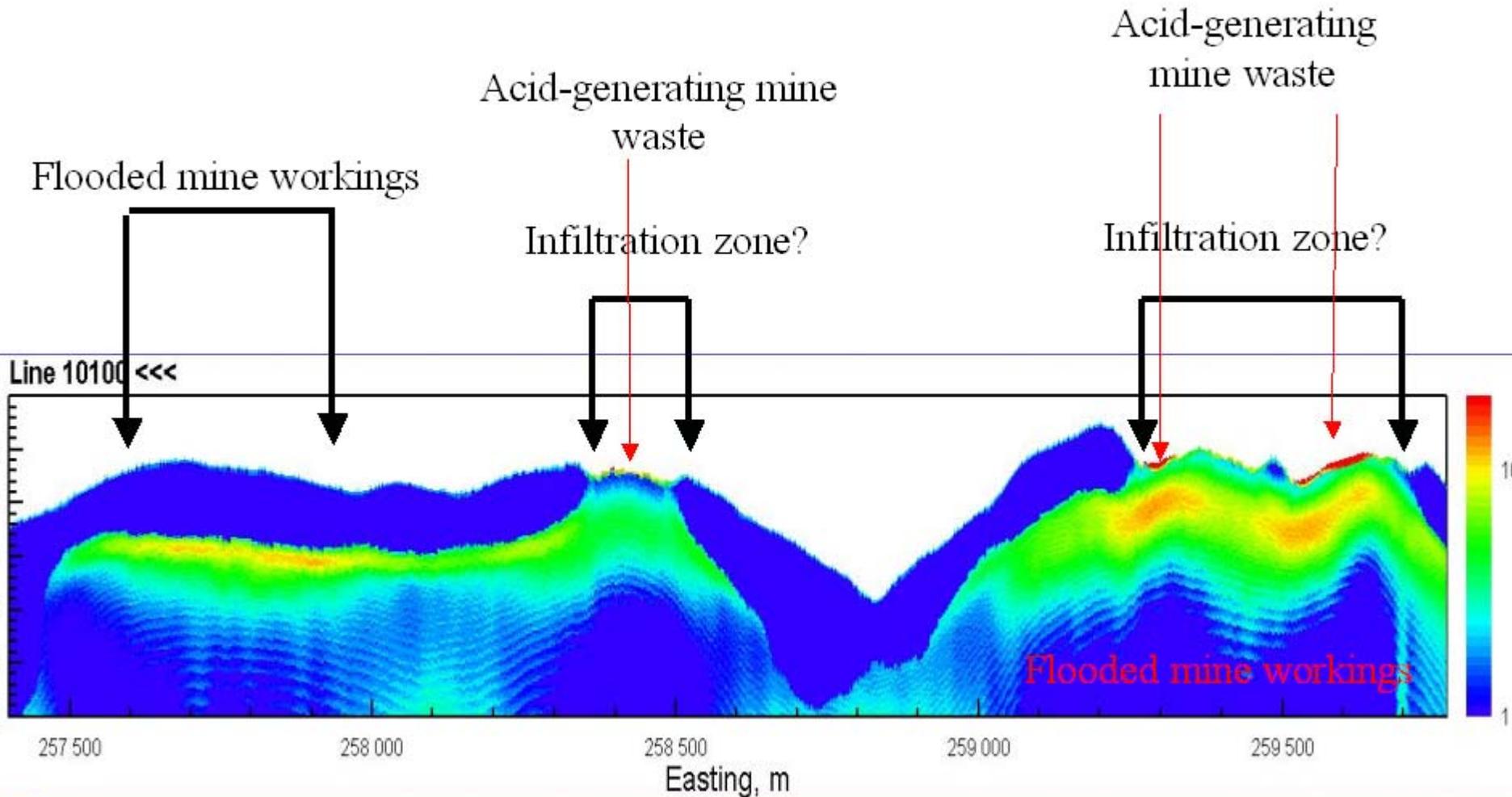


PLAN VIEW OF TAILINGS AREA ALONG LINE 10650



Conductivity depth section from Helicopter EM survey along line shown in plan view map from spectral survey

