



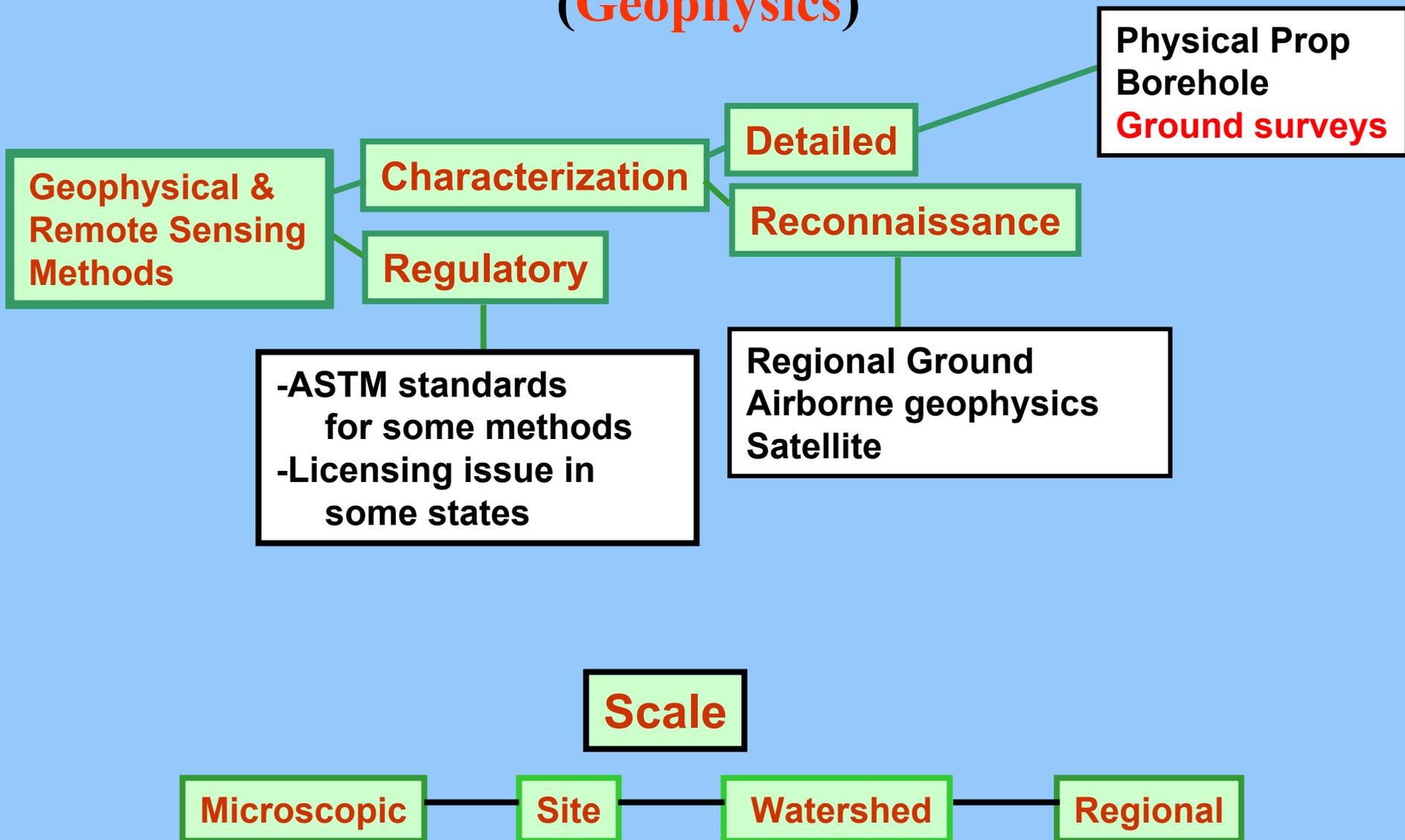
# Geophysical Applications Mine Waste Piles

**Bruce D. Smith, USGS**

[bsmith@usgs.gov](mailto: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????**

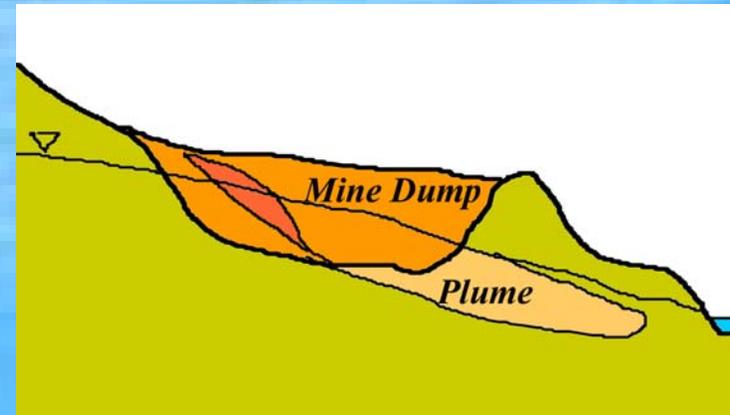
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- **Non invasive (usually)**
- **Rapid surface and subsurface mapping information**
- **Money: Survey costs can be high but savings can be great**
- **Airborne no access problems (PRP issues) and large areas**

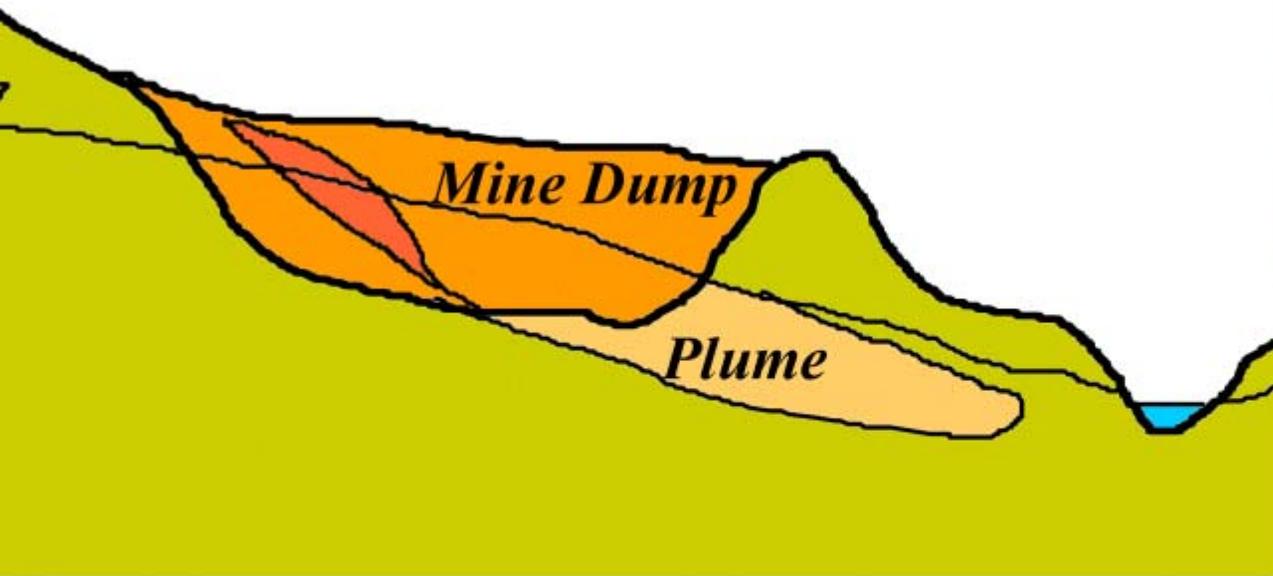
# What's the Objective

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- **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

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- **Remote Sensing**

  - Satellite

  - High Altitude (U2, Aviris, other)

- **Airborne**

  - Electromagnetic (induction)

  - Magnetic

  - Radiometric

- **Ground** (as above and )

