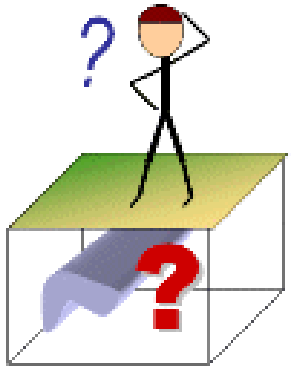
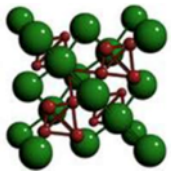
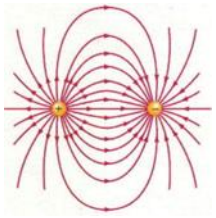
# 7-Step Framework



# From last time

- Characterize materials by physical properties:
  - Density
  - Magnetic susceptibility
  - Electrical conductivity
  - Chargeability
  - Electrical permittivity
  - Elastic moduli/velocity

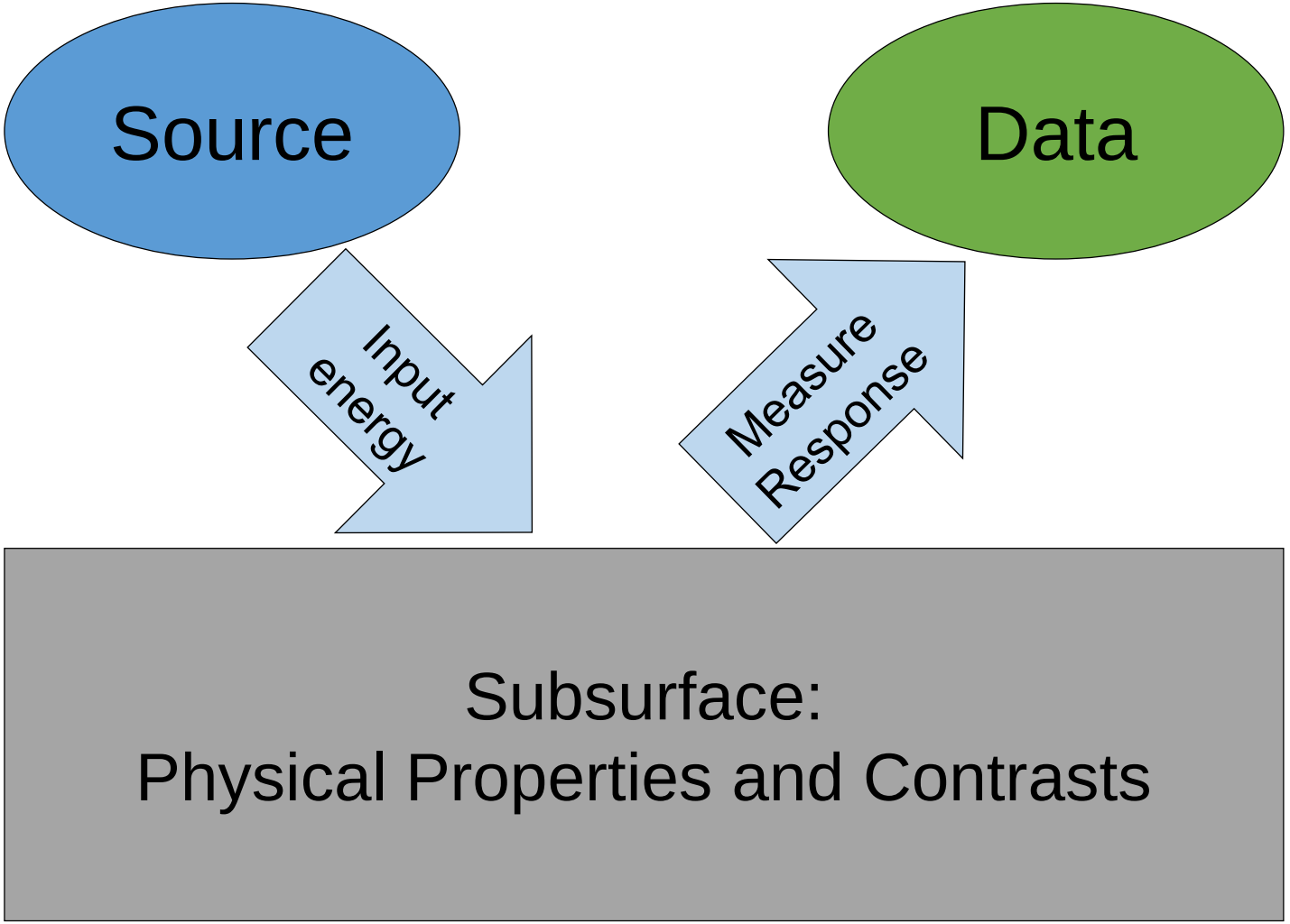




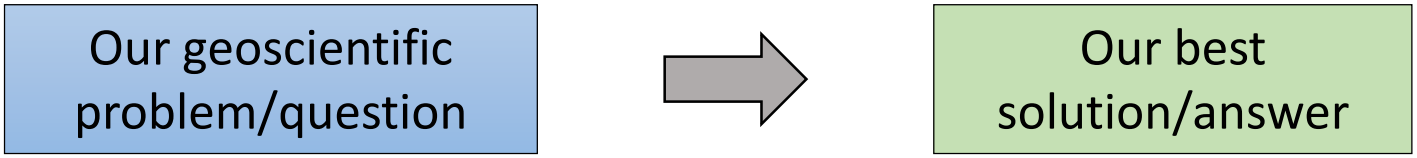
# From last time

- Each physical property has one or more survey methods:
  - Density → Gravity
  - Magnetic susceptibility → Magnetics
  - Electrical conductivity → DCR and EM
  - Chargeability → IP
  - Electrical permittivity → GPR
  - Elastic moduli/velocity → Seismology

# Geophysics requires physical property contrast(s)



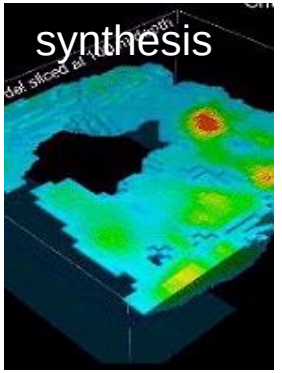
# Today

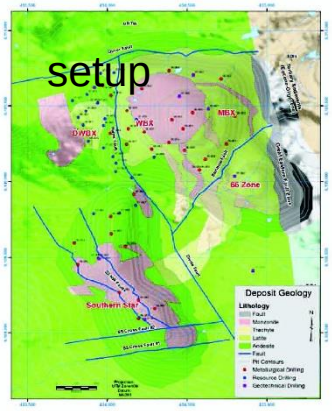


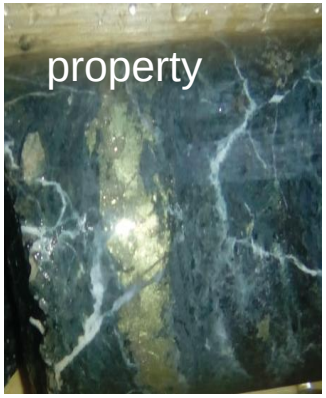

**We need to develop a framework!**

# The seven-step framework

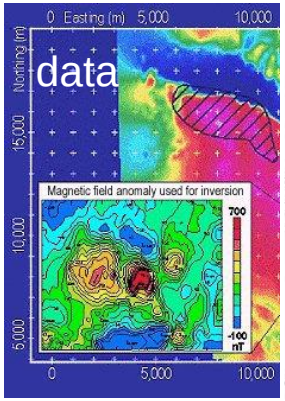
1. Setup: What is the geoscientific question/problem?
2. Physical Properties: Which are diagnostic?
3. Survey: What survey type(s) should we use?
4. Data: What data are collected?
5. Processing: Turning raw data into something we can interpret
6. Interpretation: Inferring answer to question from data
7. Synthesis: Comparing your answer with other interpretations

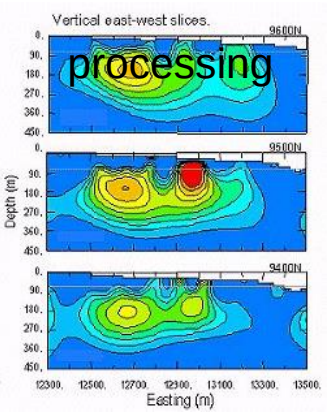


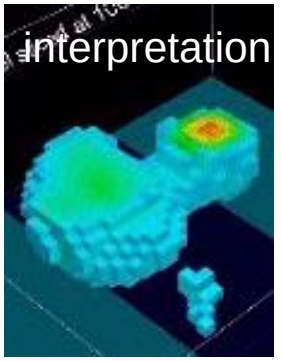







# 1. Setup

- Ask questions…
- Gather information…
- Establish expectation…

Bad question: “Where is the water?”
Good question: ”Where is the best location for drilling some test boreholes?”

Showing of small water gushing/wet ceiling/leakage
Fresh or salt water
Interference from mining activities
Budget and feasibility

Existence or details about water location
A cross section image or a 3D volume?
Use the results as input to another survey? Spot a test drill hole?
Be realistic!