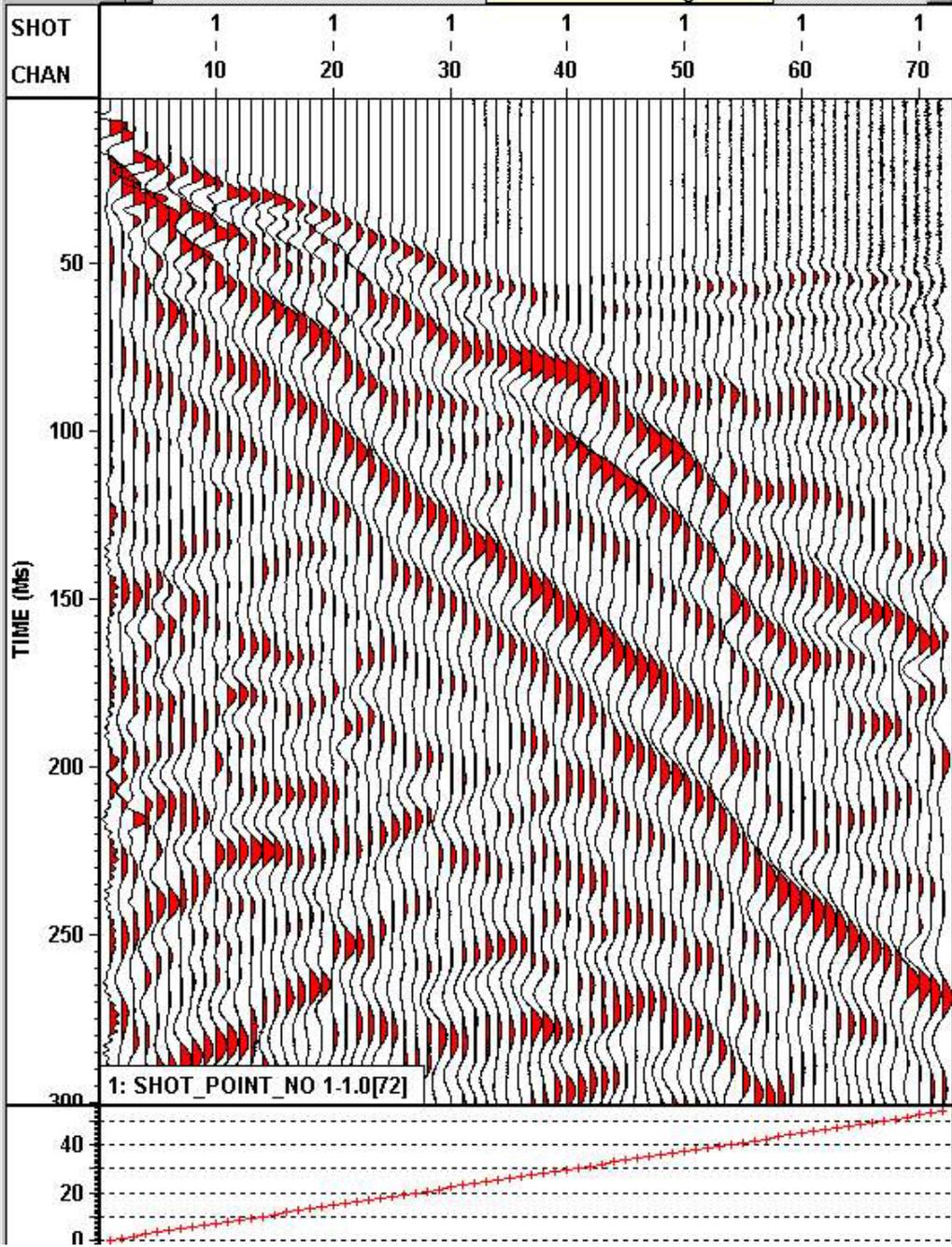
Acid-Generating Mine Waste



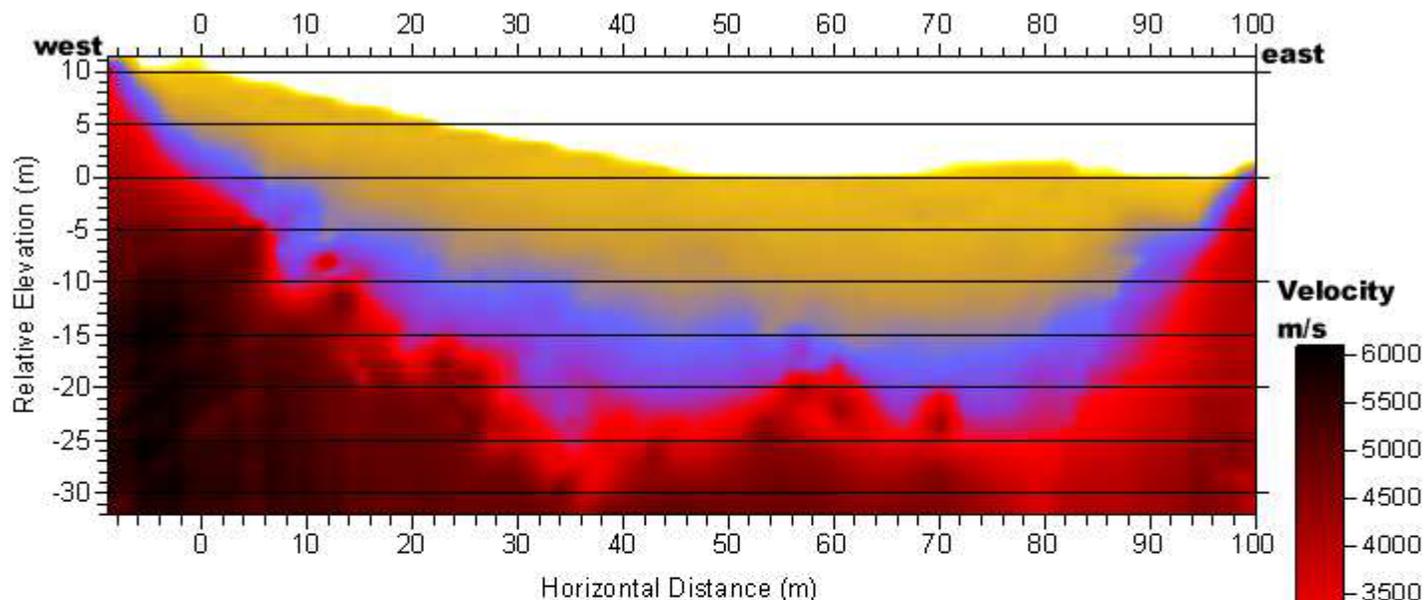
Engineering GP Methods

- **Seismic Reflection and Refraction velocity contrasts needed**
- **Ground Penetrating Radar need very resistive ground but generally not deep (few feet)**