  - Ground Penetrating Radar

  - Seismic

  - Gravity

  - DC Resistivity

  - Induced Polarization

# Remote Sensing

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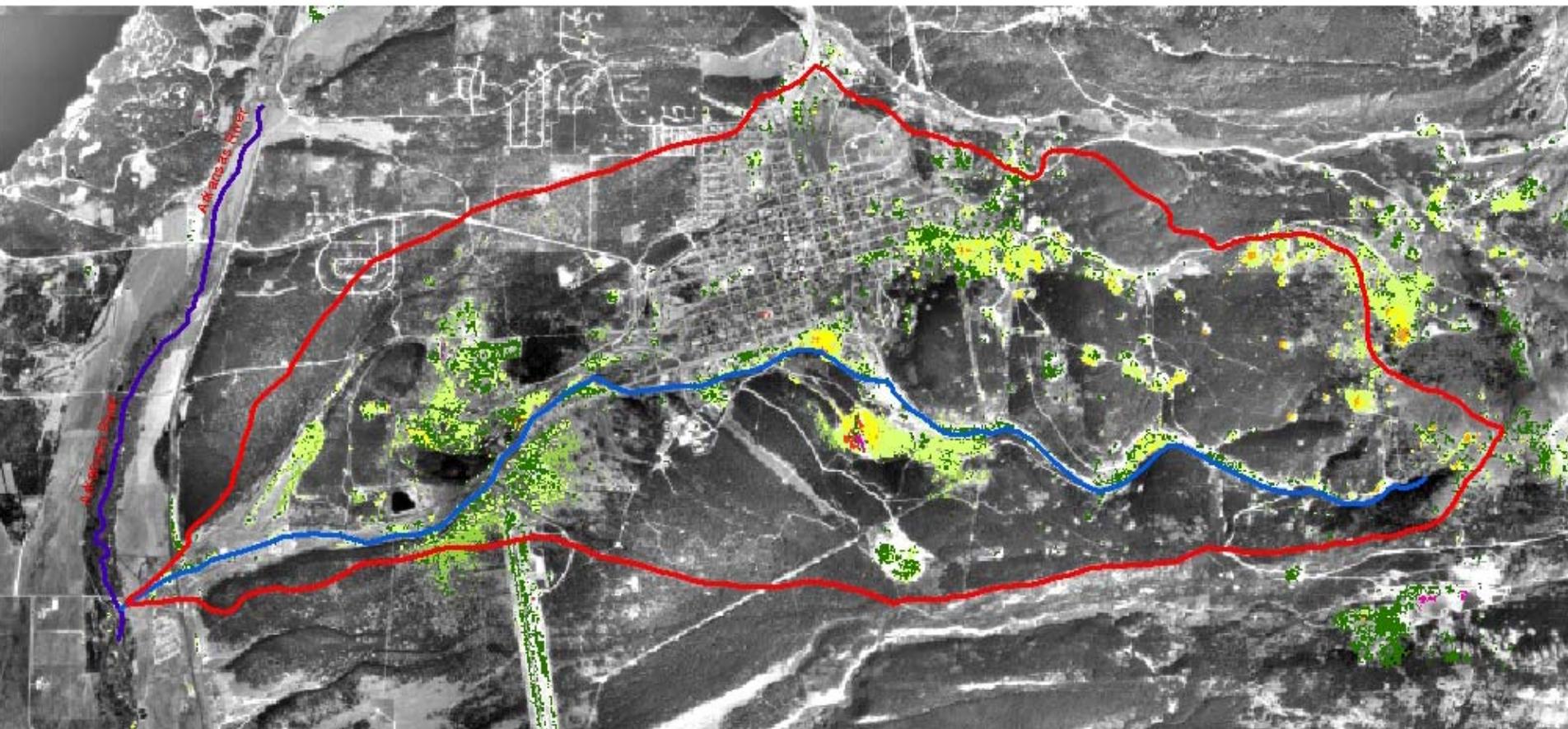
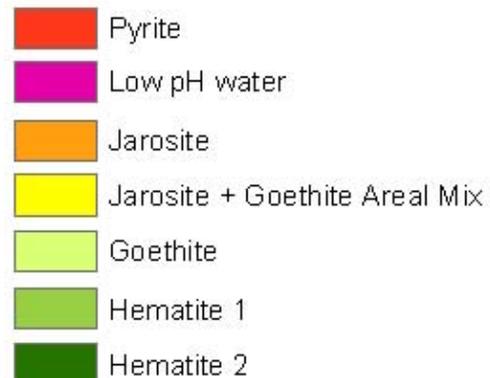
- **Linear feature mapping using a variety of satellite data such as LandSat and Thematic mapper**
- **Mapping areas of alteration (limonite mapping)**
- **Surface mineral and chemical mapping high and low altitude AVIRIS**

