# EOSC 350 : Environmental, Geotechnical and Exploration Geophysics I

## FINAL WRAP UP: WHAT DID WE LEARN

# Problems in Geoscience

**Resource Exploration**
- Minerals
- Hydrocarbons
- Ground water

**Geotechnical Engineering**
- Tunnels
- Slope stability
- In-mine safety

**Natural Disasters**
- Earthquakes
- Landslides

**Environmental**
- Salt-water intrusion
- Water contamination
- UXO


http://www.centennialofflight.gov

# Framework for Applied Geophysics: 7 steps

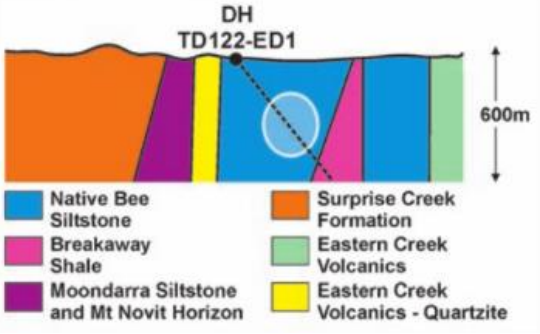
- **Setup:** What is the question to be answered?
- **Physical Properties:** What contrast(s)?
- **Survey:** Type and design
- **Data:** What is the signal being measured?
- **Processing:** Turn raw data into something we can interpret
- **Interpretation:** Best explanation based on geophysical data
- **Synthesis:** Evaluate and compare my interpretation

# Setup

# Examples: A Clear Geoscientific Objective

**Mt. Isa (mineral exploration)**

**Q:** Where is sulphide mineralization within Native Bee Siltstone unit?



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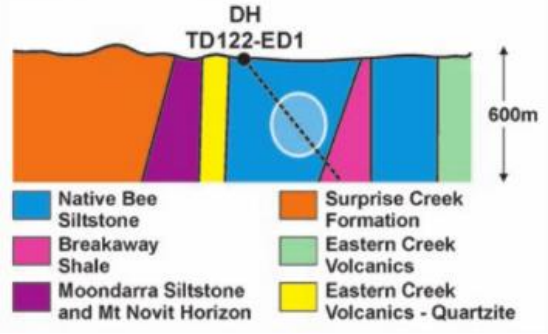
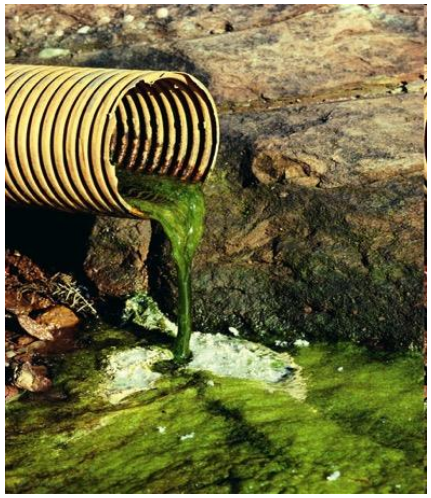



**Pollution**

**Q:** Is the barrier I put around my landfill preventing leachate from entering the water table?



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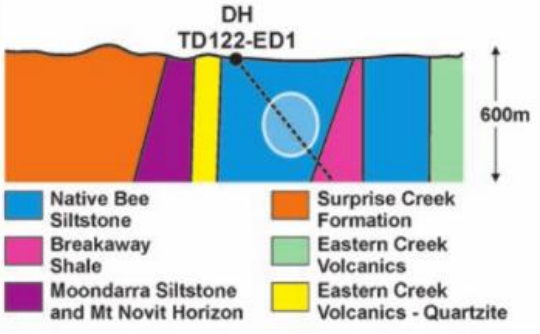


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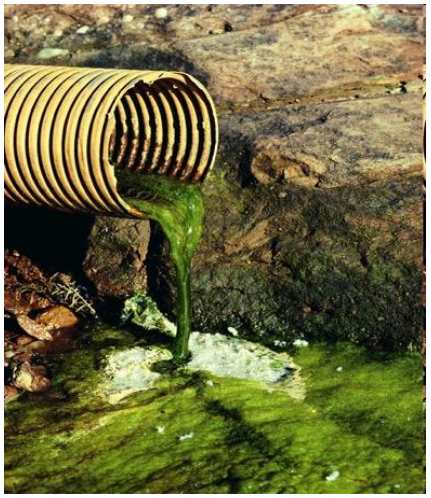
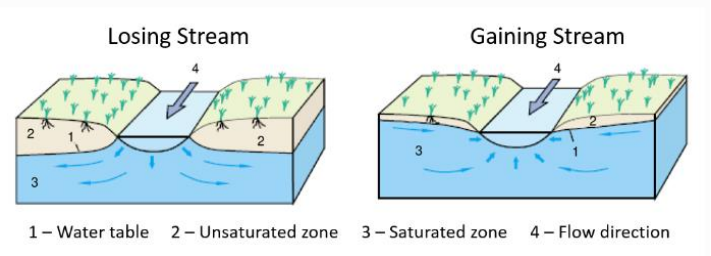


**Bookpurnong (salt-water intrusion)**

**Q:** At what locations is saline water from irrigation entering the river system and causing ecological damage?



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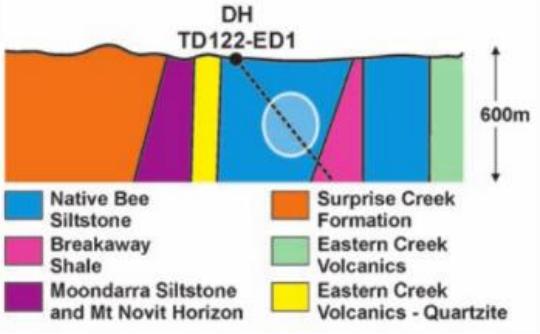


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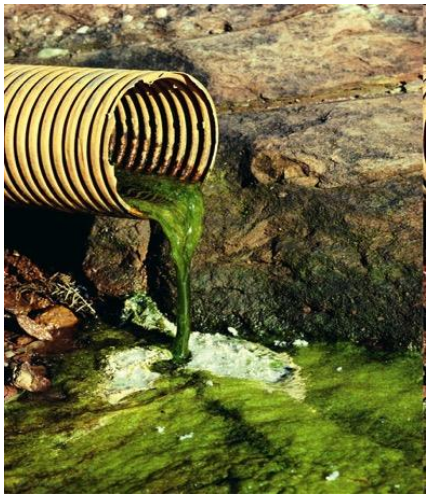

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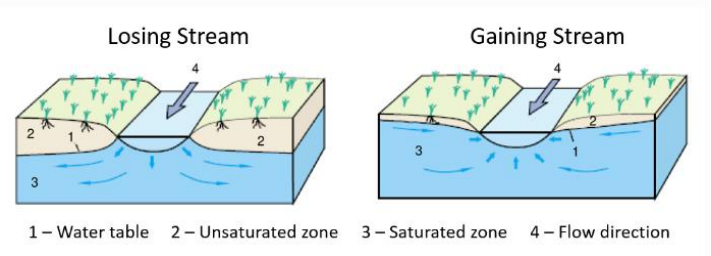