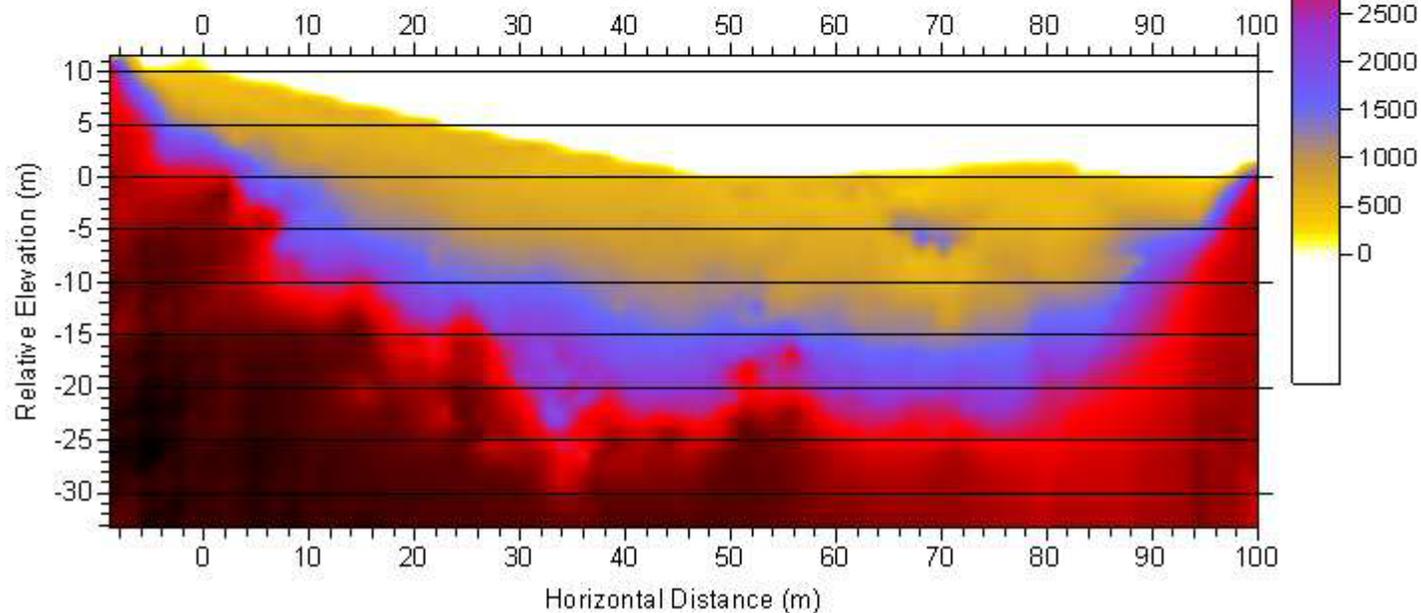




Line 2: Velocity Depth Model A (meters per second)



Line 2: Velocity Depth Model B (meters per second)