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



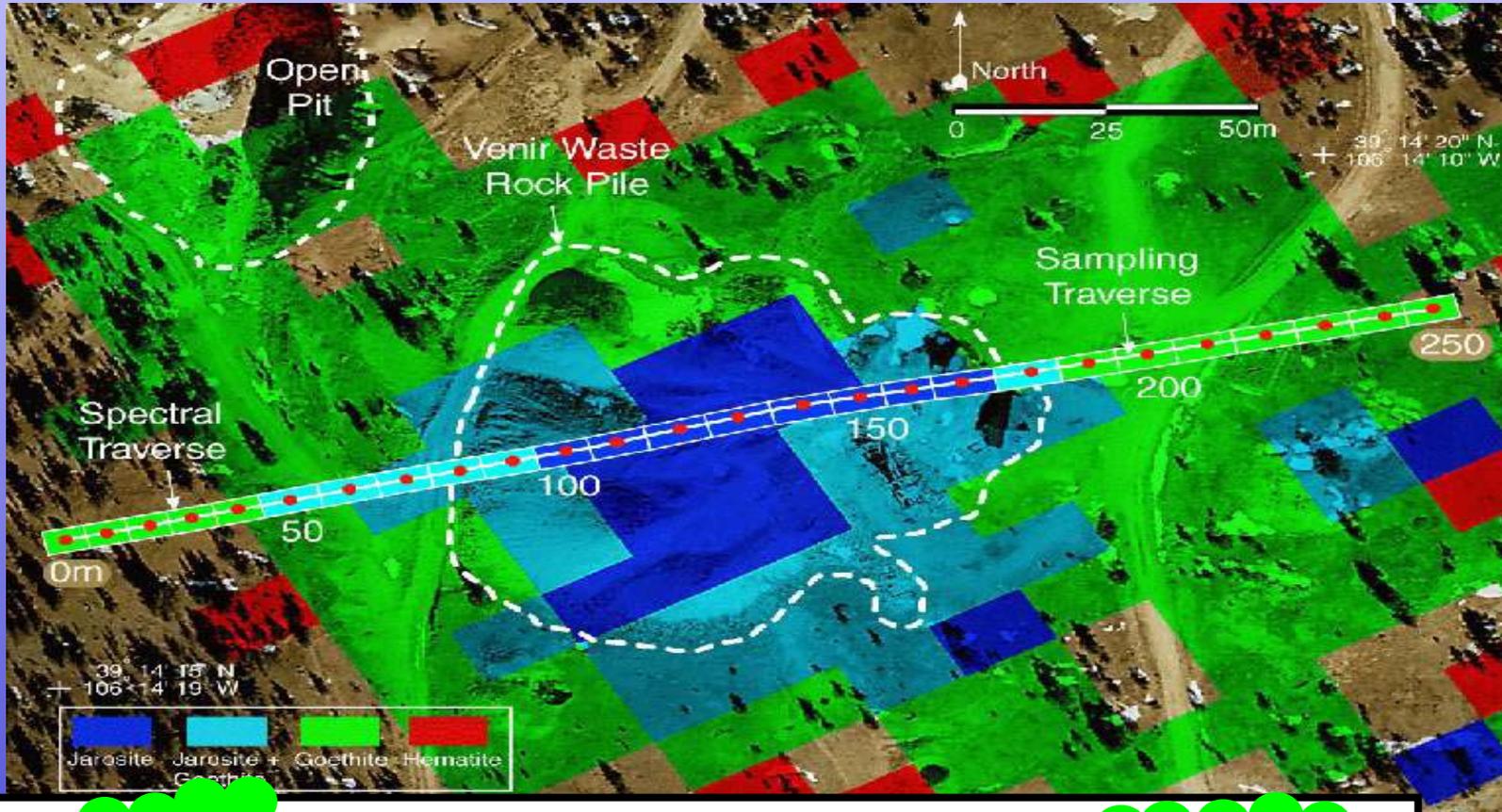
**ACIDIC  
High Leachability**

**NEUTRAL  
Low Leachability**



**AVIRIS Leadville**

# Imaging Spectroscopy (AVIRIS)



6  
Leachate  
pH  
2

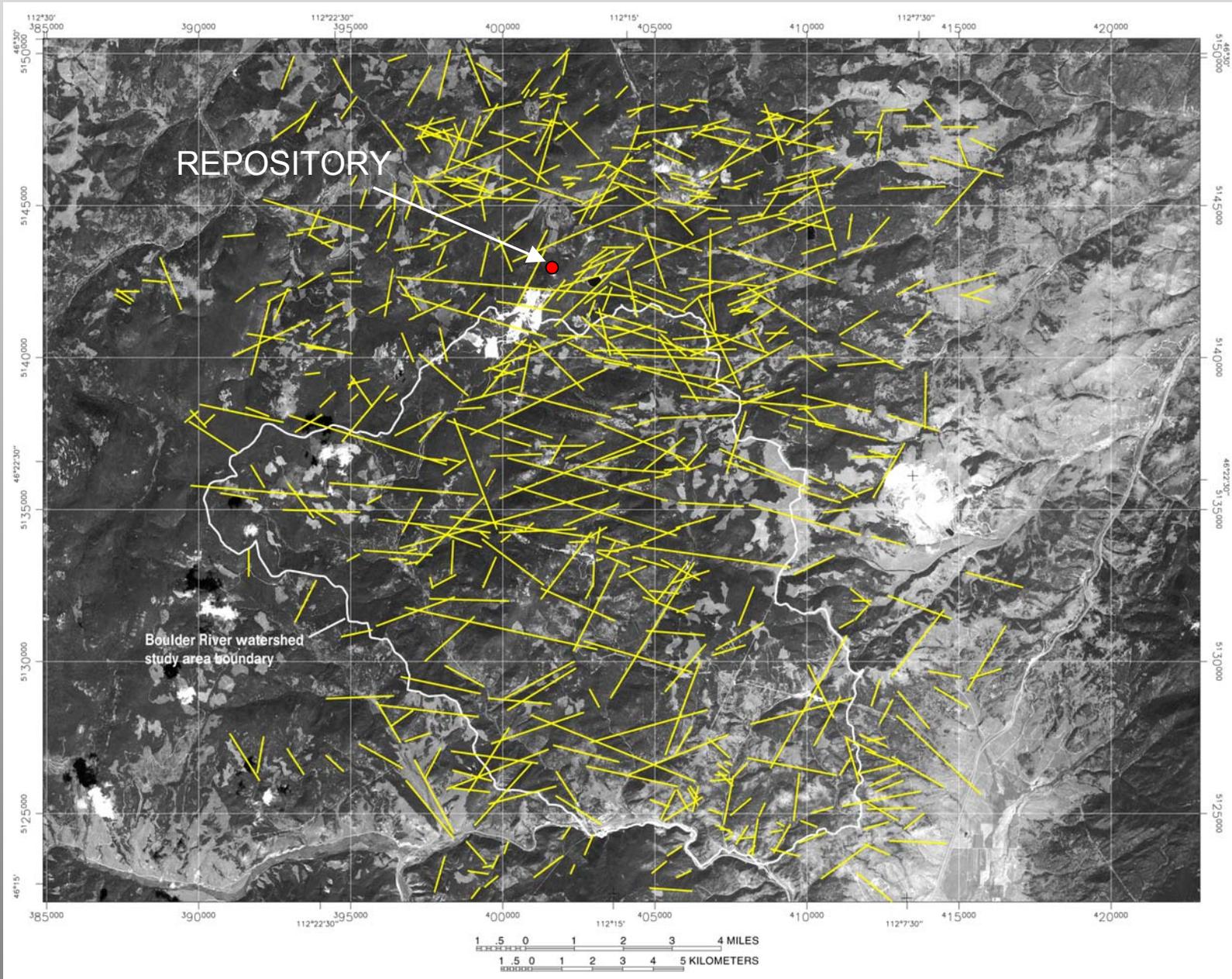


# Linear Feature Mapping

## Boulder Watershed, MT

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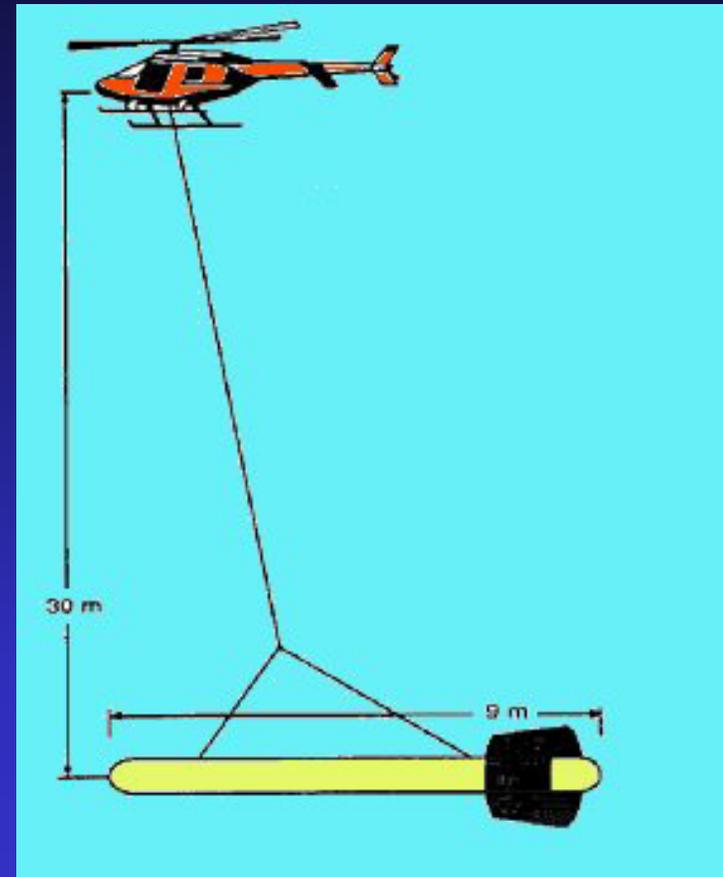
- Four data sets were used as base images for linear feature mapping
  - Landsat Thematic Mapper (TM)
  - India Remote Sensing (IRS) satellite data
  - Digital Orthophoto Quads (DOQ)
  - USGS Digital Elevation Model (DEM)
- Images were directionally filtered to enhance linear features
- DEM shaded relief images were artificially illuminated from several directions to minimize sun angle bias



# Airborne Geophysical Surveys

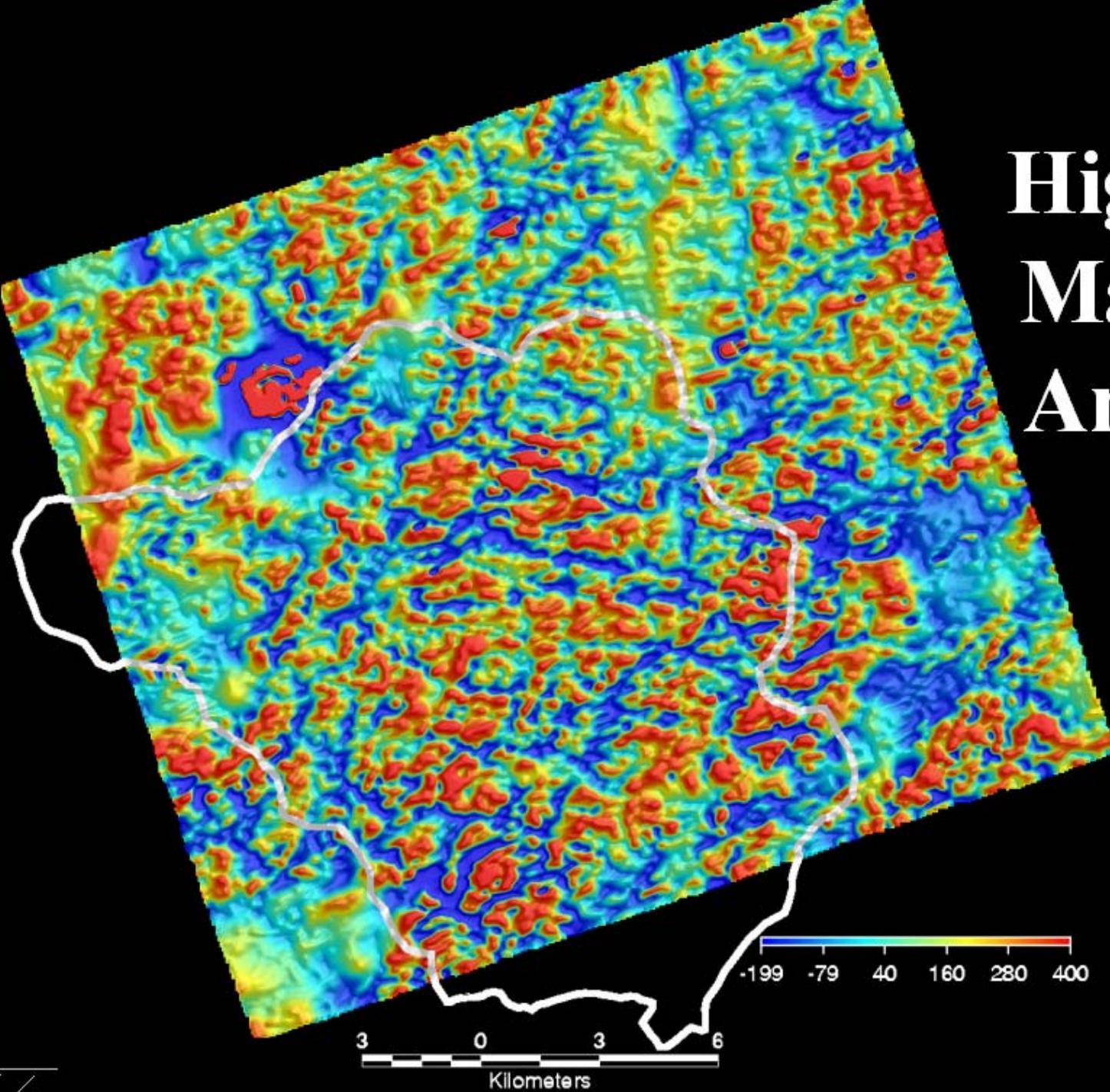
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- Radiometrics
- Total field magnetics
  - Magnetization
- Electromagnetics
  - Subsurface conductivity