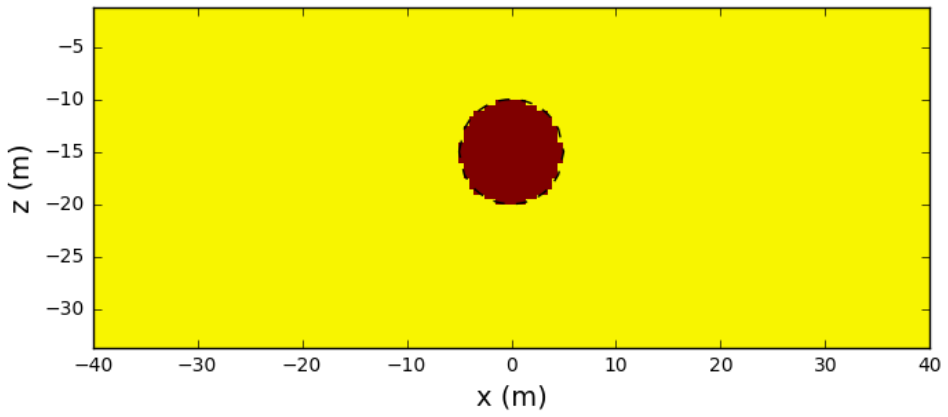

## Road construction in karst terrain

**Q:** Where is karstified rock so I can avoid when building a road?

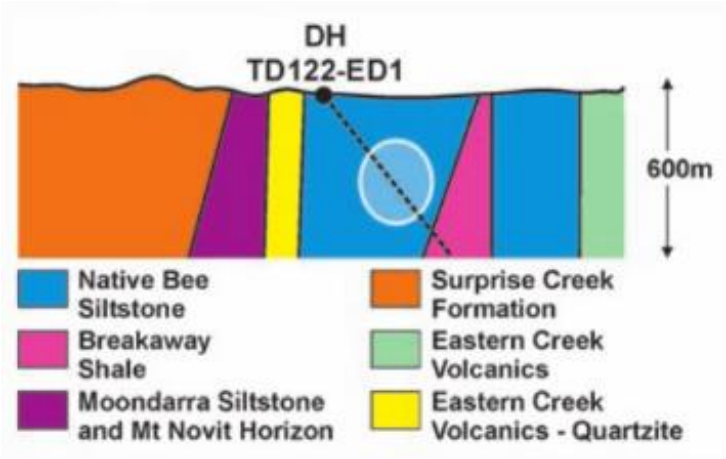
# What do you know about the problem?

- What is the target? And what is the host?
- What is the scale of your problem? 10s, 100s or 1000s of meters?
- Any geological mapping, cross-sections or drilling?
- Any previous geophysical studies?
- Any physical rock property measurements?

**Minimal Background Info**




**A Lot of Background Info**



# Physical Properties

# Physical Properties Types

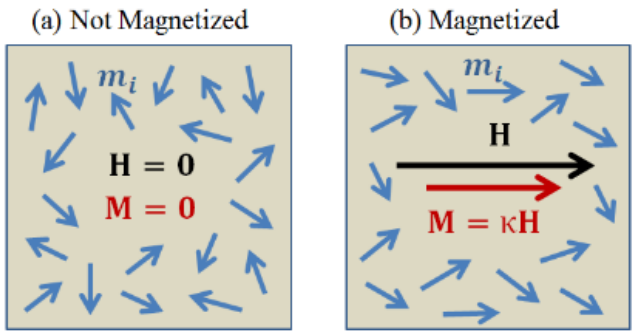
- **Density:**

$$\rho = \frac{m}{V}$$

- **Magnetic Susceptibility and Permeability:**

$$\vec{M} = \kappa \vec{H}$$

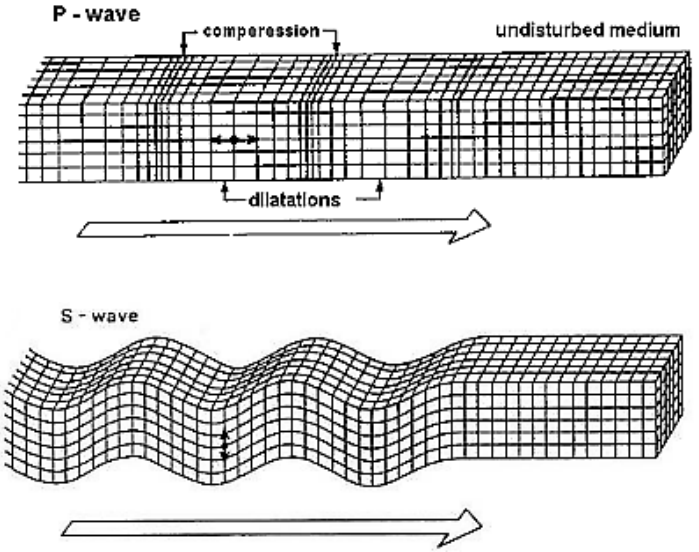
$$\mu = \mu_0 (1 + \kappa)$$




- **Seismic Velocity:**

$$v_p = \sqrt{\frac{K + 4/3\mu}{\rho}}$$

$$v_s = \sqrt{\frac{\mu}{\rho}}$$



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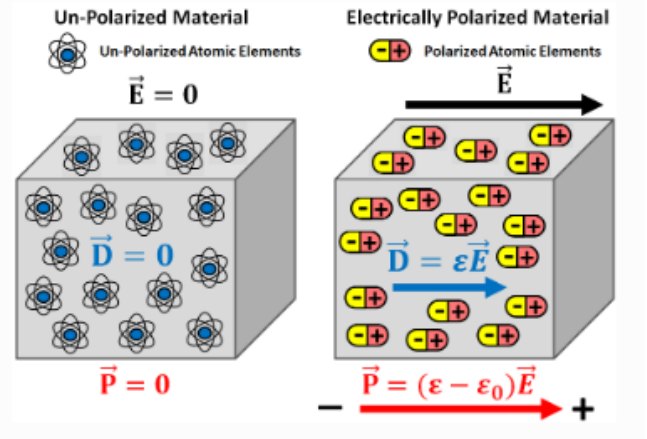
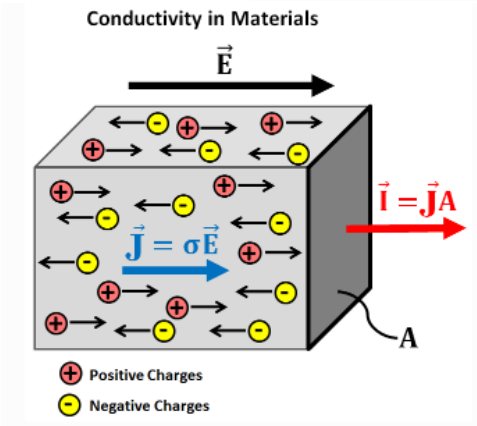



- **Dielectric Permittivity:**

$$\varepsilon_r = \frac{\varepsilon}{\varepsilon_0} \qquad V = \frac{c}{\sqrt{\varepsilon_r}}$$

- **Electrical Conductivity/Resistivity:**

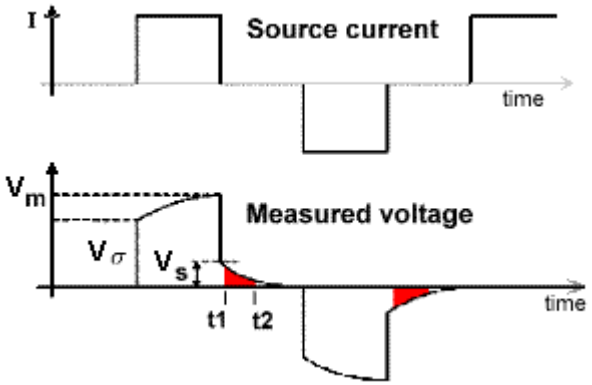
$$\vec{J} = \sigma\vec{E} \qquad \rho = \frac{1}{\sigma}$$