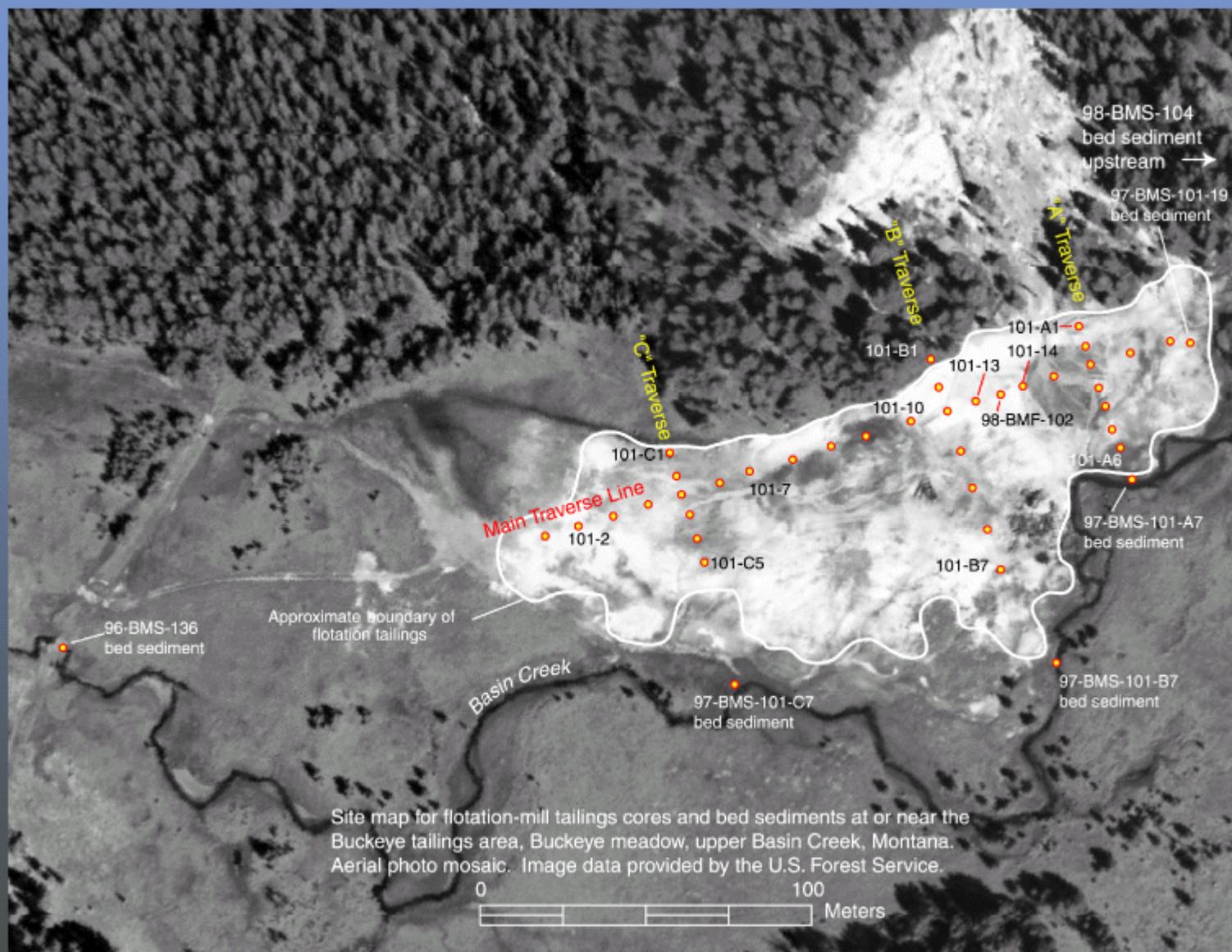
Geonics EM-31



One of several different types of terrain conductivity systems

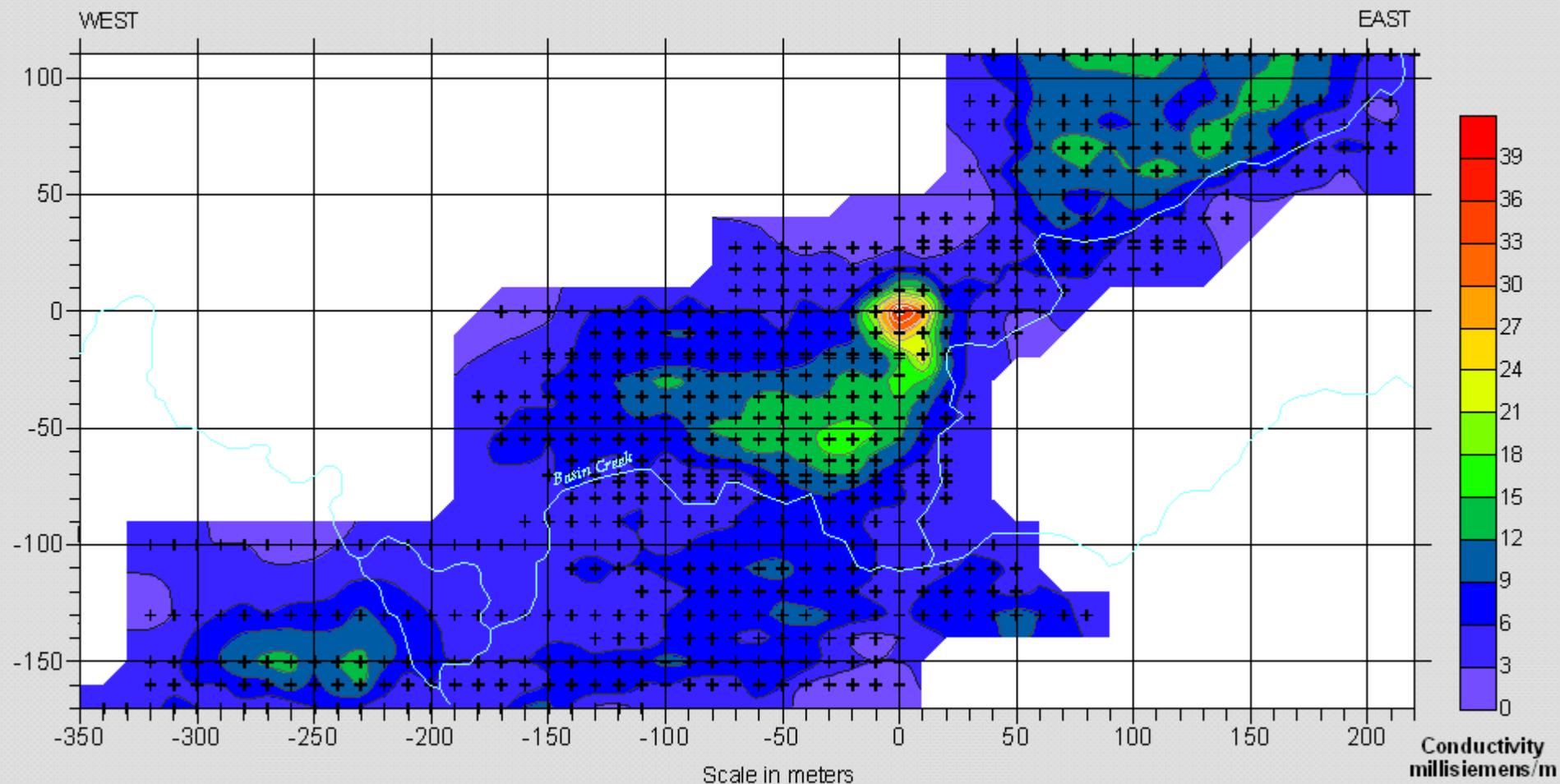


Site map for tailings cores and stream bed-sediment samples



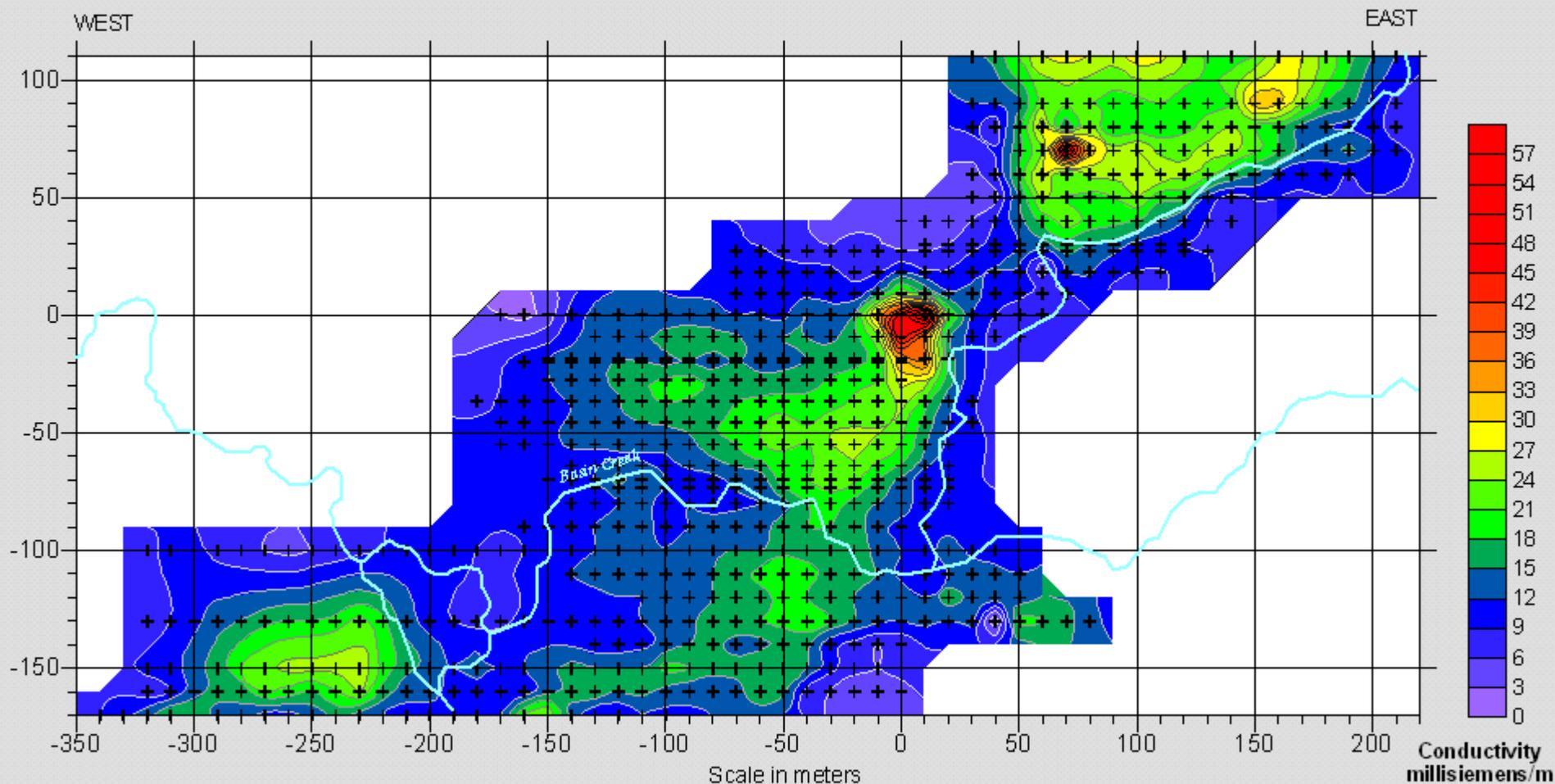