# High Pass Magnetic Anomaly



# Unaltered Butte Granite

## Acid Neutralizing Minerals

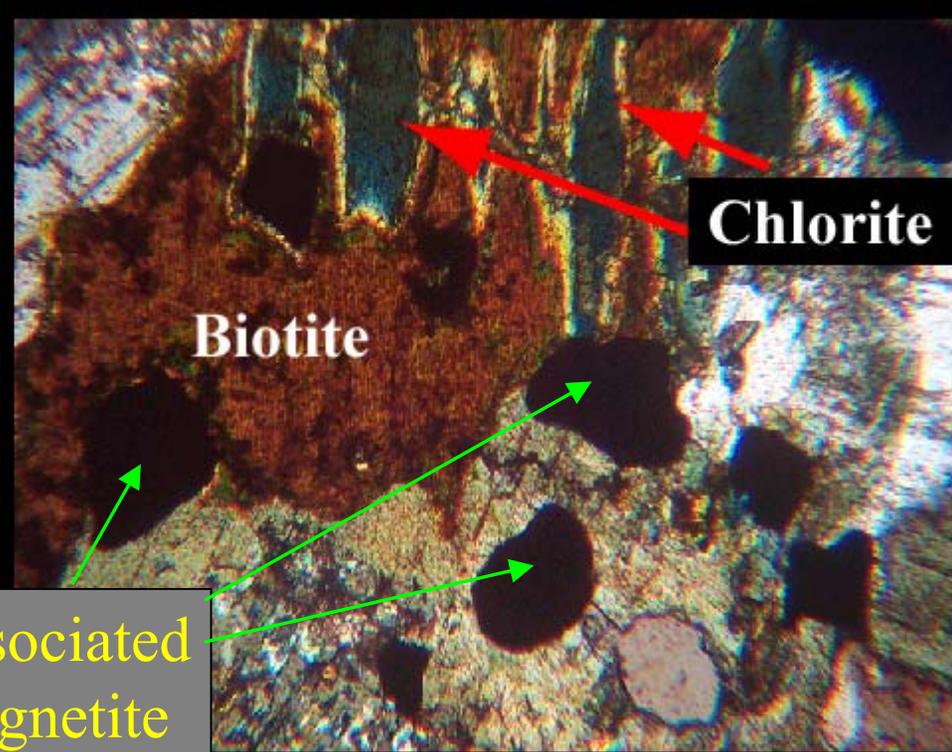
Chlorite

Biotite

Hornblende

Plagioclase

Calcite

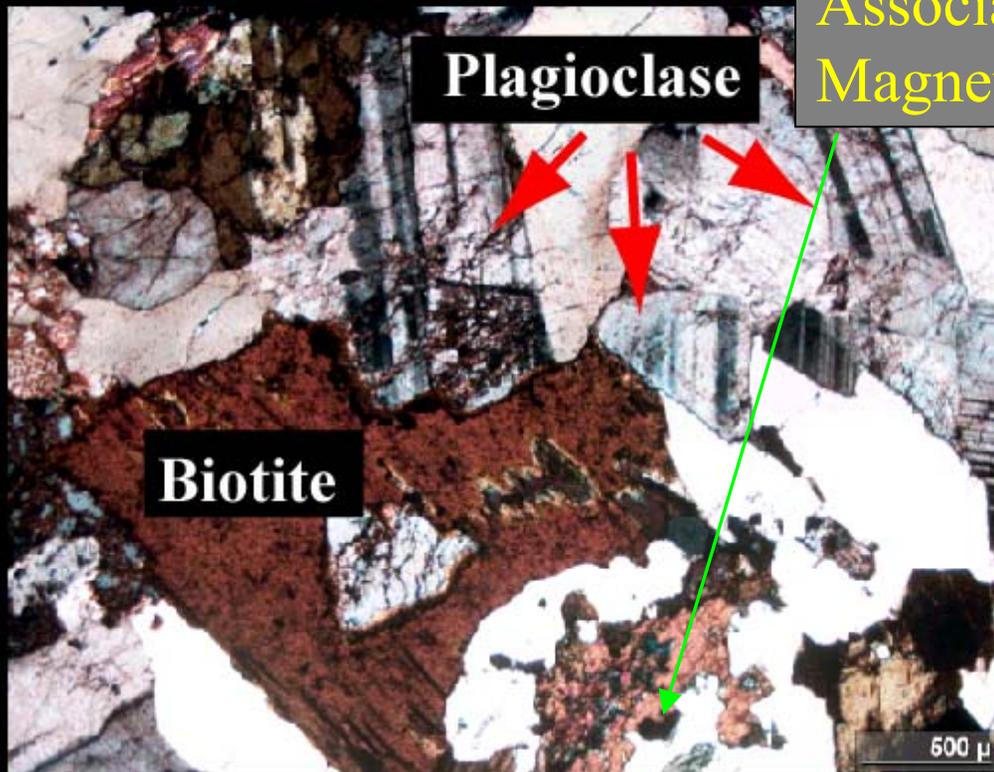


Chlorite

Biotite

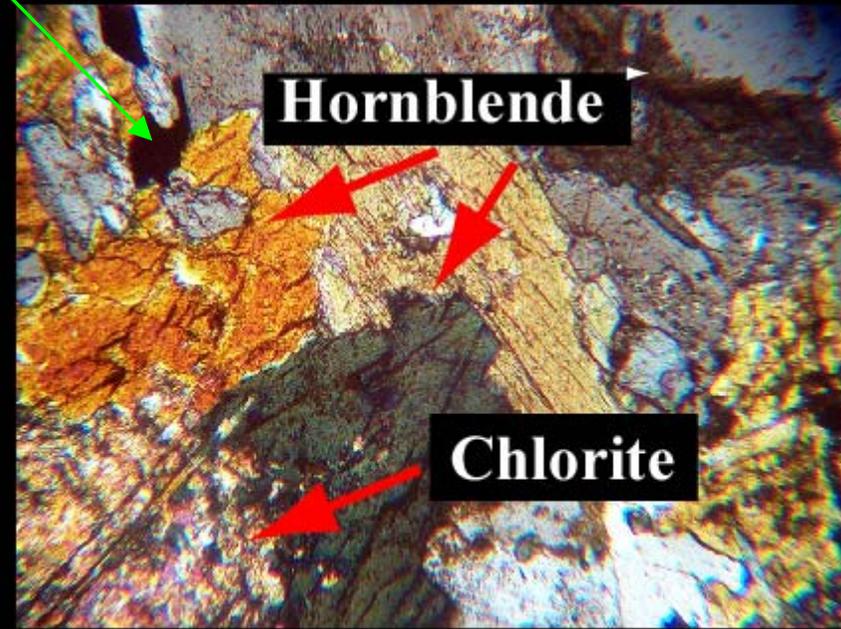
Associated  
Magnetite

Plagioclase



Biotite

500 μ



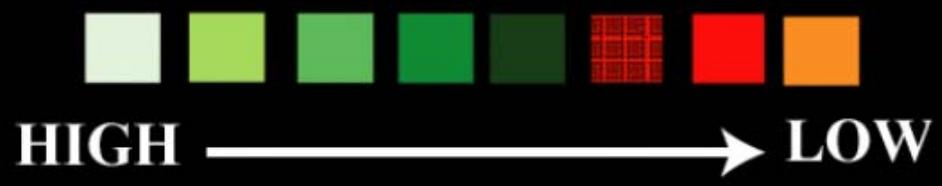
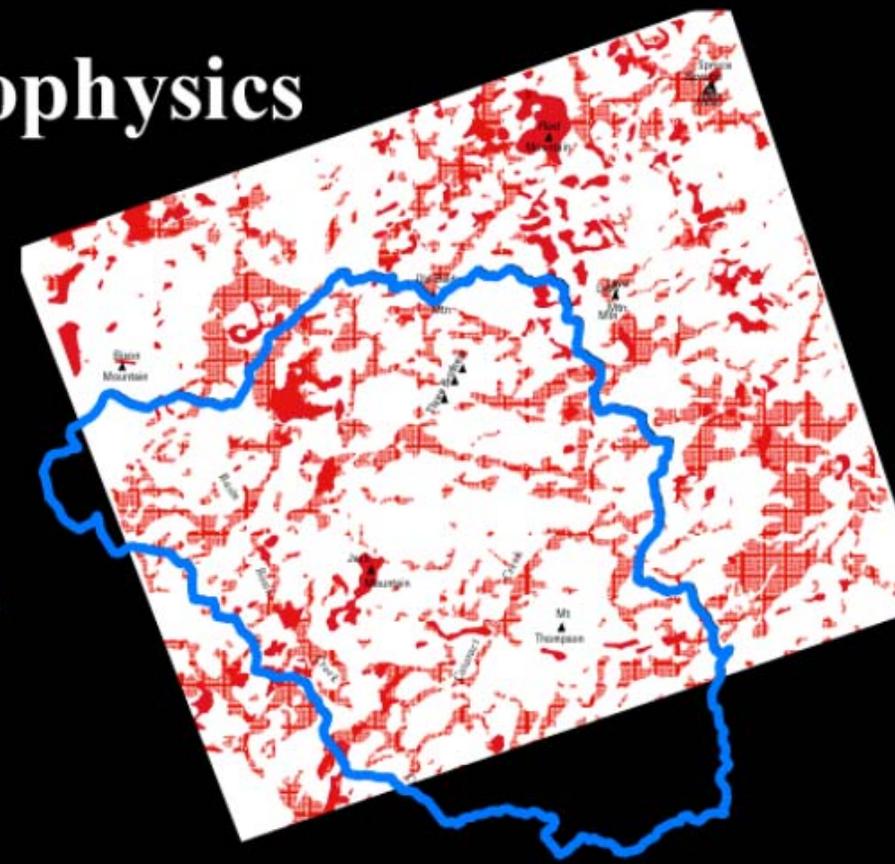
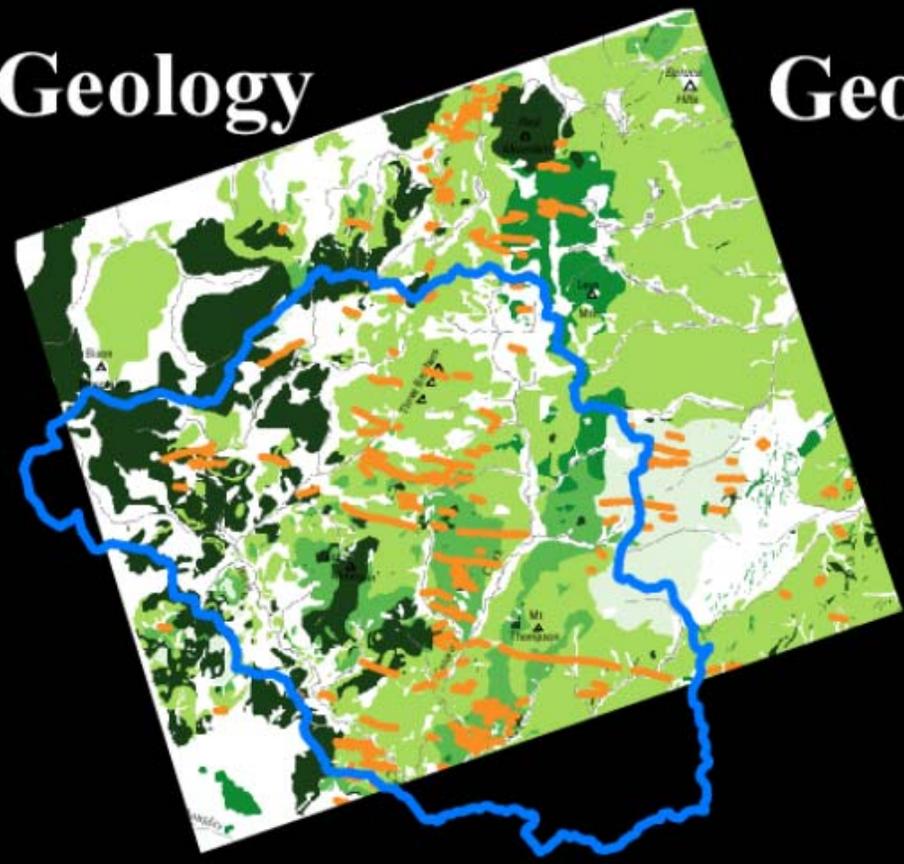
Hornblende