# 2. Property

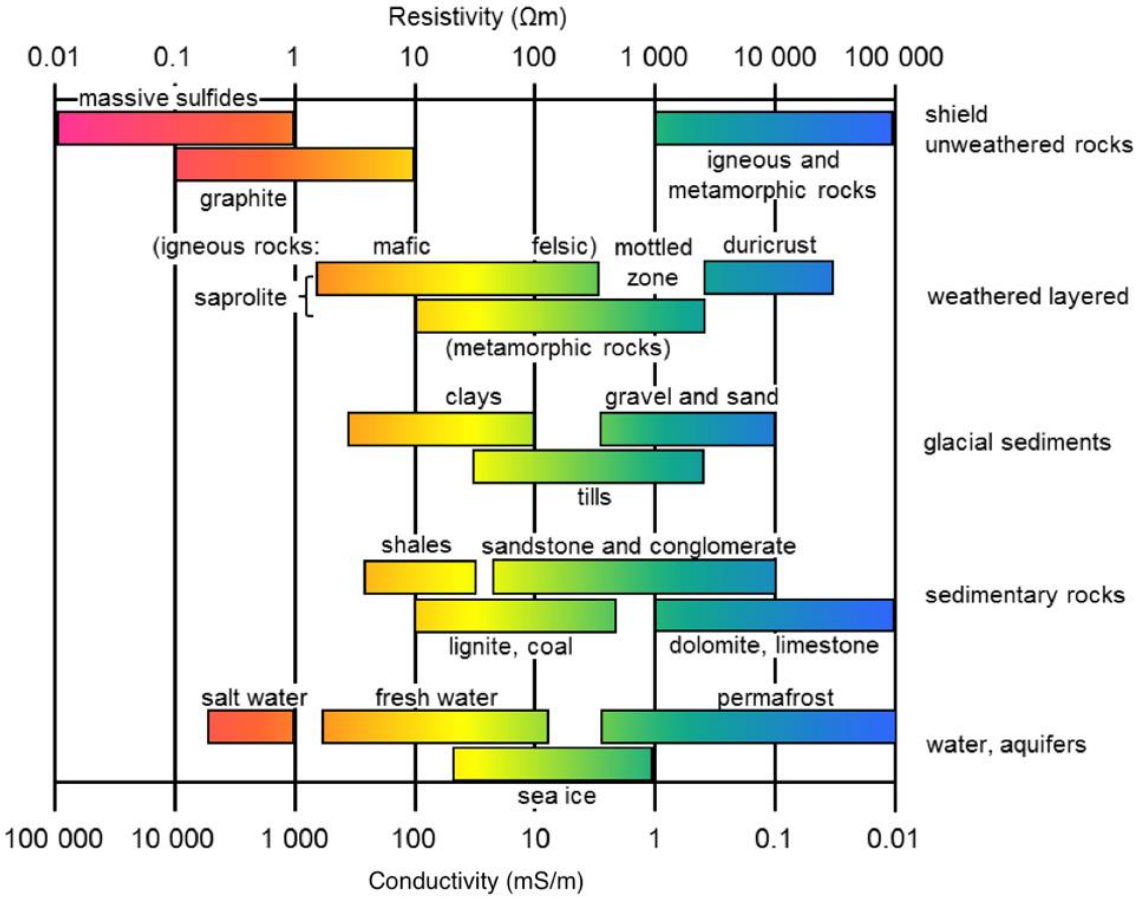
Host: rock salt or sandstone

Target: water

What physical property?

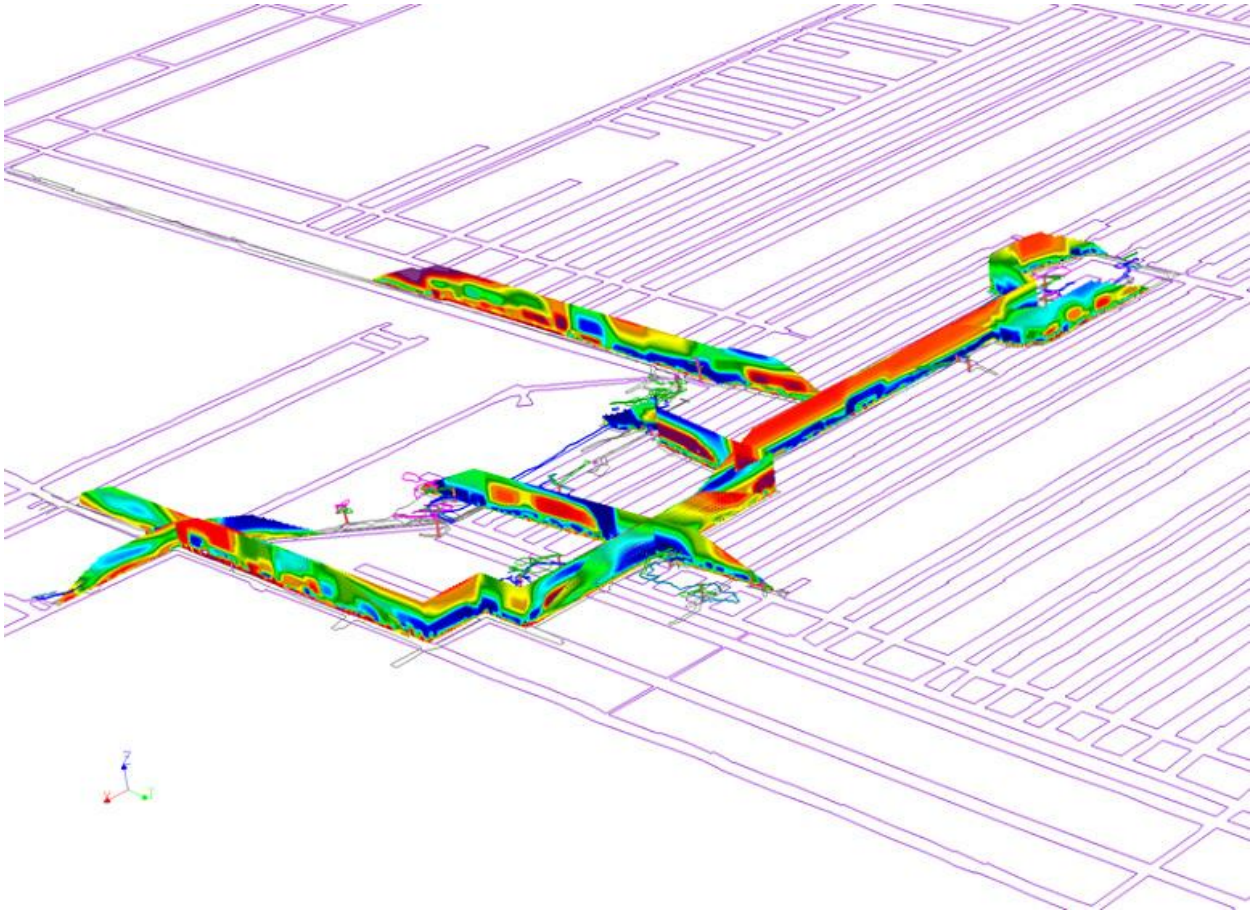
Contrast large enough?

What survey can exploit the physical property contrast?



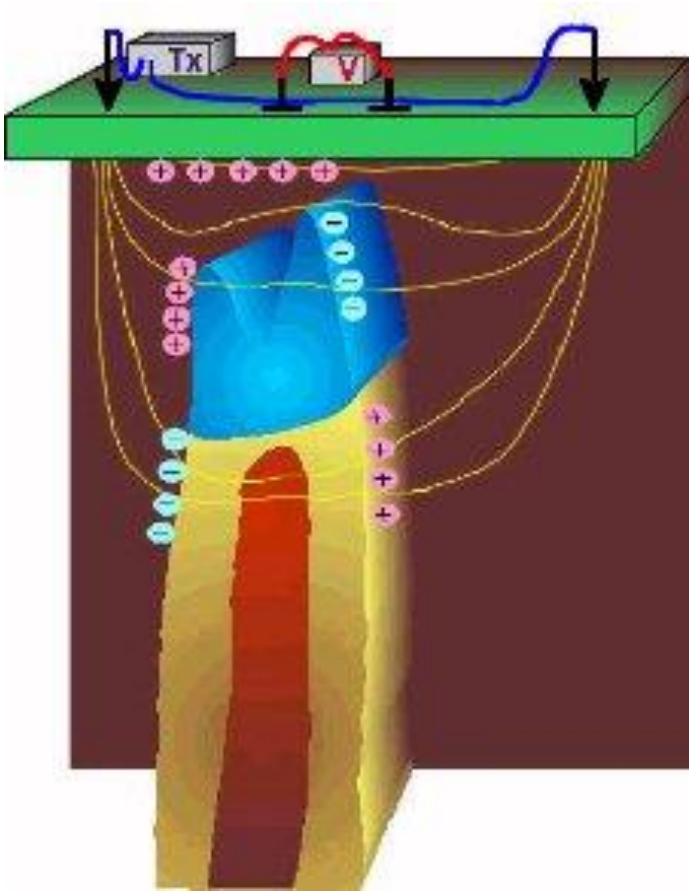
# 3. Survey

3.5 km of DC resistivity survey along tunnels

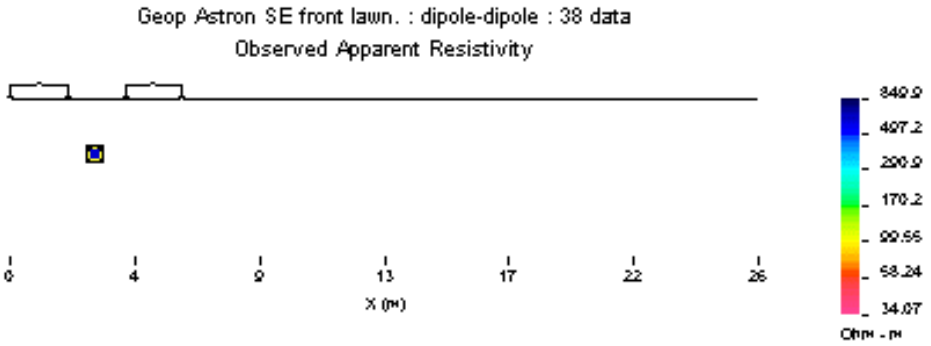


- Active or passive
- Platform
- Station/line spacing
- Cost-effectiveness
- Feasibility study
- Noise source
- Instrumentation