- **Chargeability:**

$$\eta = \frac{V_s}{V_m}$$

$$M = \frac{1}{V_P}\int V_S(t)\,\mathrm{d}t$$



# Physical Properties and Surveying

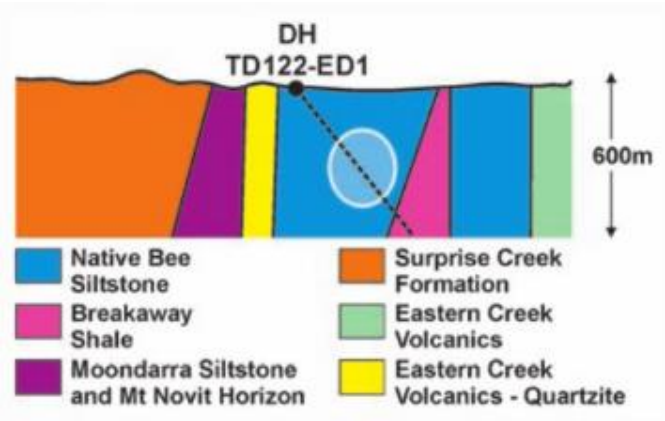
- **Is there a significant contrast between target and host?**
- **More than one?**
- **Are two physical properties needed to differentiate?**

**Road construction in karst terrain**

Voids are less dense, more resistive, large reflectors of seismic and radiowaves.

**Mt. Isa (mineral exploration)**

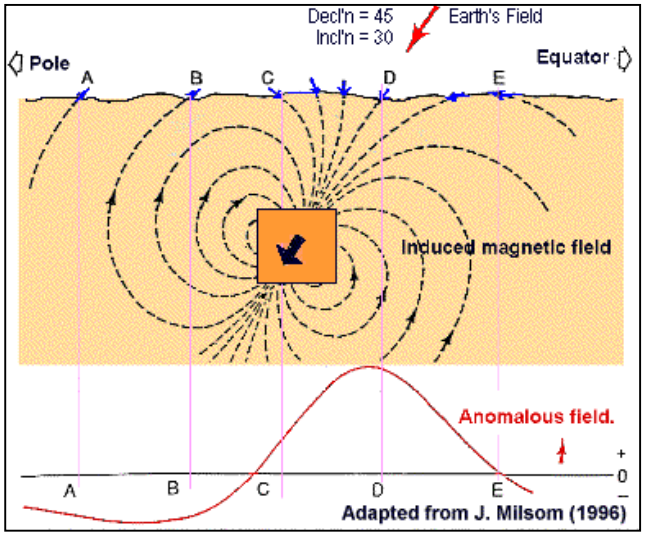
Only target was both conductive **and** chargeable!



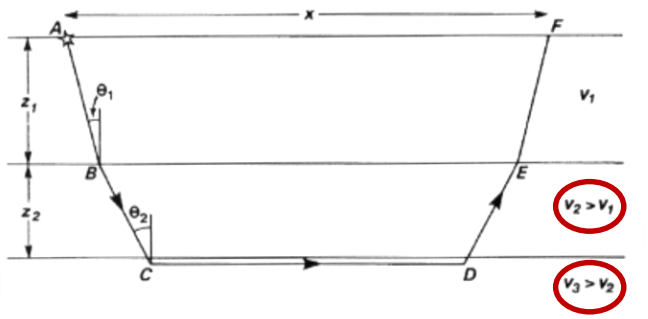
# Survey

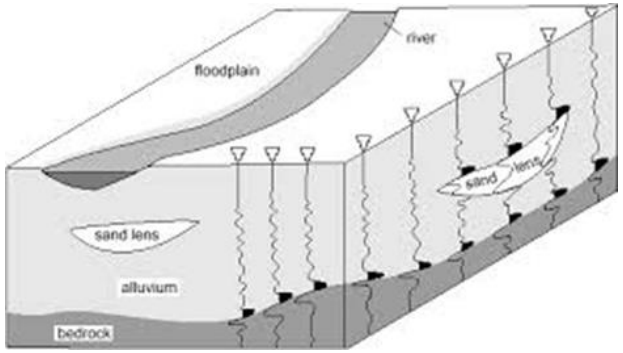
# Physical Properties and Surveying

- **Density → Gravity Survey**
- **Magnetic Susceptibility → Magnetic Survey**



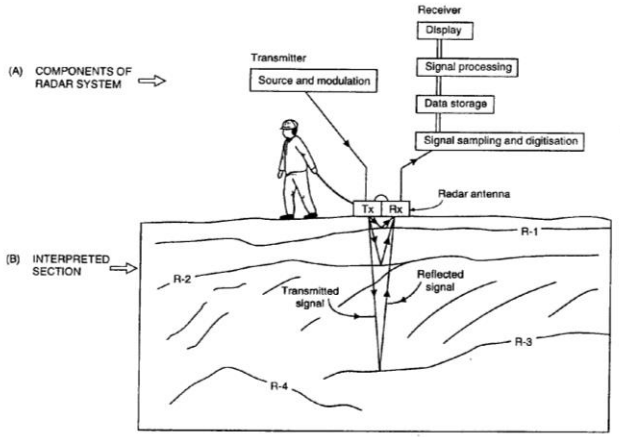

- **Seismic Velocity → Seismic Refraction, Reflection, MASW**



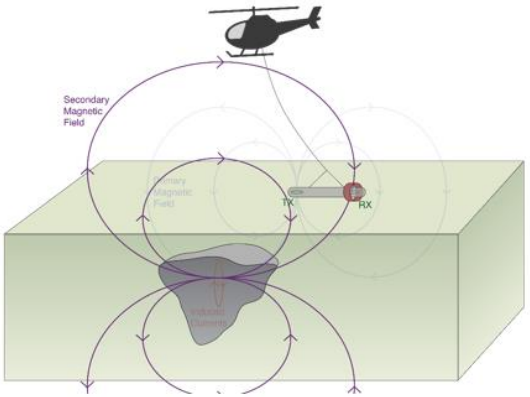



# Physical Properties and Surveying

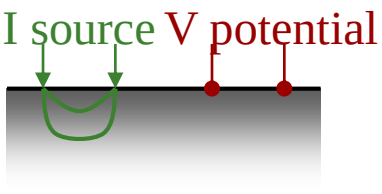
- **Dielectric Permittivity → GPR**



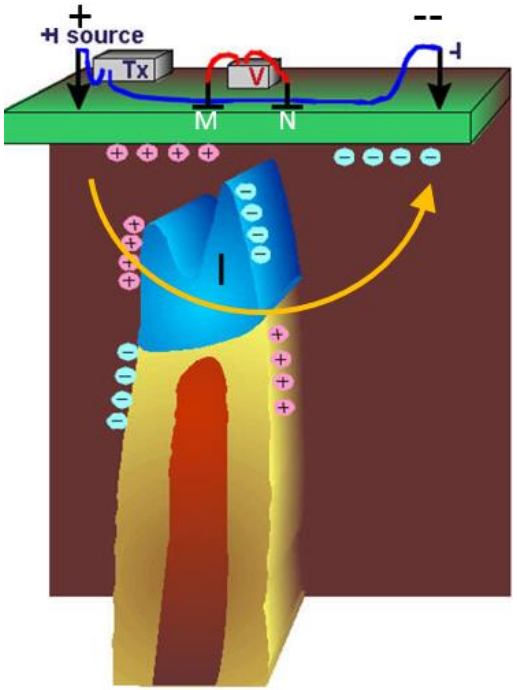

- **Electrical Conductivity/Resistivity → EM, DCR**




- **Chargeability → DCIP**




| | Not chargeable | Chargeable |
|---|---|---|
| Source (Amps) |  |  |
| Potential (Volts) |  |  |



# Survey Design

- **Airborne, ground-based, borehole?**
  - Rugged terrain?
  - Acquisition over large areas?
  - Scale of the problem
  - Resolution required
  - Looking for a particular target?