Chlorite

# Relative Acid-Neutralizing Potential

## Geology

## Geophysics



# Geoelectrical Methods

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## CONTACTING

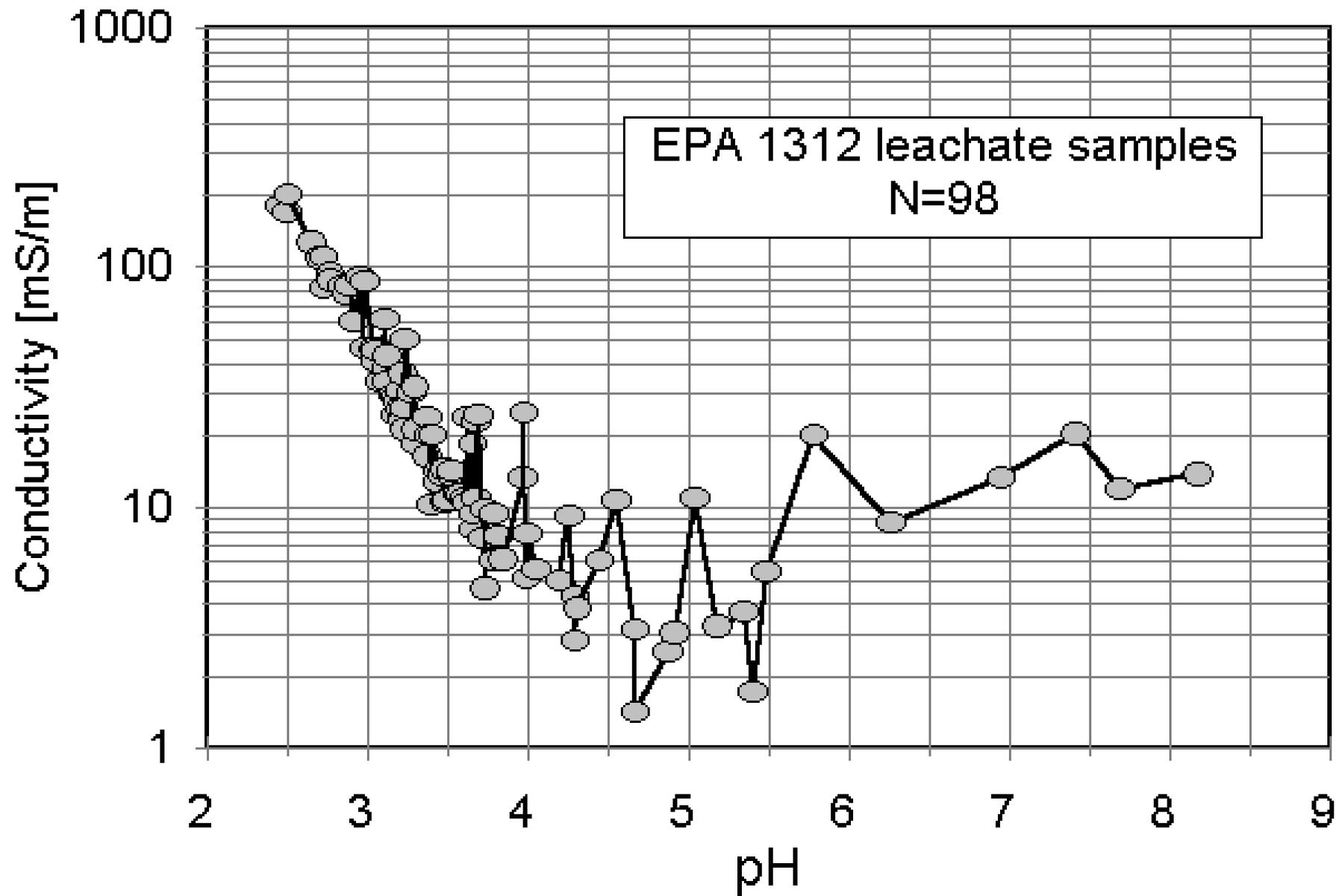
- DC (direct current resistivity)
- IP (induced polarization)