# 4. Data

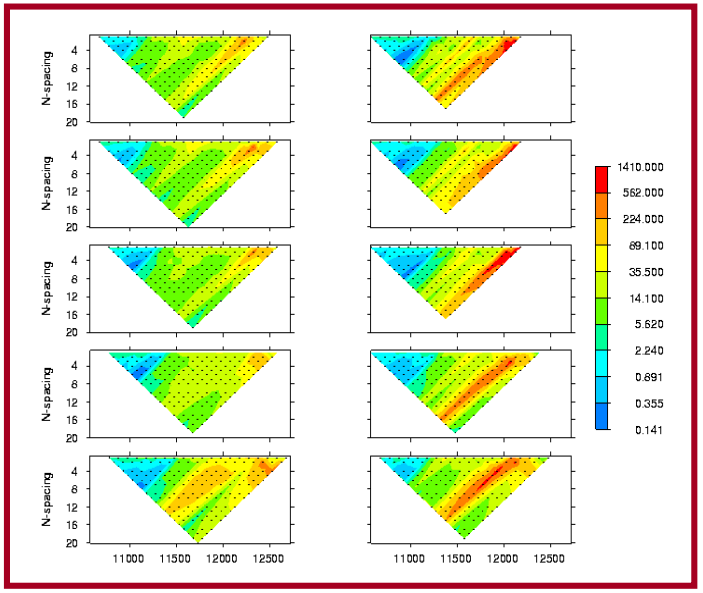


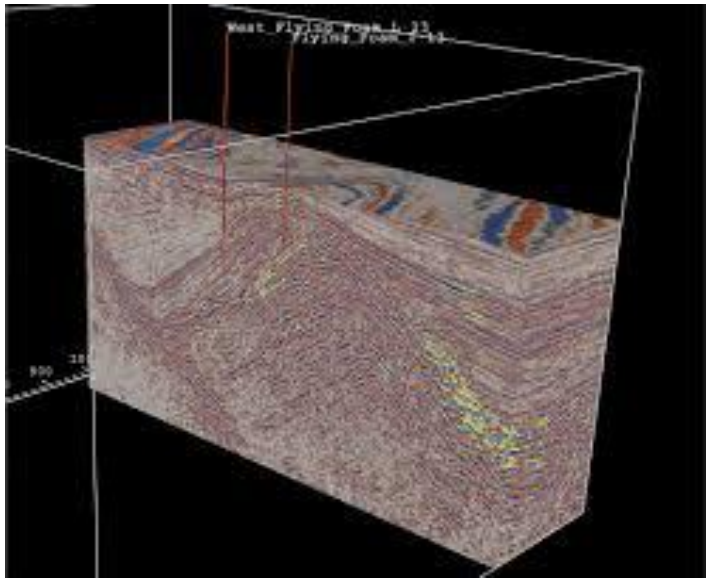

Apparent resistivity pseudo-section

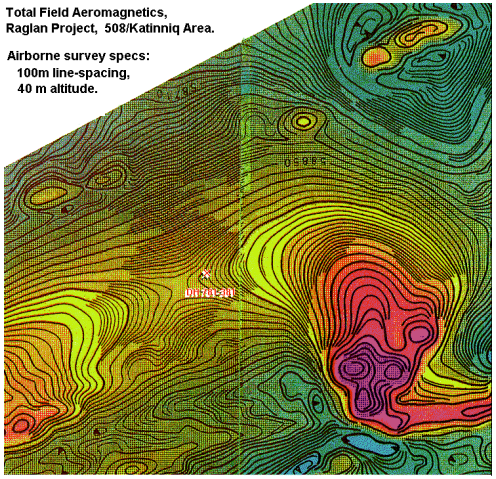


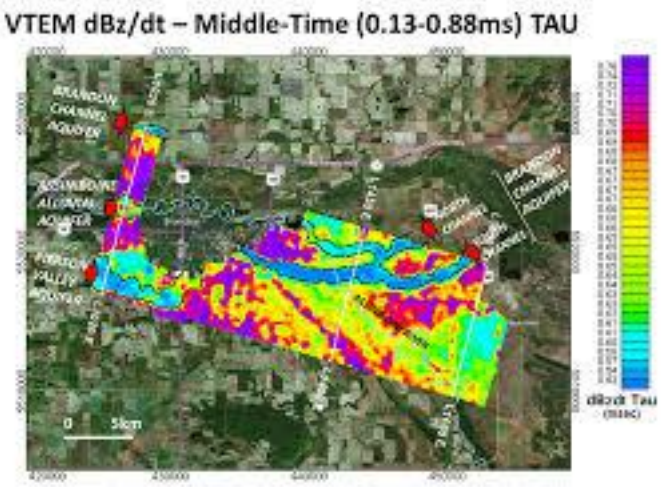

- Data QC & visualization
- Bad electrode removal
- Reciprocity check
- Preliminary processing/interpretatio

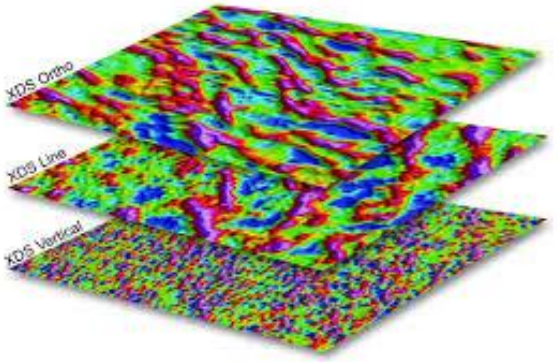
# 4. Data


N-spacing
4
8
12
16
20
11000
11500
12000
12500
1410.000
562.000
224.000
89.100
35.500
14.100
5.620
2.240
0.891
0.355
0.141



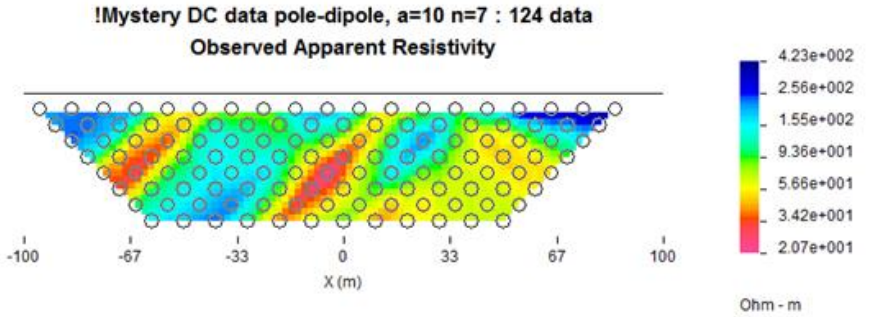

Total Field Aeromagnetics,
Raglan Project, 508/Katinniq Area.
Airborne survey specs:
100m line-spacing,
40 m altitude.