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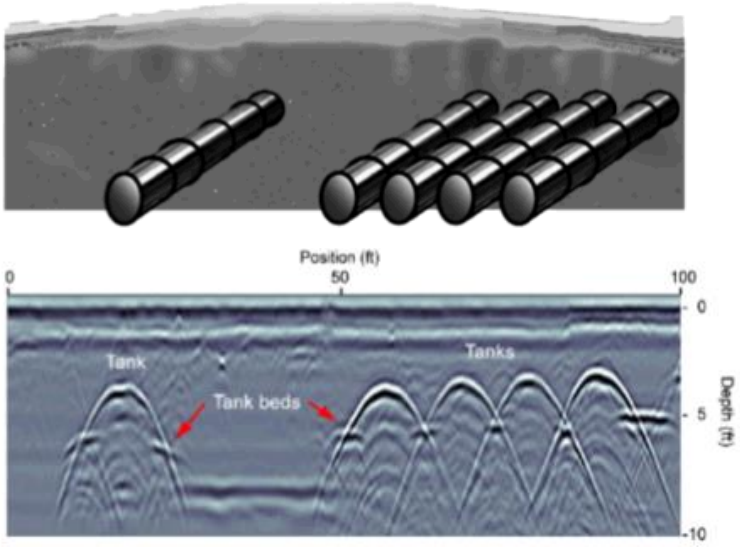
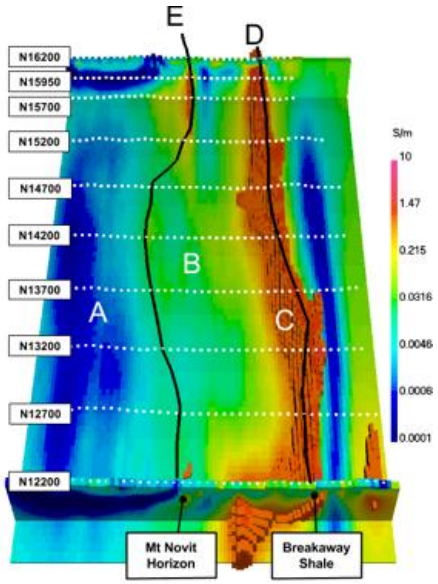
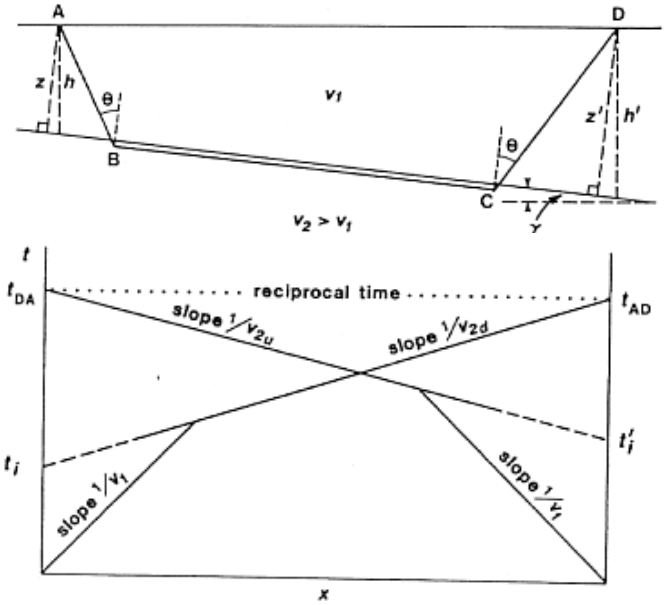
- **Survey/instrument orientation**
  - Good coupling
  - Easy data to interpret




**GPR: petroleum tanks**



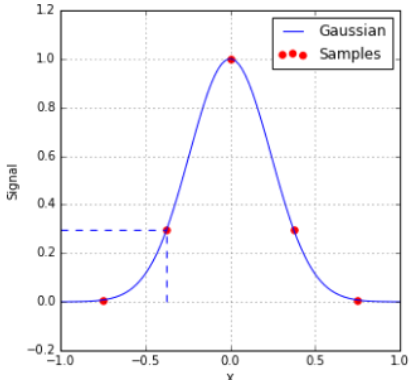

**DCIP: NS geology**




**Seis. refraction: dipping layer**

# Survey Design

- **Line and station spacing**
  - Time and cost vs. benefits
  - Spacing needed to quantify target anomaly