## INDUCTION

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

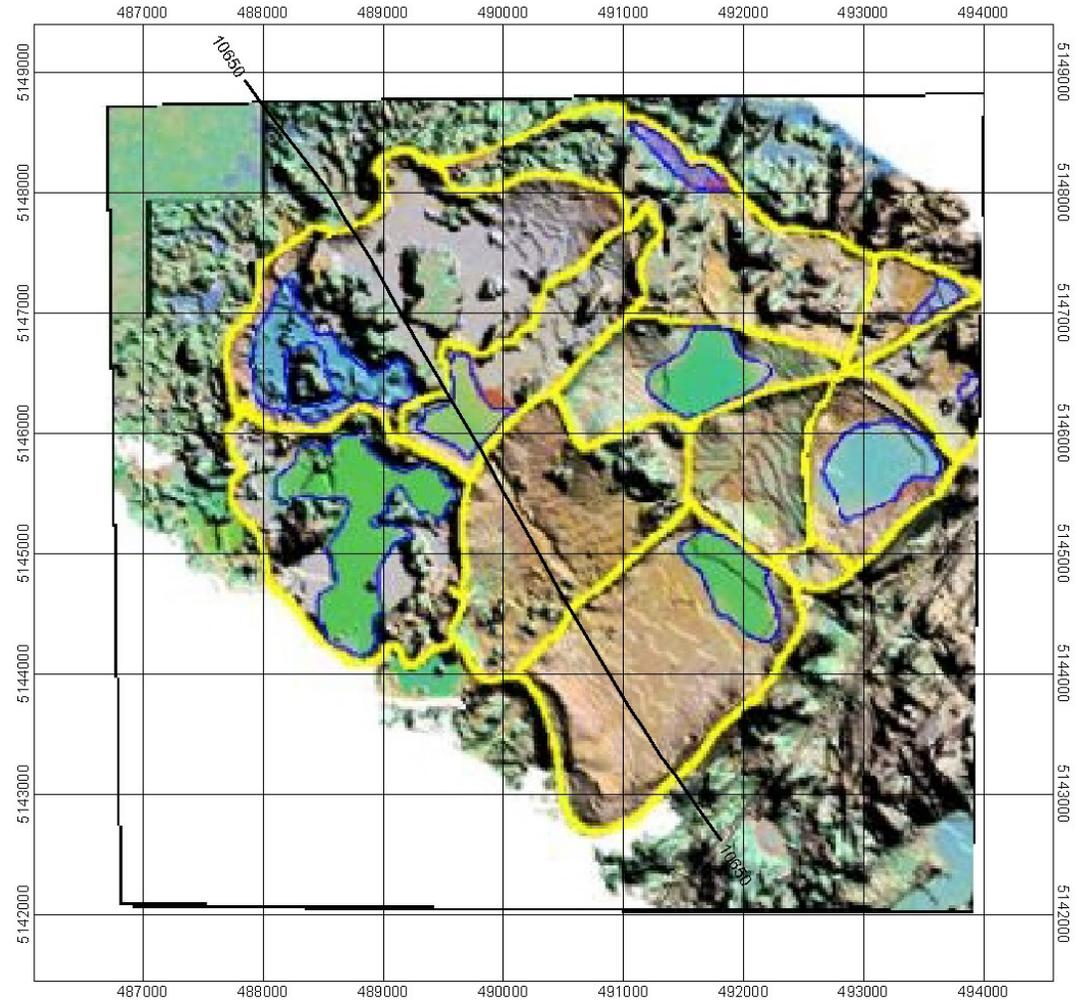
## NATURAL FIELDS

- SP (spontaneous polarization)
- AMT/MT

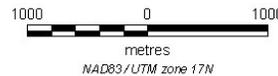


# Sudbury Tailings

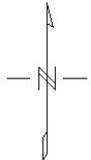
## low altitude spectral scanner



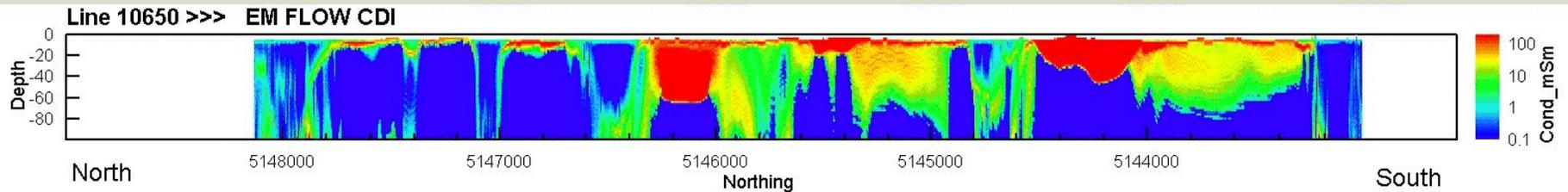
**Condor Consulting, Inc.**



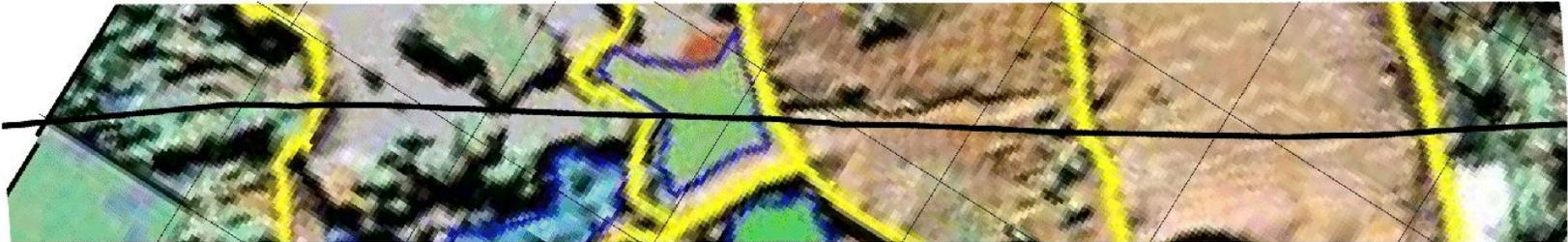
**Copper Cliff Tailings Area**  
Location of Flight Line 10650