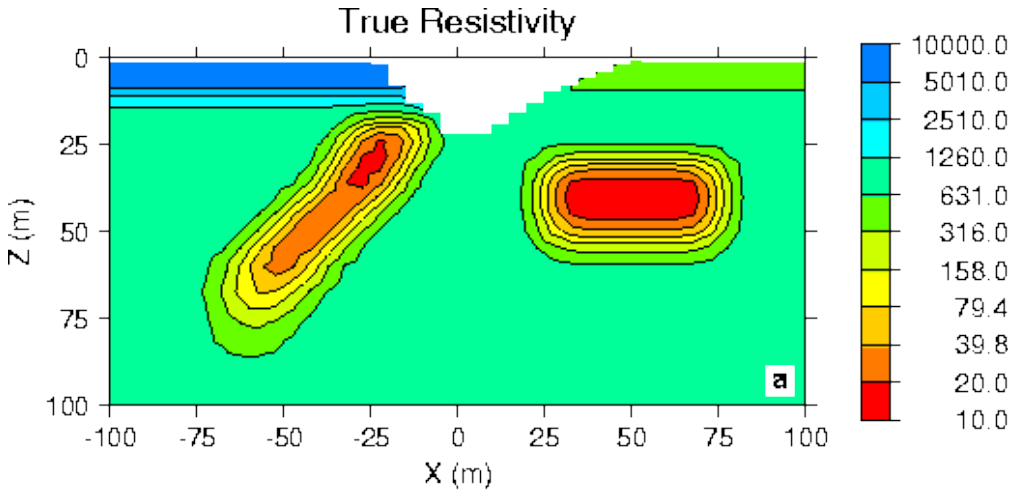

VTEM dBz/dt – Middle-Time (0.13-0.88ms) TAU
0
5km

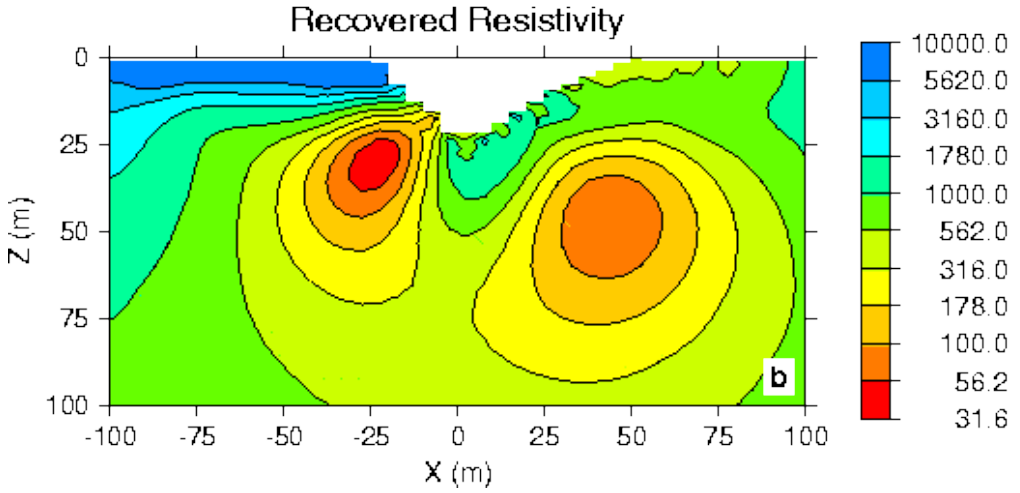

XDS Ortho
XDS Line
XDS Vertical

# 5. Processing

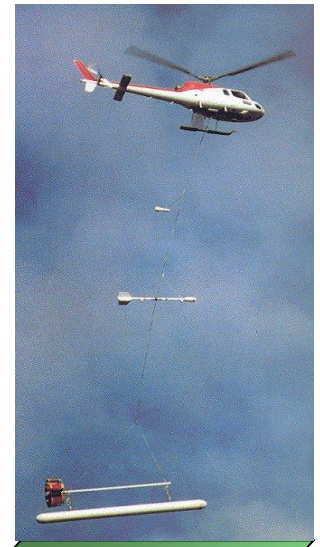
- A pseudo-section (plot of data)  may not be a good representation of subsurface
- Use a technique called inversion to convert data to a physical property model through physical modeling



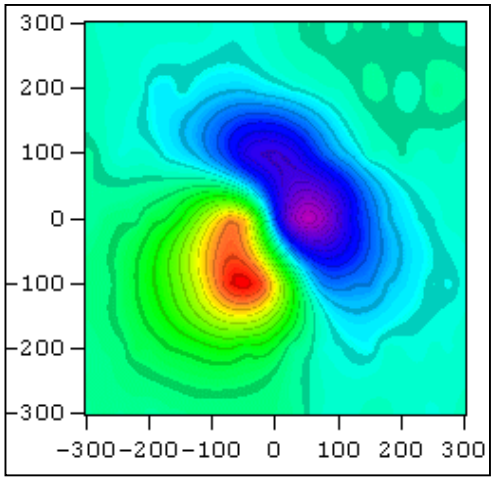



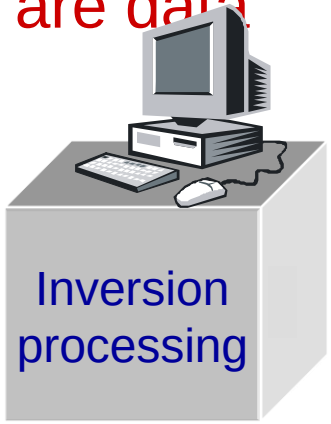
# What is inversion?

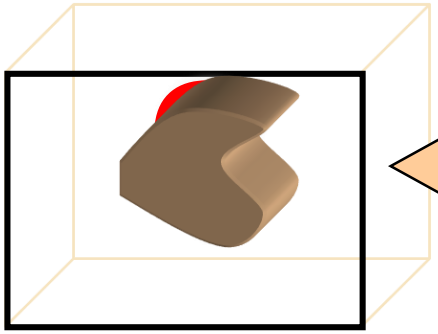


Airborne, surface or borehole measurements are data

Data



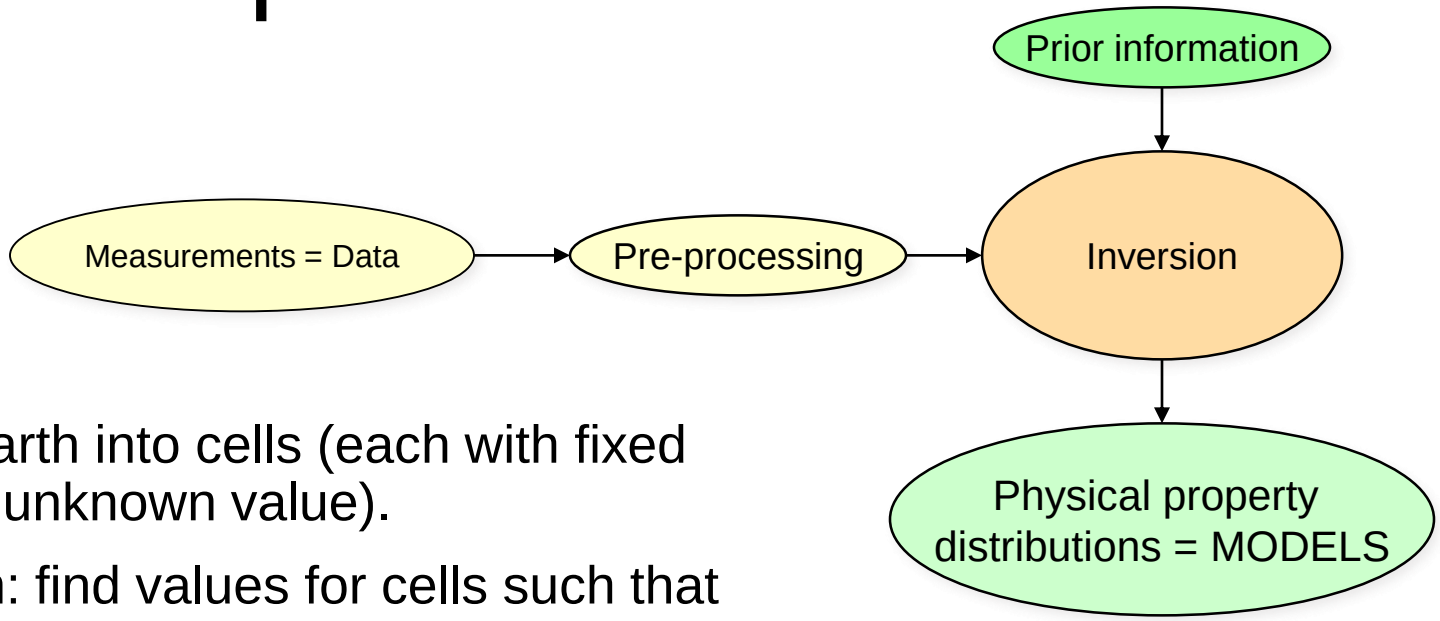



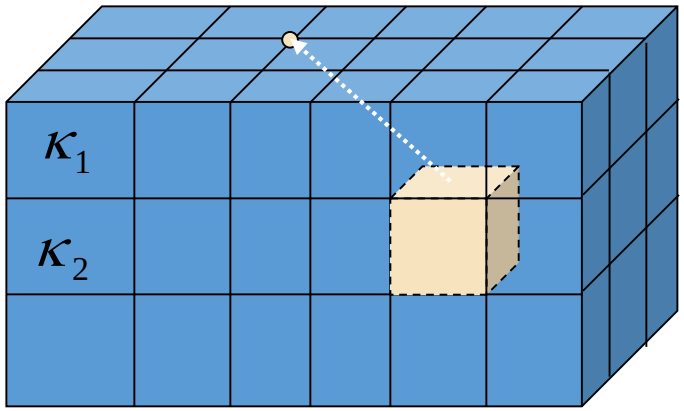
Model

Goal: Estimate the Earth model that reproduces the field data

# Inversion procedure




- Divide Earth into cells (each with fixed size and unknown value).
- Inversion: find values for cells such that data are explained.
- Use mathematical optimization theory.
- Difficulties:
  - Solution is non-unique.
  - Computationally demanding.




3D, and ~ $10^5$ cells

# Geophysical inversion is analogous to medical imaging

Image of a brain based on MRI measurements.