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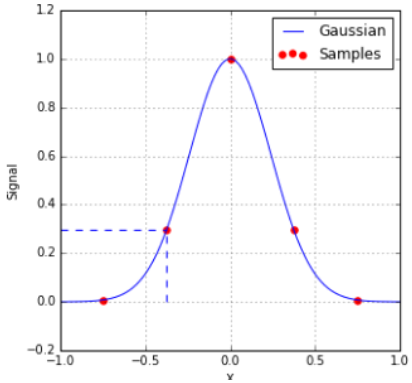
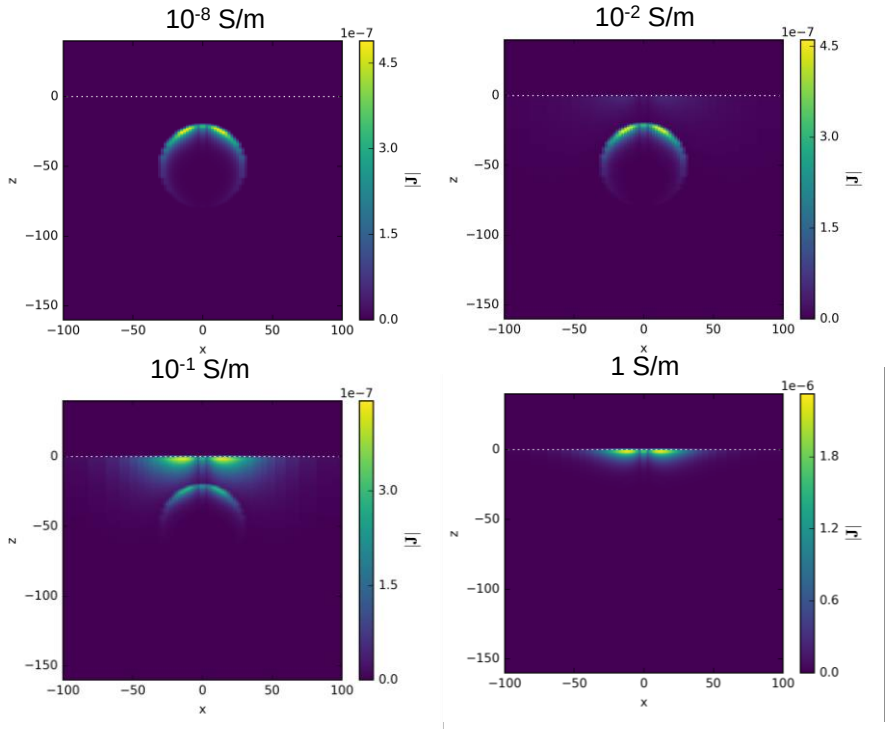
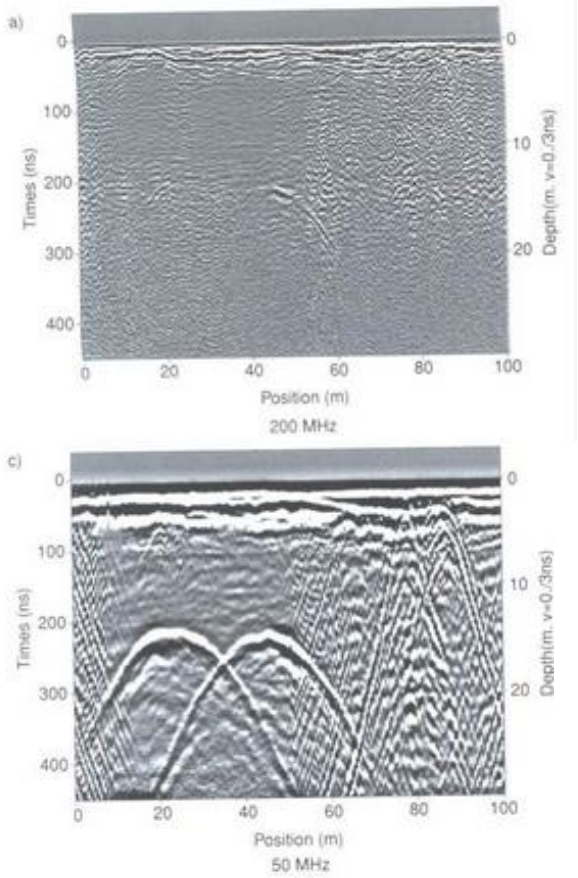



- **Frequencies**
  - Skin depth, horizontal/layer resolution
  - Depth of penetration vs. resolution

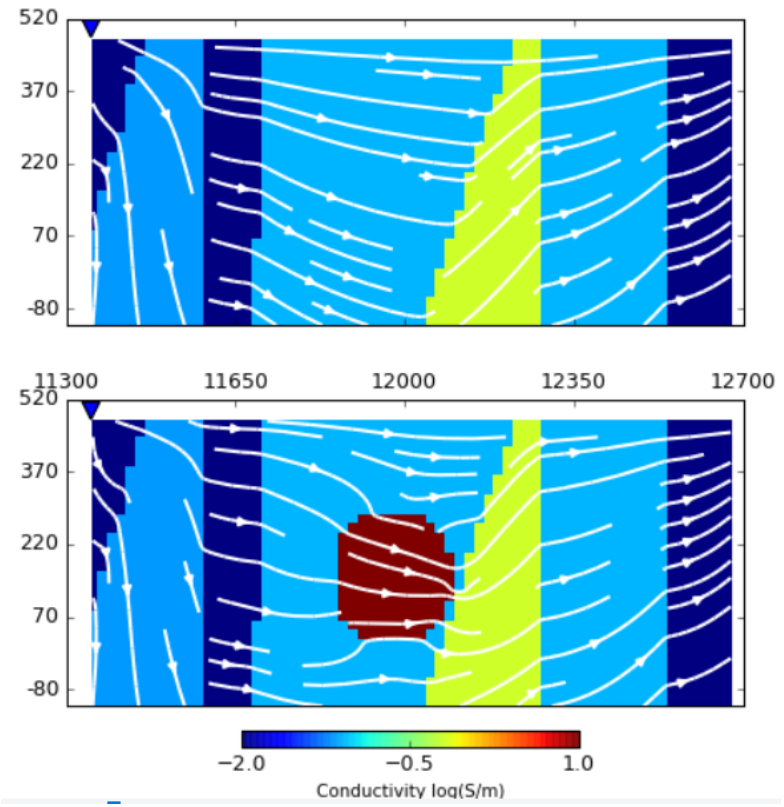


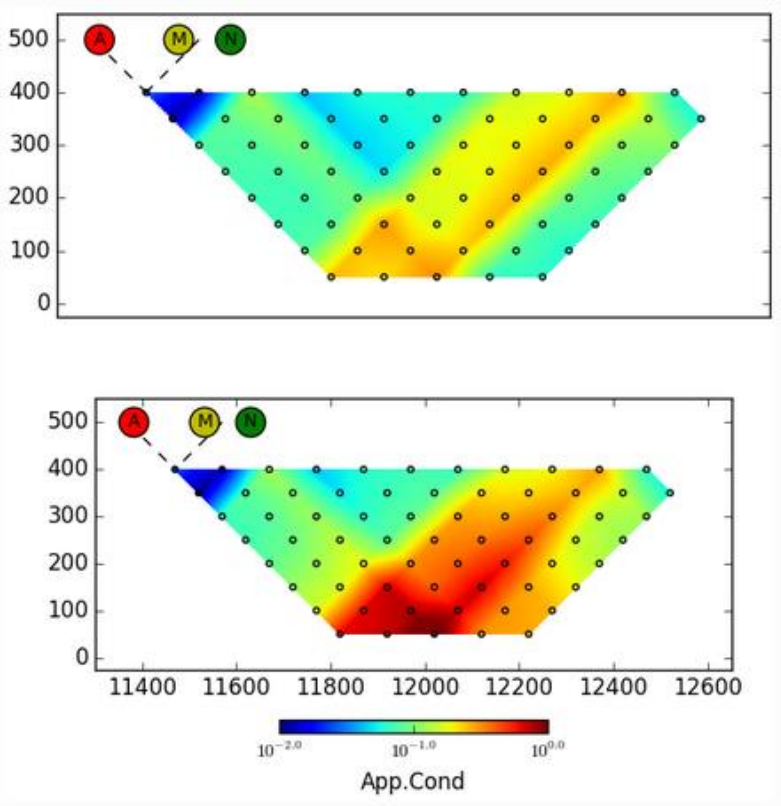



# Survey Design

- **Sensitivity**
  - Is my survey sensitive to target?
  - How can I verify this?
    → synthetic modeling

***Mt. Isa example – would I see target if it was there?***



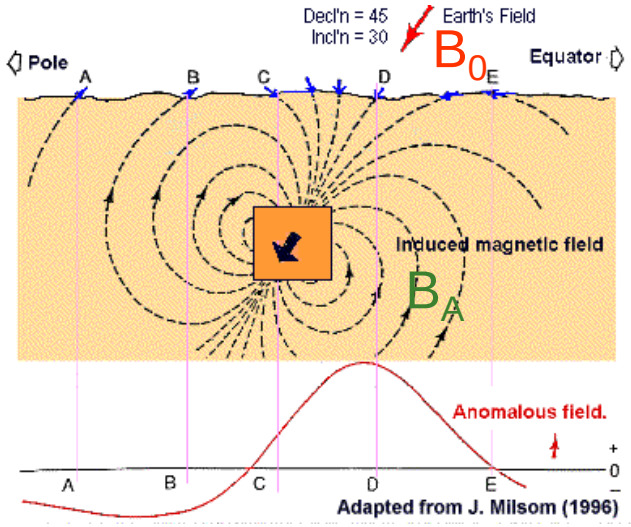
# Data

# Field Measurements and Data

- What is raw signal being measured?
- What quantity is used to represent data?
- What are the units?