# Conductivity Depth Section

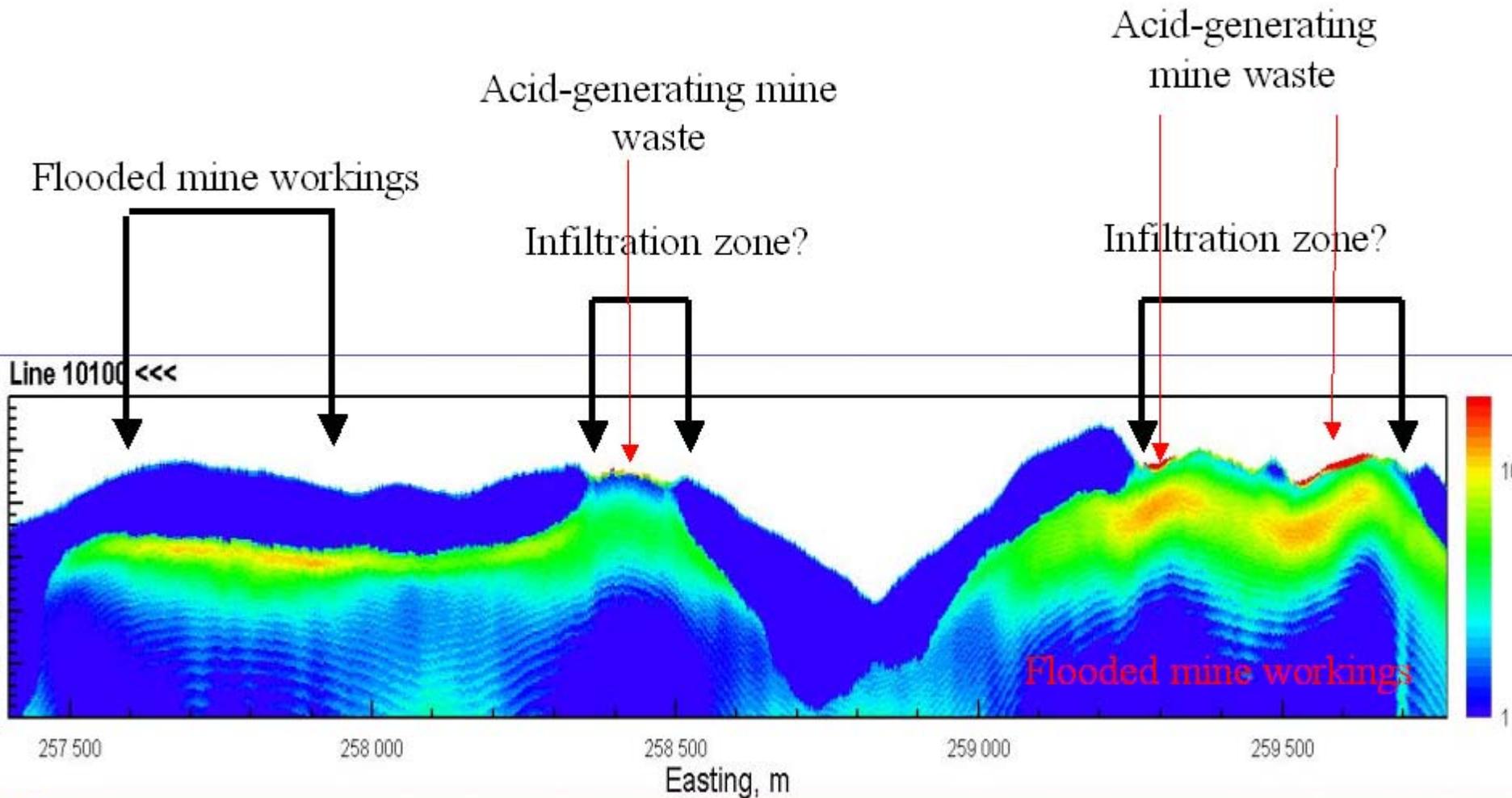


PLAN VIEW OF TAILINGS AREA ALONG LINE 10650



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

# Acid-Generating Mine Waste

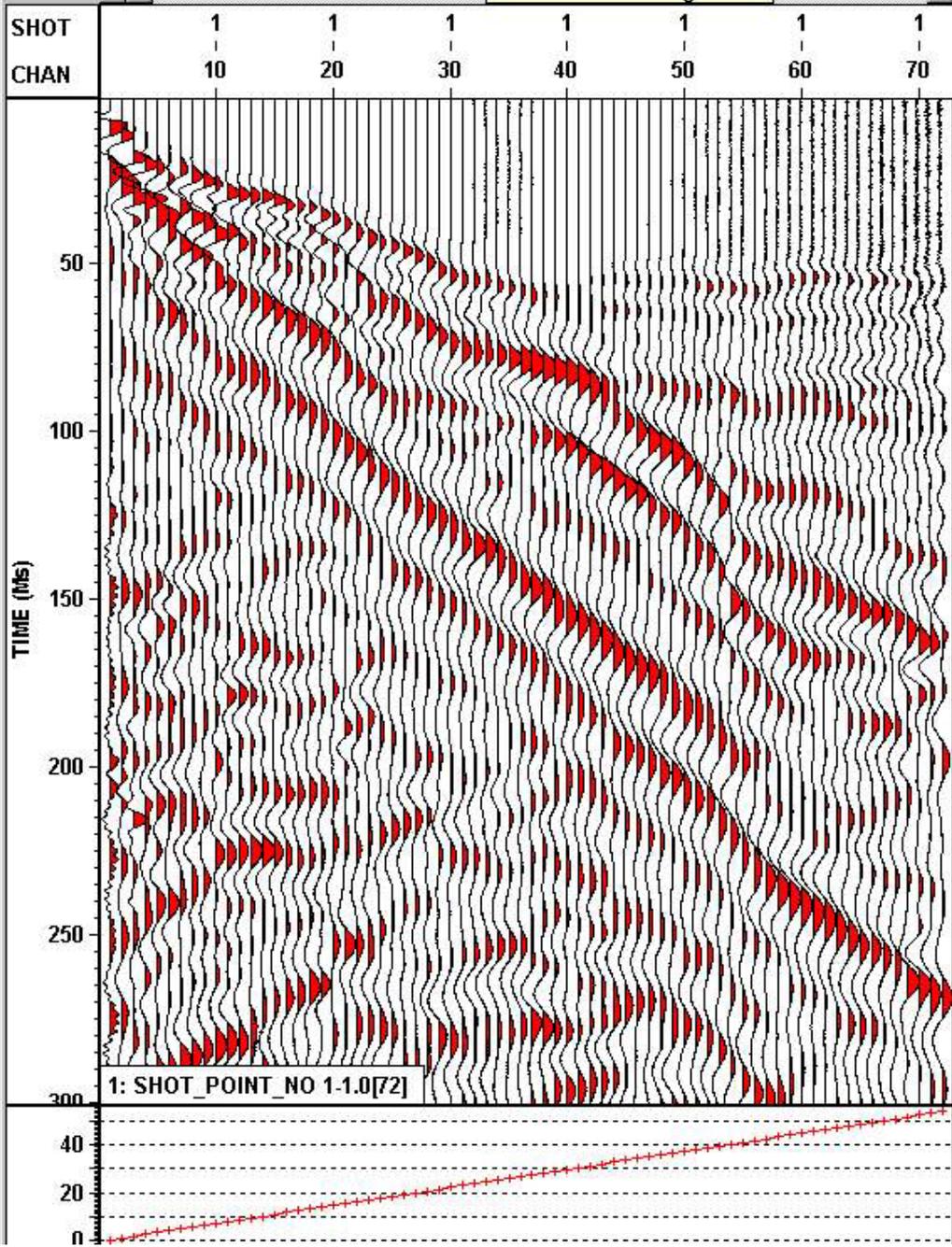


# Engineering GP Methods

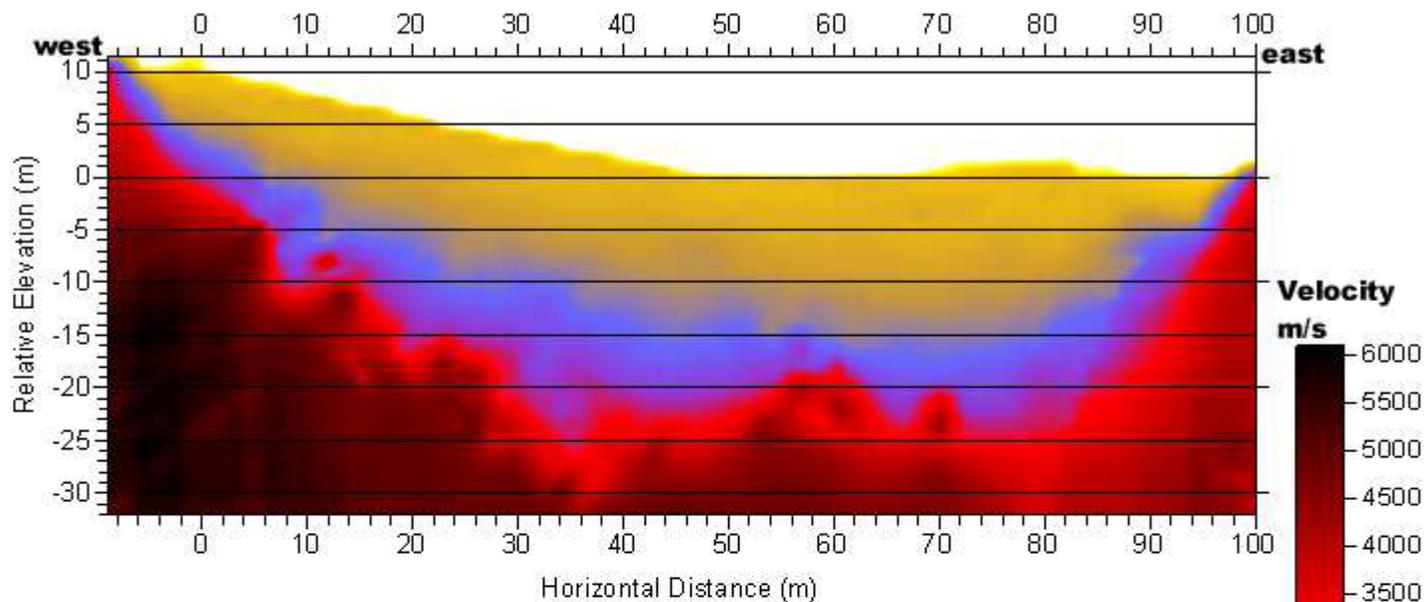
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- **Seismic Reflection and Refraction velocity contrasts needed**
- **Ground Penetrating Radar need very resistive ground but generally not deep (few feet)**