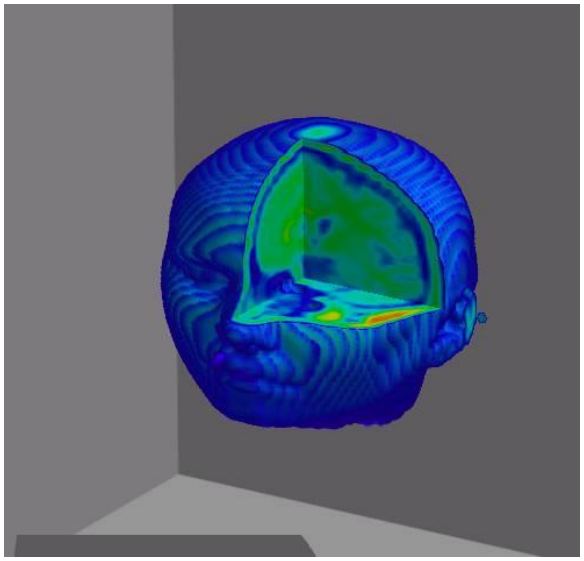
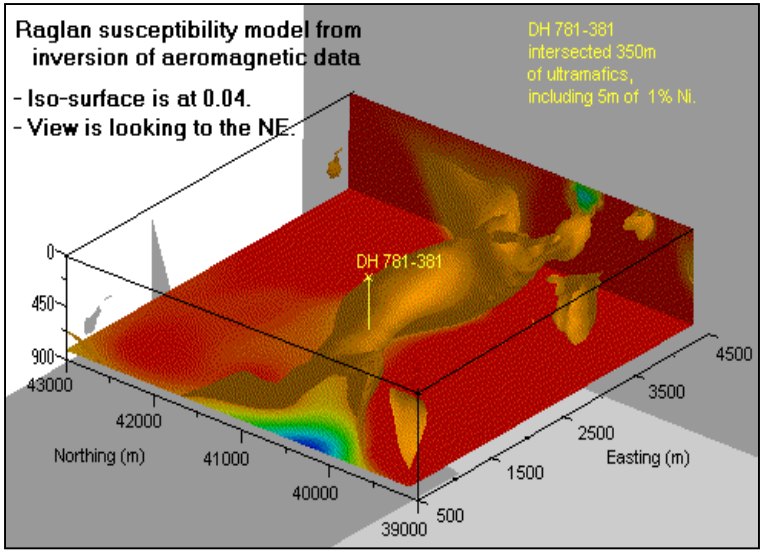
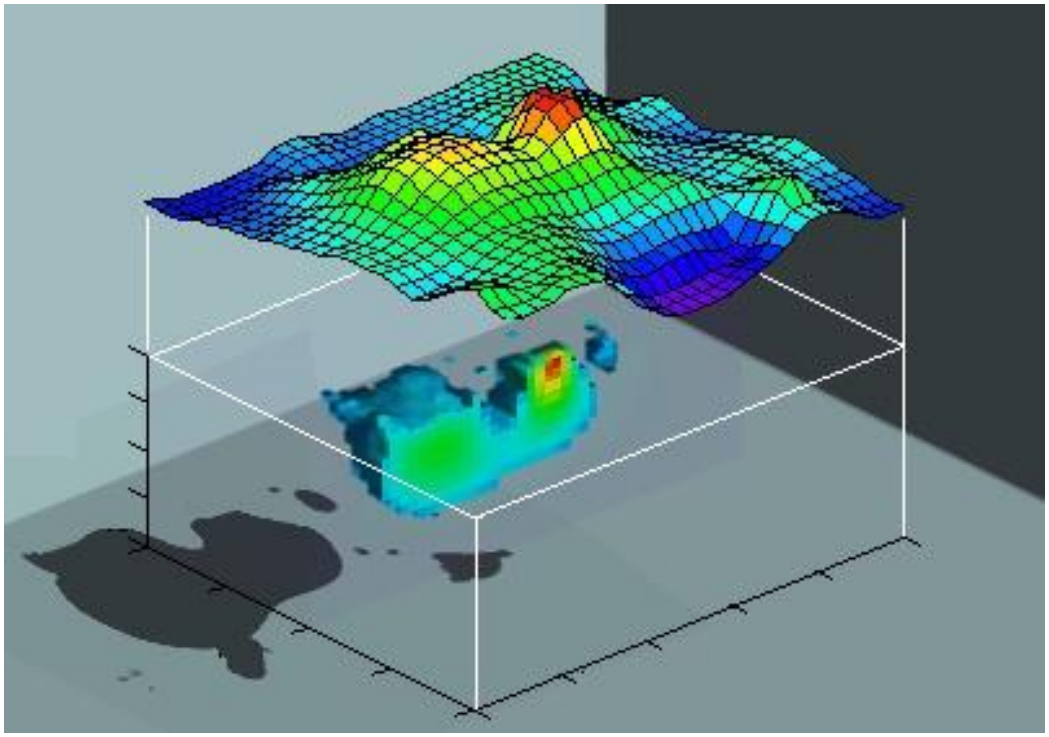


Image of an ore body based on magnetic field measurements.

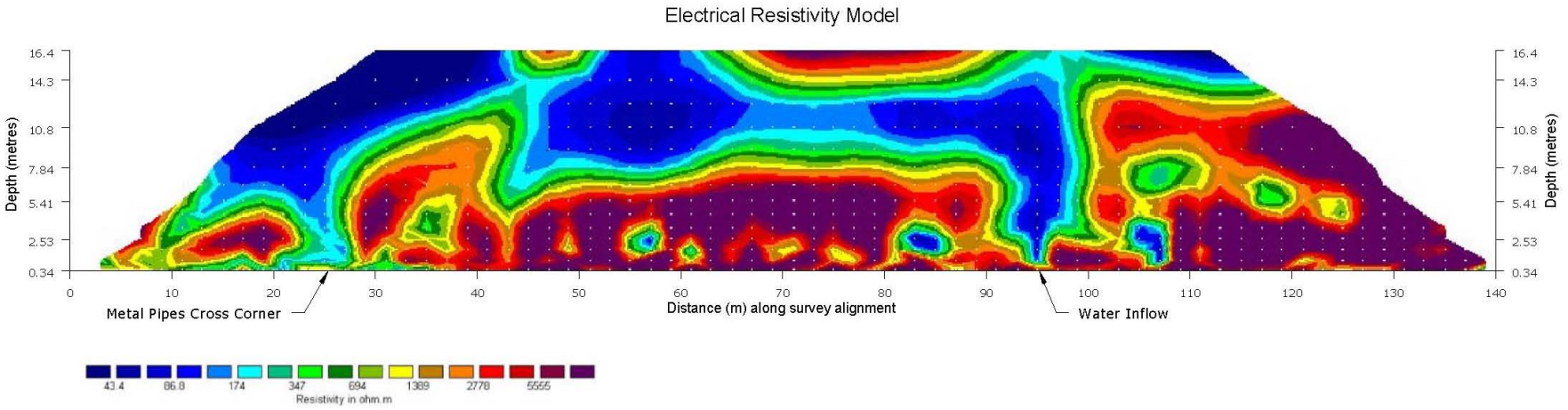


# Viewing an inversion result

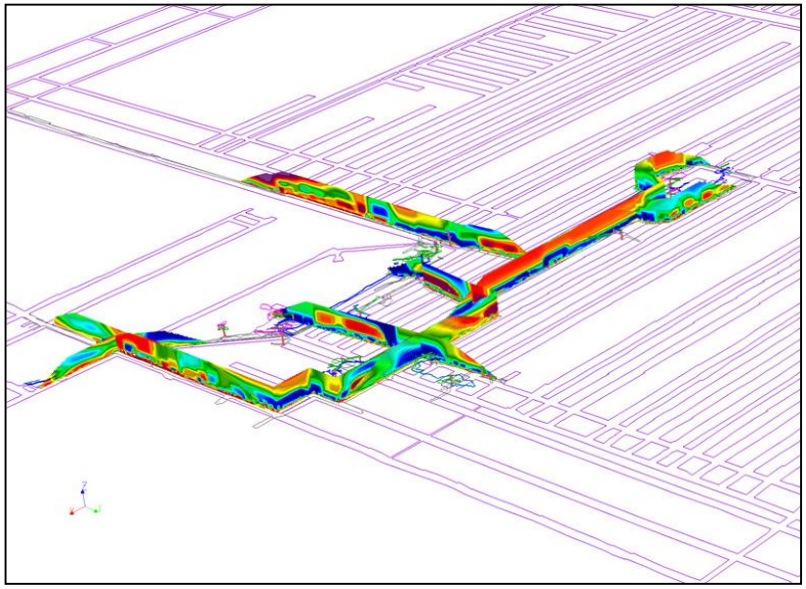
- 3D volume can be viewed in many ways. Here:
  - Data on top
  - Pixels showing material property values visible along the slice.
  - Isosurface highlighting the ore bodies