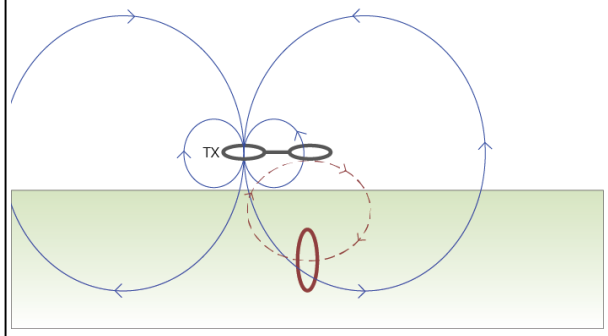
**Magnetic Anomaly Data**

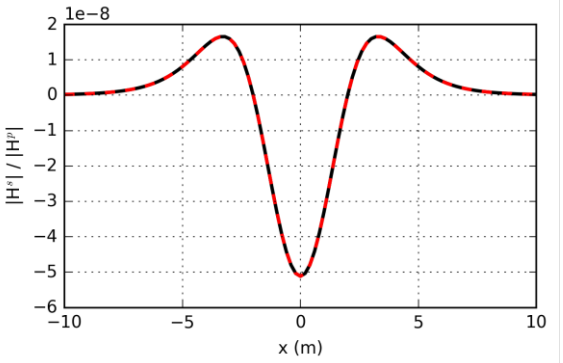
- **Measure:** $|B| = |B_0 + B_A|$
- **Data are:** $\Delta B = \vec{B}_A \cdot \hat{B}_0$
- **Units: nT**




**Frequency-Domain EM example**

- **Measure:** Total field in direction perpendicular to loop
- **Data are:** Frequently Hs/Hp
- **Units:** ppm or %

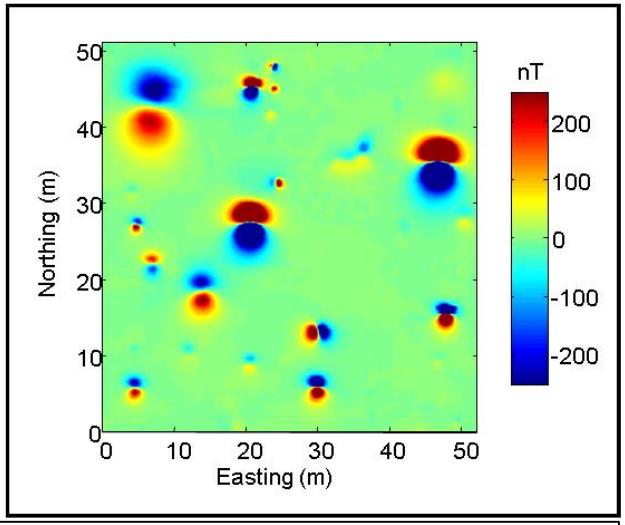


# Plotting

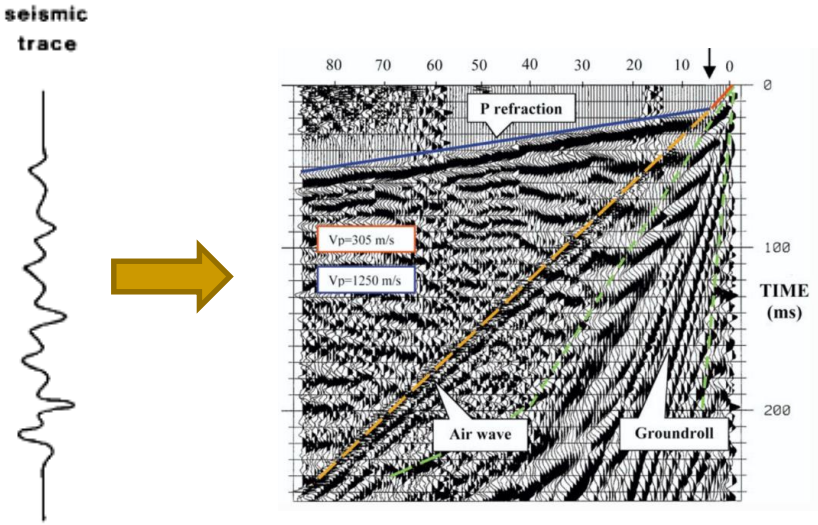
How can we represent our field measurements?

- Seismogram/radargram
- Time decay or frequency response
- Contour maps or surface plots
- Pseudosections



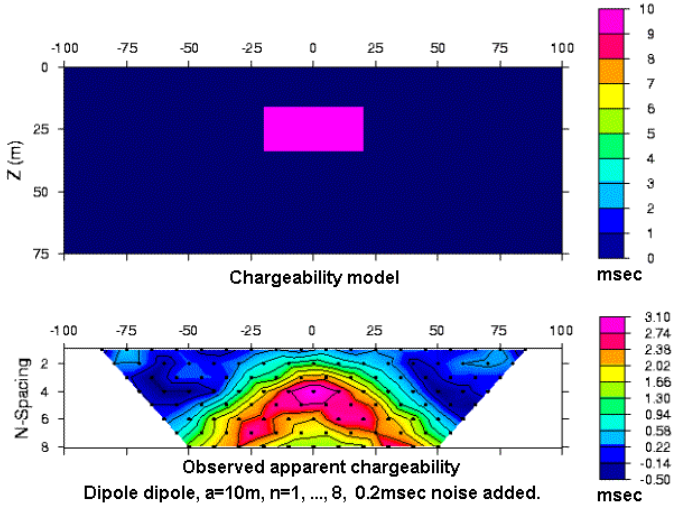

**Seismic and GPR Data**

- **Measure:** seismic or GPR traces
- **Plot:** seismogram or radargram




**DCIP Data:**

- **Measure:** voltage and integrated chargeability
- **Plot:** pseudosection



# Processing

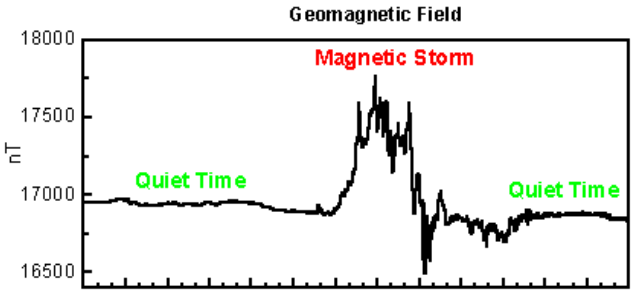
# Concept

**Turning raw data into something more easy to interpret:**

- Erroneous data that should be removed?
- Filtering algorithms to remove various unwanted signals
- Represent data as a quantity more easy to interpret
  (i.e. apparent conductivity instead of raw voltage)
- Geophysical inversion