Electromagnetic Survey using EM-31

Horizontal Magnetic Dipole



Electromagnetic Survey using EM-31

Vertical Magnetic Dipole

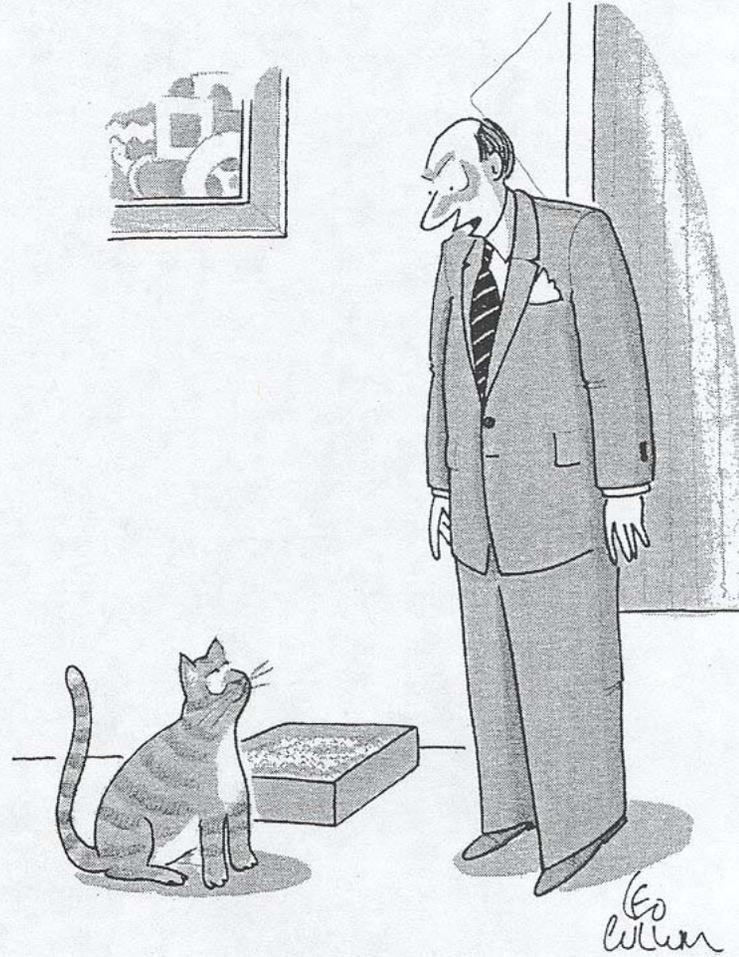




Geophysics TRY IT!

- **Cost effective for subsurface mapping at site and watershed scale**
- **Integration with geology and geochemistry..NOT a black box universal solution**
- **Avoid “nothing else works ... try geophysics”**
- **Match the method to the problem...do not use EM under power lines**

THANKS FOR THE ATTENTION



"Never, ever, think outside the box."