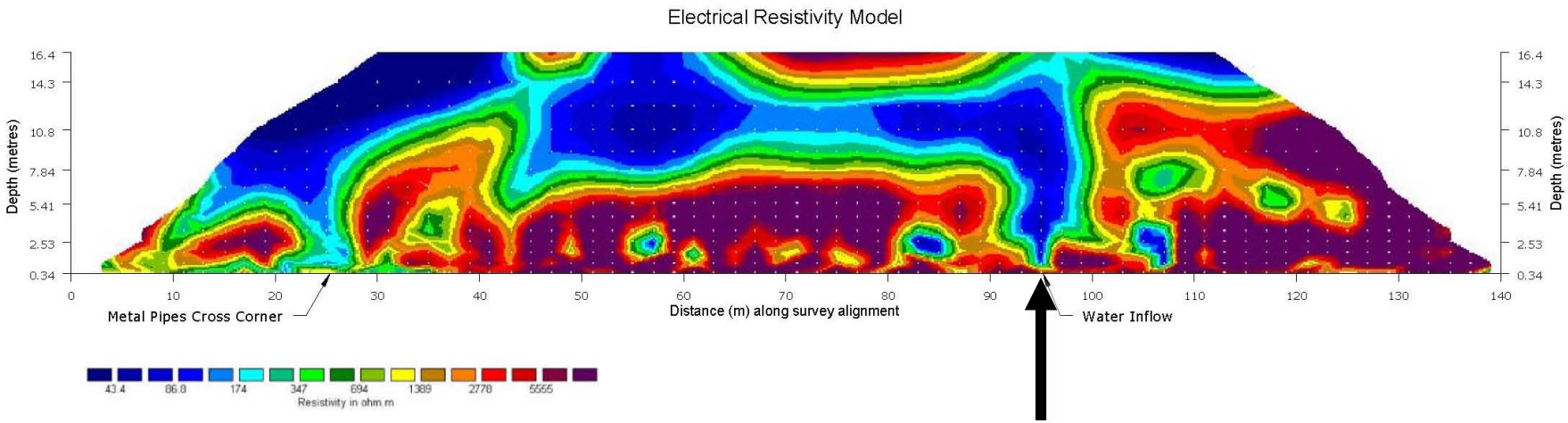
# 6. Interpretation

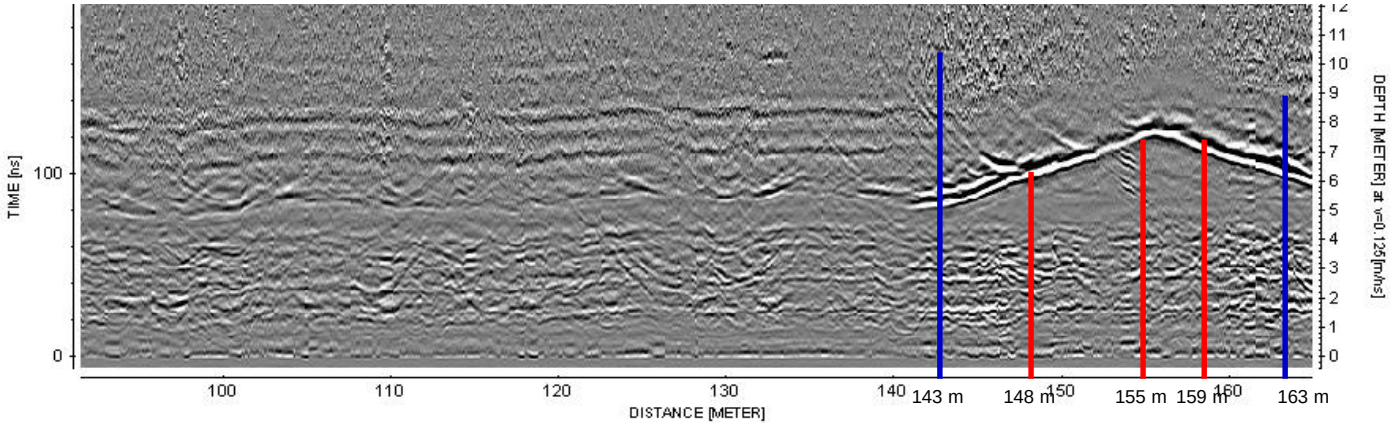



- Large area of “blue” (low res.)
- Two “out-cropping” – both are water?
- One is metal pipe; the other is water inflow



# 7. Synthesis

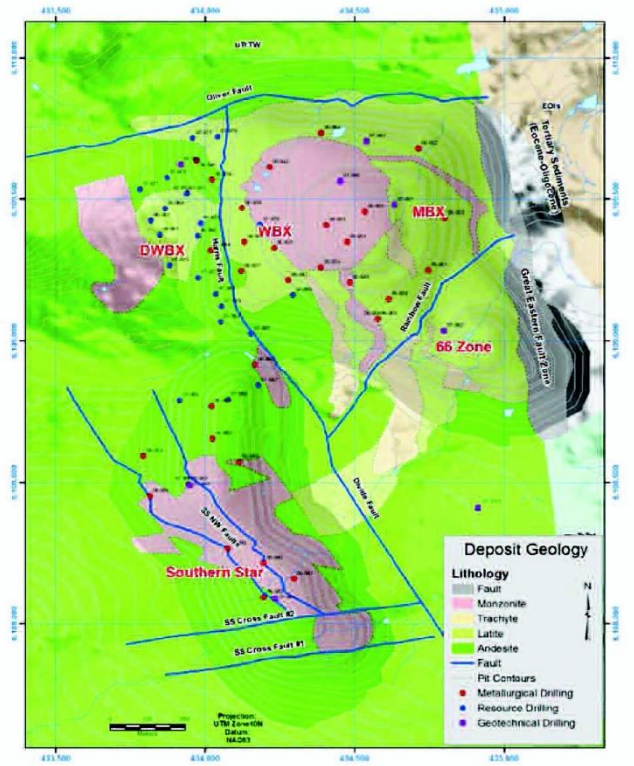


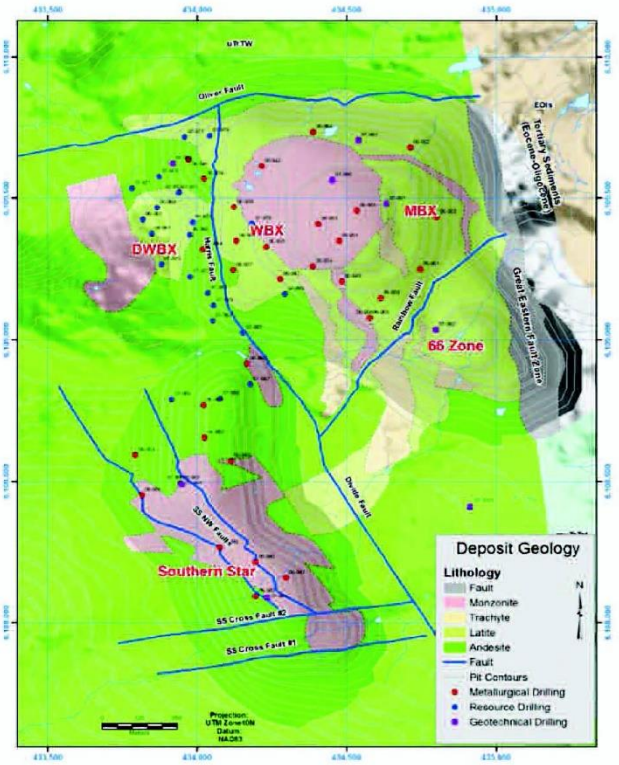

Ground Penetrating Radar  Drill-holes with no water

Water found

# Mt. Milligan: A mining example

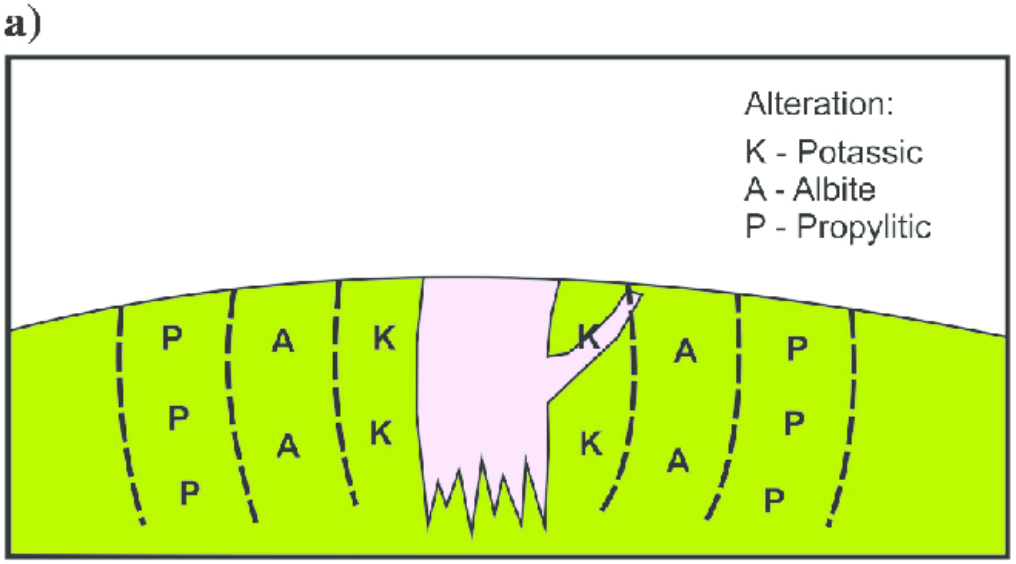



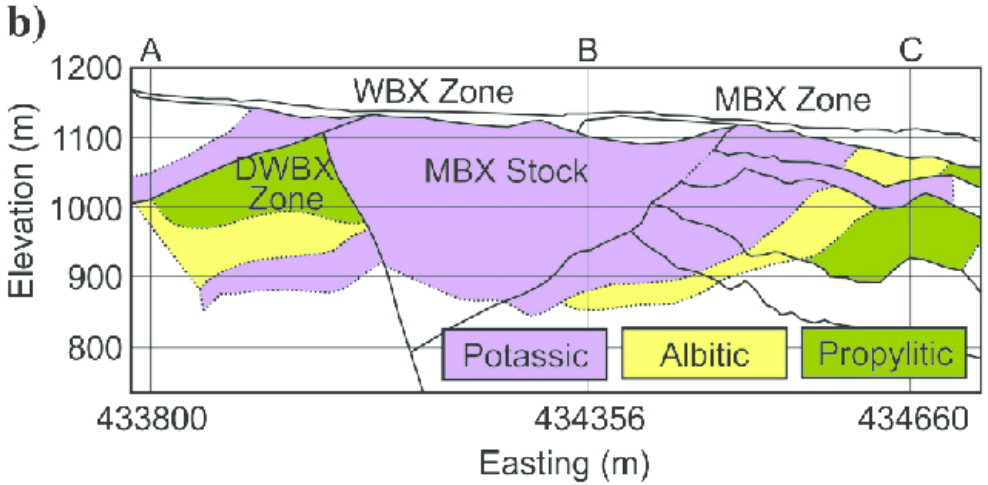
# Mt. Milligan: Setup


- Geologic engineers need to know where to drill or to dig for ore
- Geophysics will try to provide information regarding:
  - Location and geometry of ore-bearing rocks in the region
  - Concentration and grade of the deposit