# Magnetic Anomaly Data

**Remove Primary Field (base stn)**



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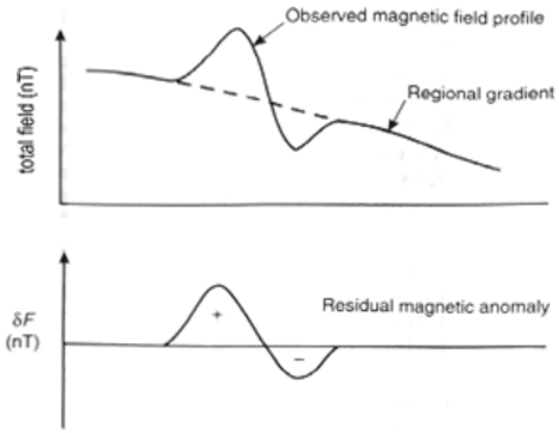
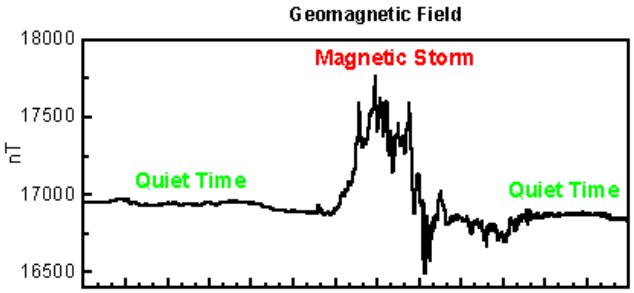



**Remove Primary Field (base stn)**

**Regional Removal**



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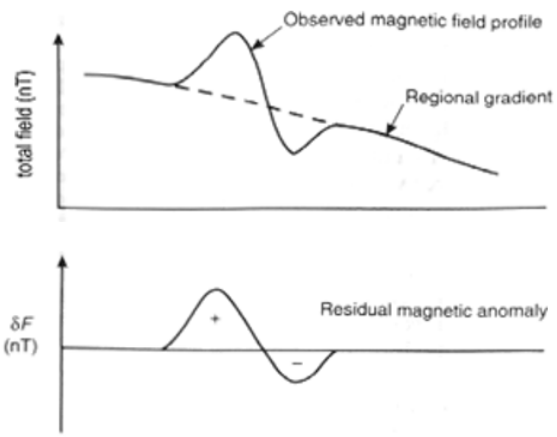


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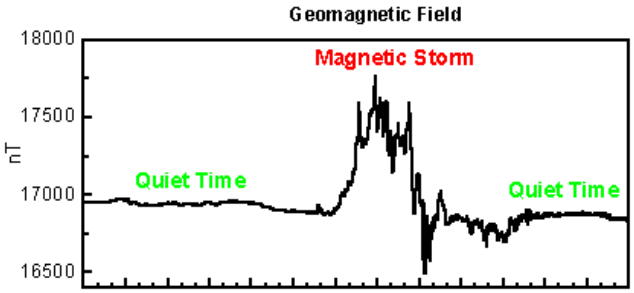
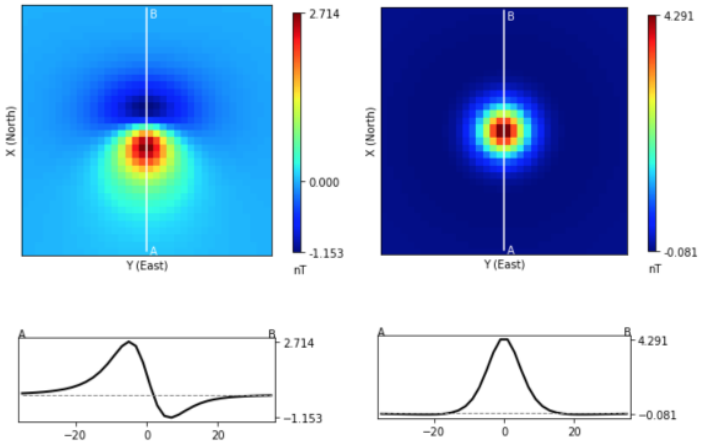
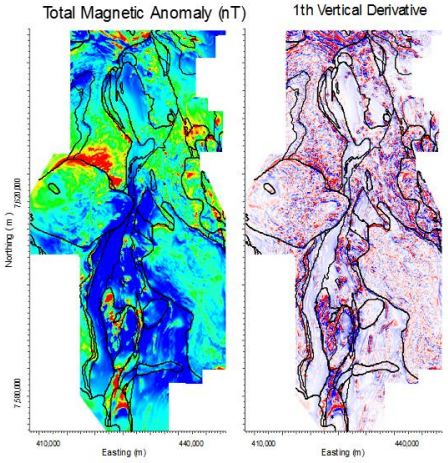