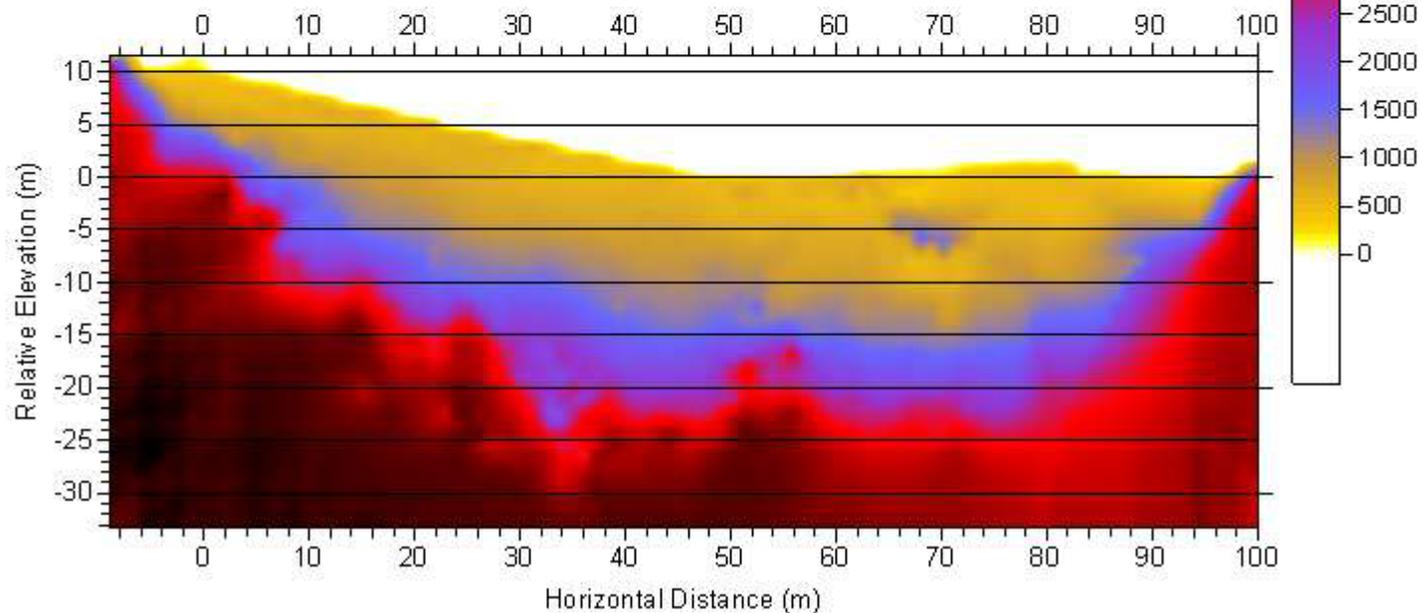




**Line 2: Velocity Depth Model A (meters per second)**



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



# Geonics EM-31



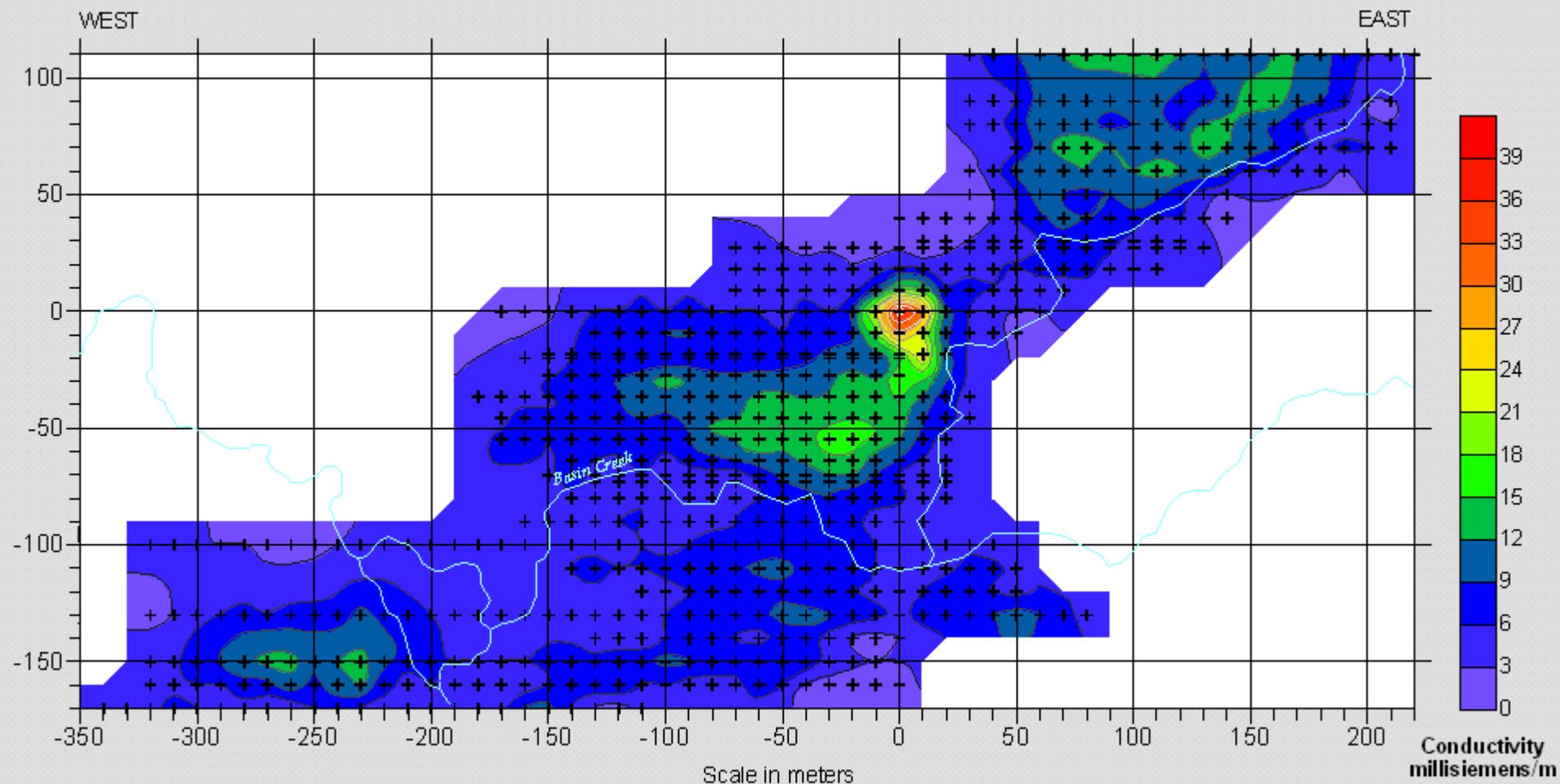
One of several different types of terrain conductivity systems





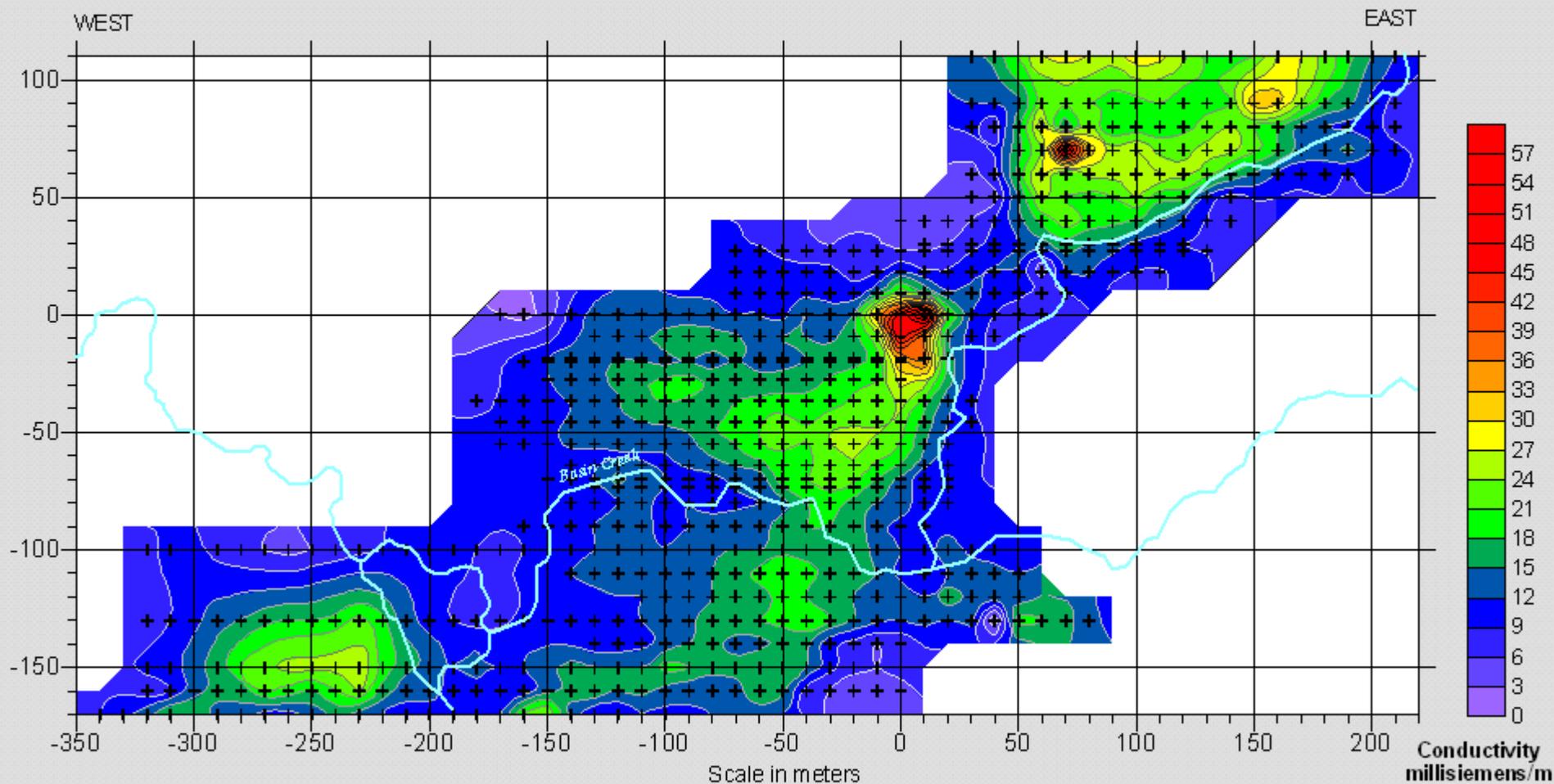
# Electromagnetic Survey using EM-31

## Horizontal Magnetic Dipole



# Electromagnetic Survey using EM-31

Vertical Magnetic Dipole

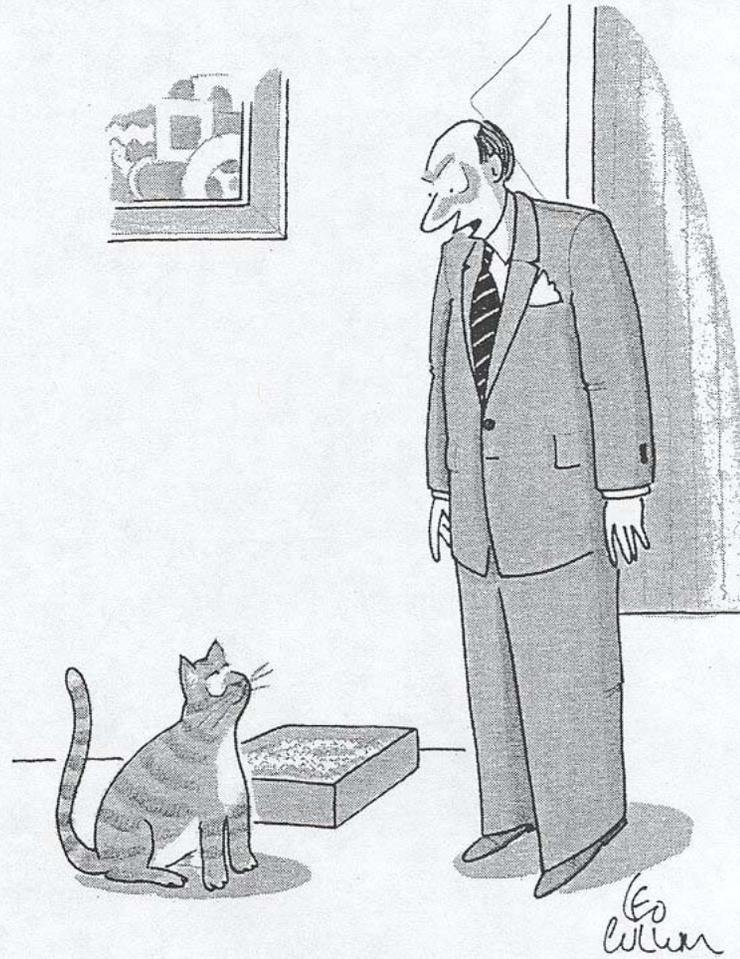




# Geophysics TRY IT!

- **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."*