# Mt. Milligan: Physical Properties

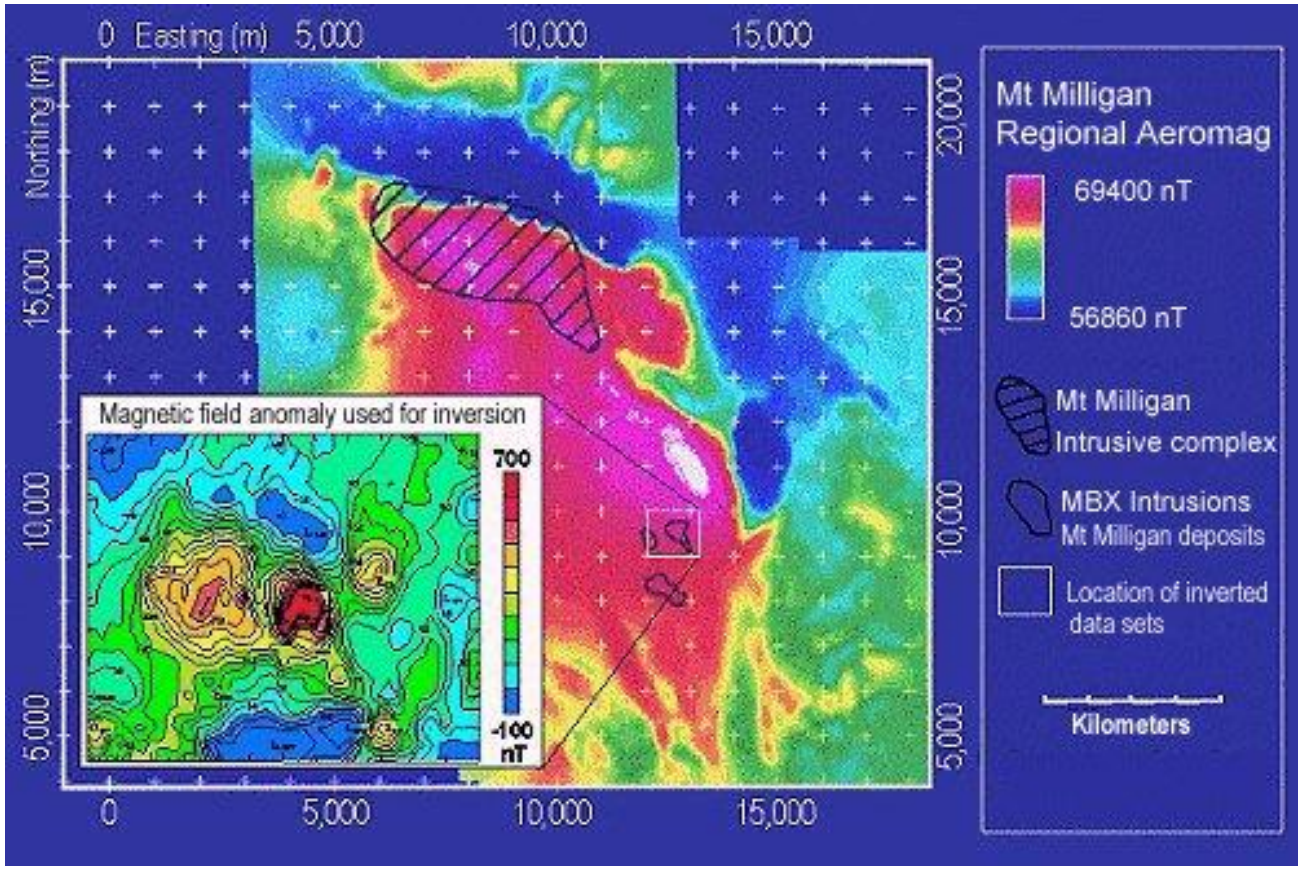



Porphyry deposit with Pyrite and chalcopyrite (sulfides)

- susceptibility
- conductivity
- chargeability

# Mt. Milligan: Aeromagnetic Survey and Data

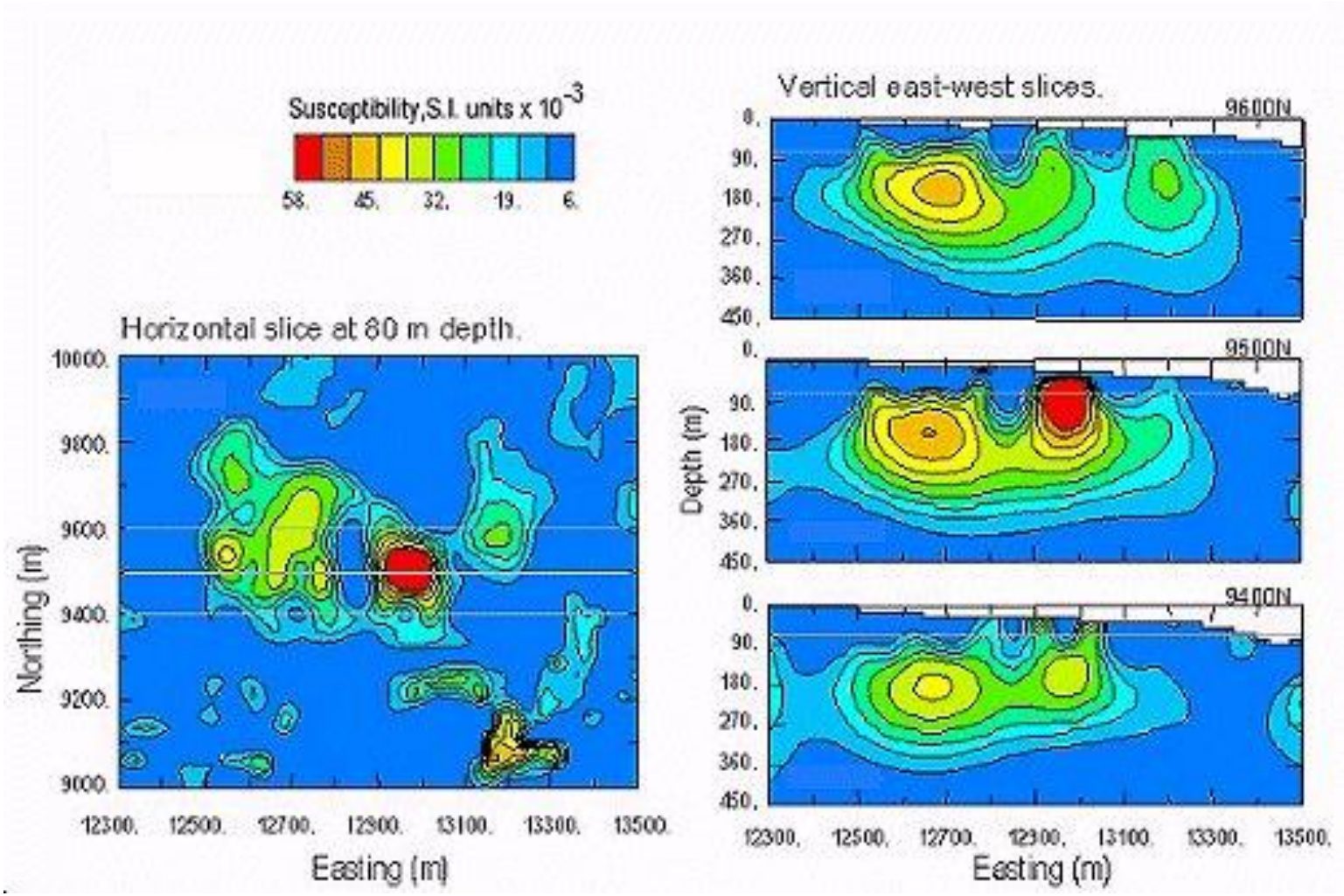



Helicopter-borne magnetometer

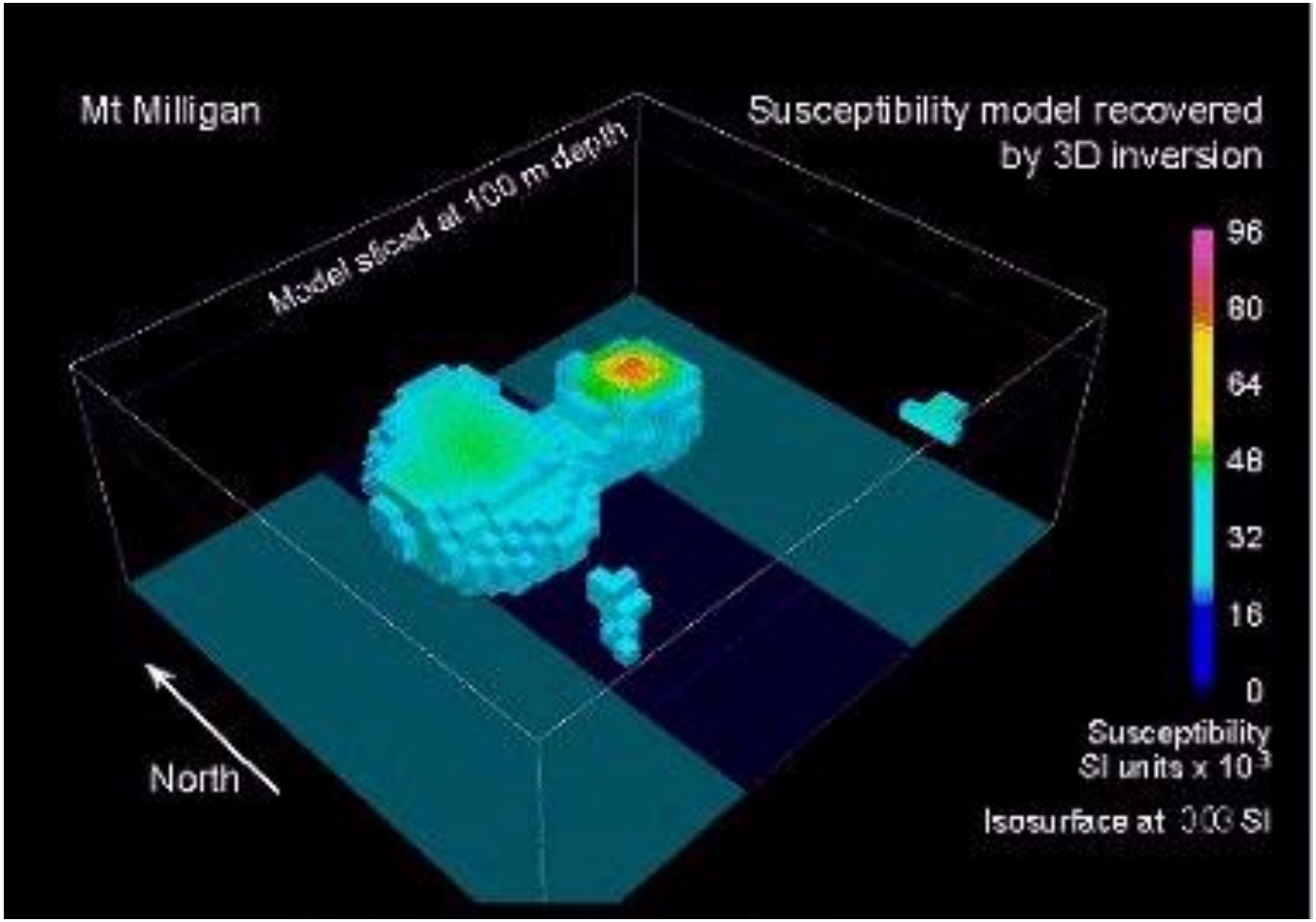
Total magnetic field (nT)

Question: can you answer the questions asked at the beginning by looking at the magnetic field data map?

# Mt. Milligan: Processing - 3D magnetic inversion



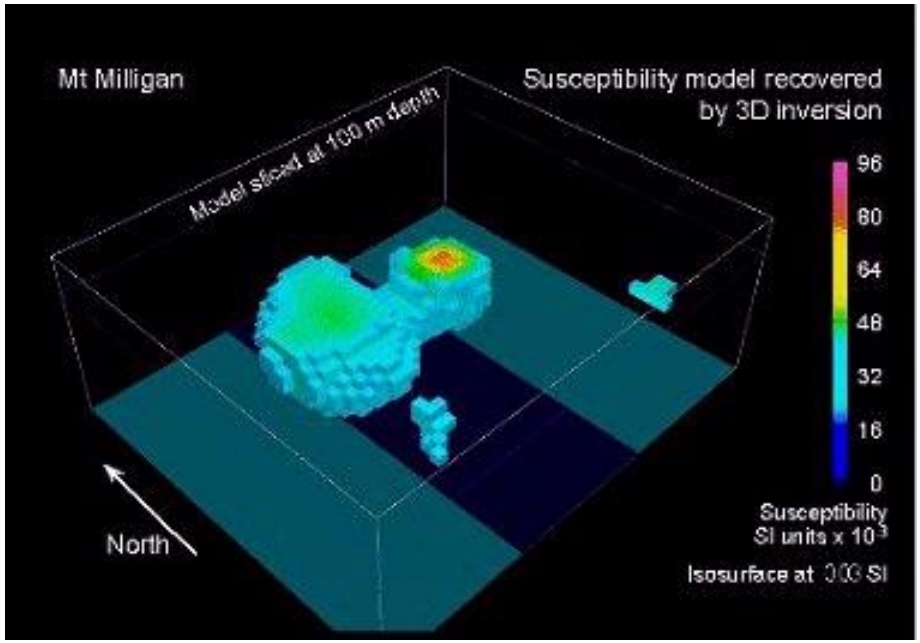
# Mt. Milligan: Interpretation



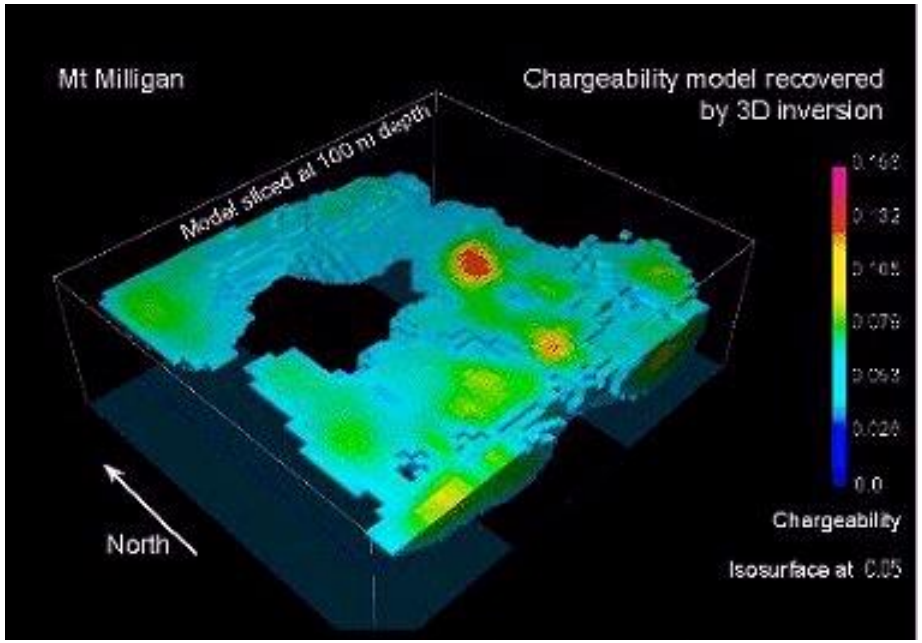

isosurface 0.03 SI

# Mt. Milligan: Synthesis

Magnetic Inversion




Chargeability Inversion



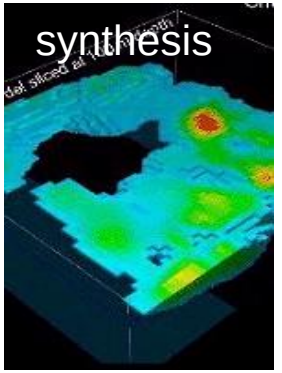

Can we answer those questions now?

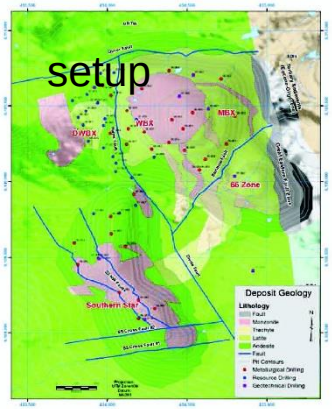
How confident?

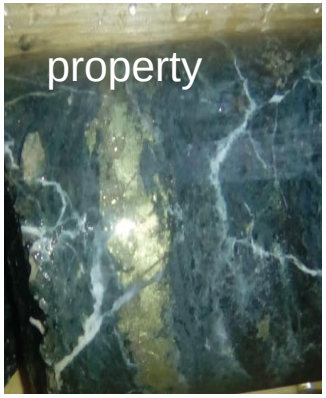
Iterate or add information from other surveys or disciplines?

# The seven-step framework

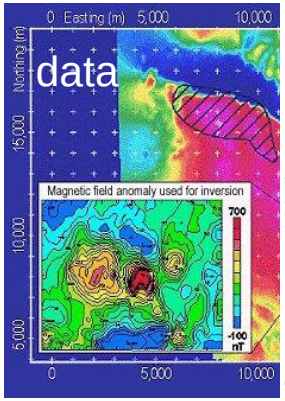
1. Setup: Want to find location, orientation and grade of ore bodies
2. Physical Properties: conductivity, chargeability, susceptibility
3. Survey: Airborne magnetics (also DCIP or EM surveys)
4. Data: Magnetic (also DCIP and EM data)
5. Processing: Plotting and 3D magnetic inversion
6. Interpretation: Localized region of high susceptibility
7. Synthesis: One area shows high susceptibility AND chargeability

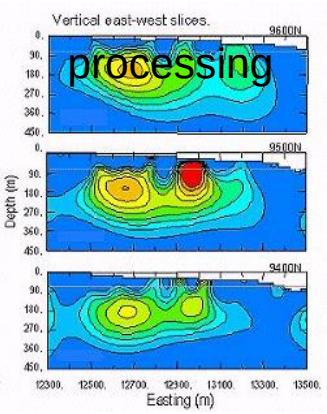


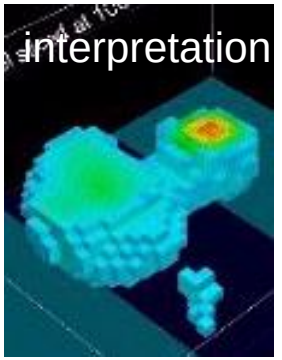







# Recap

- Seven steps for applying geophysics
  - Setup: ask good questions
  - Property: exploit property contrast
  - Survey: choose the right tools
  - Data: acquisition and QC
  - Processing: invert data to model
  - Interpretation: non-uniqueness
  - Synthesis: other information

- More case histories using the 7-step framework
  - https://em.geosci.xyz/content/case_histories/index.html

- TBL 1 exercise: A geophysical journey around Ireland
  - Practice your 7-step skills! (answer on Google Form)

# Unit Activities

- **Labs: (Physical Properties)**
  - Monday, September 9th
  - Tuesday, September 10th
- **TBL:**
  - Wednesday, September 11th
- **Quiz:**
  - Wednesday, September 11th