**Regional Removal**

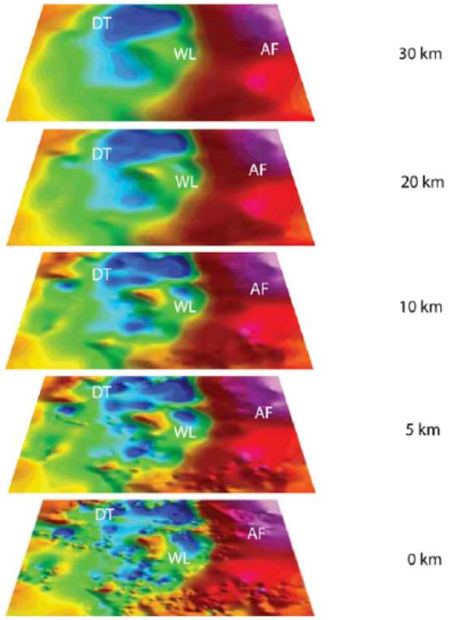
**Reduction to Pole?**




**Derivatives?**

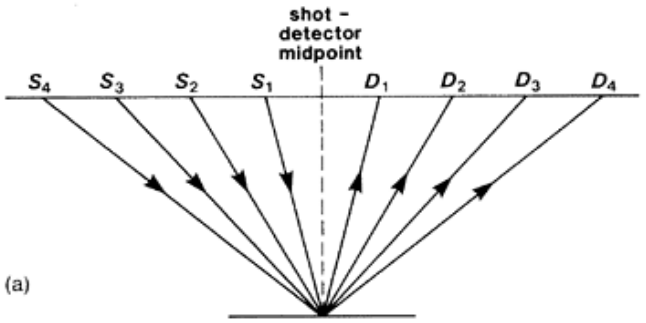



**Upward Continuation?**



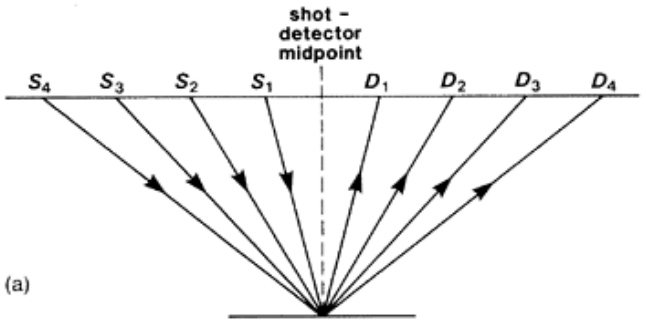
# Seismic Reflection Data

**Collect Common Midpoint Gathers**

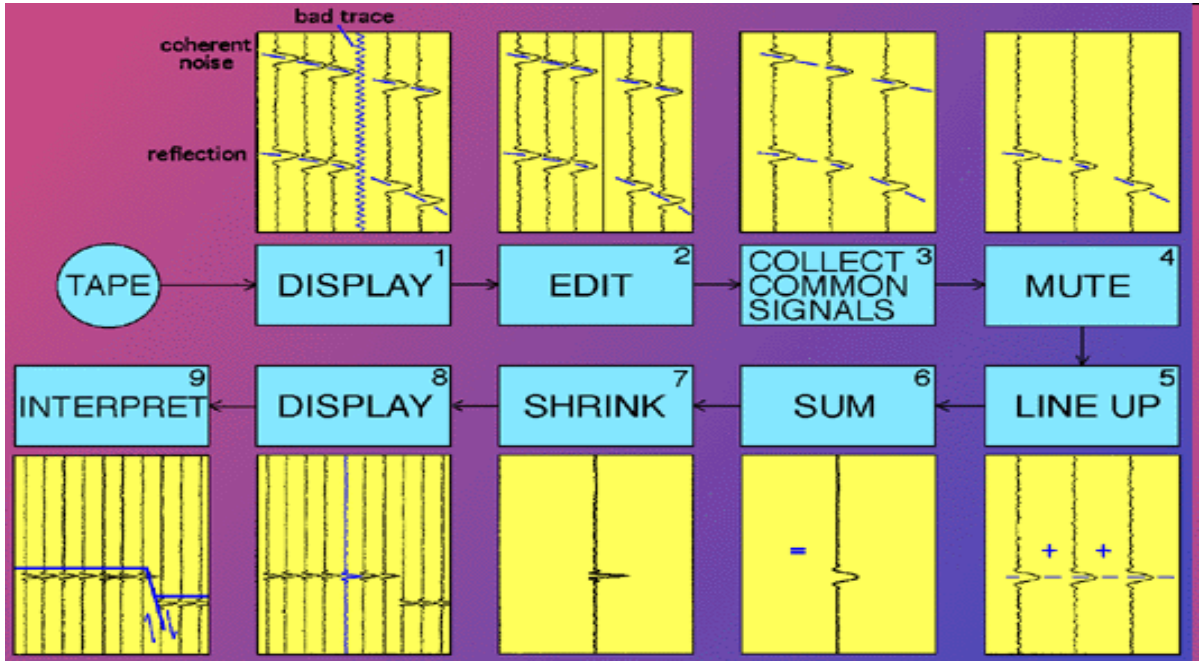


# Seismic Reflection Data

**Collect Common Midpoint Gathers**




**NMO Correction**



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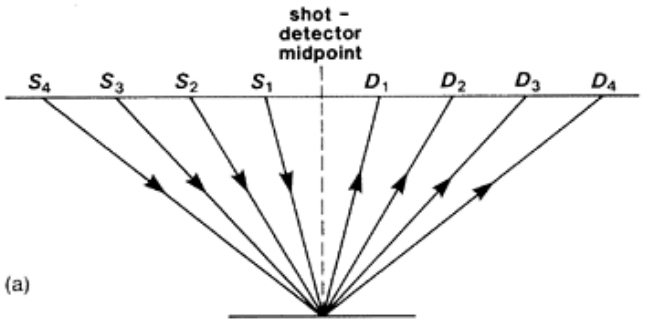
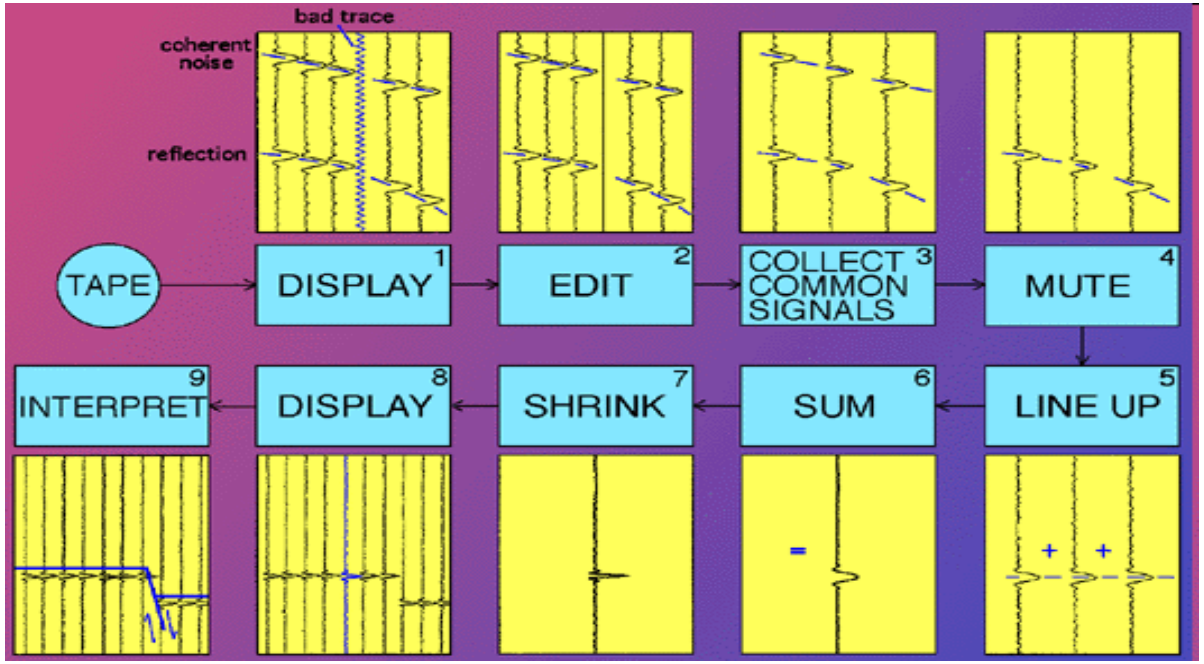
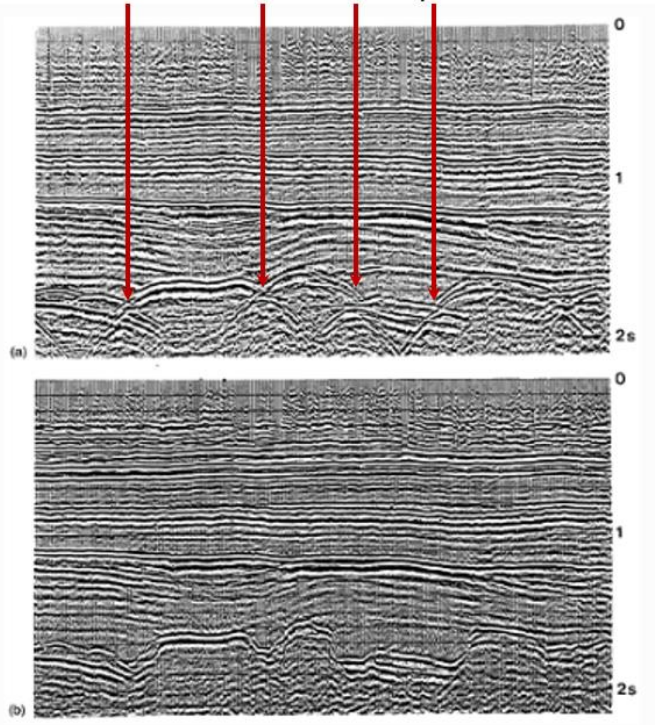



**NMO Correction**

**Migration**




Bowtie reflections from synclines

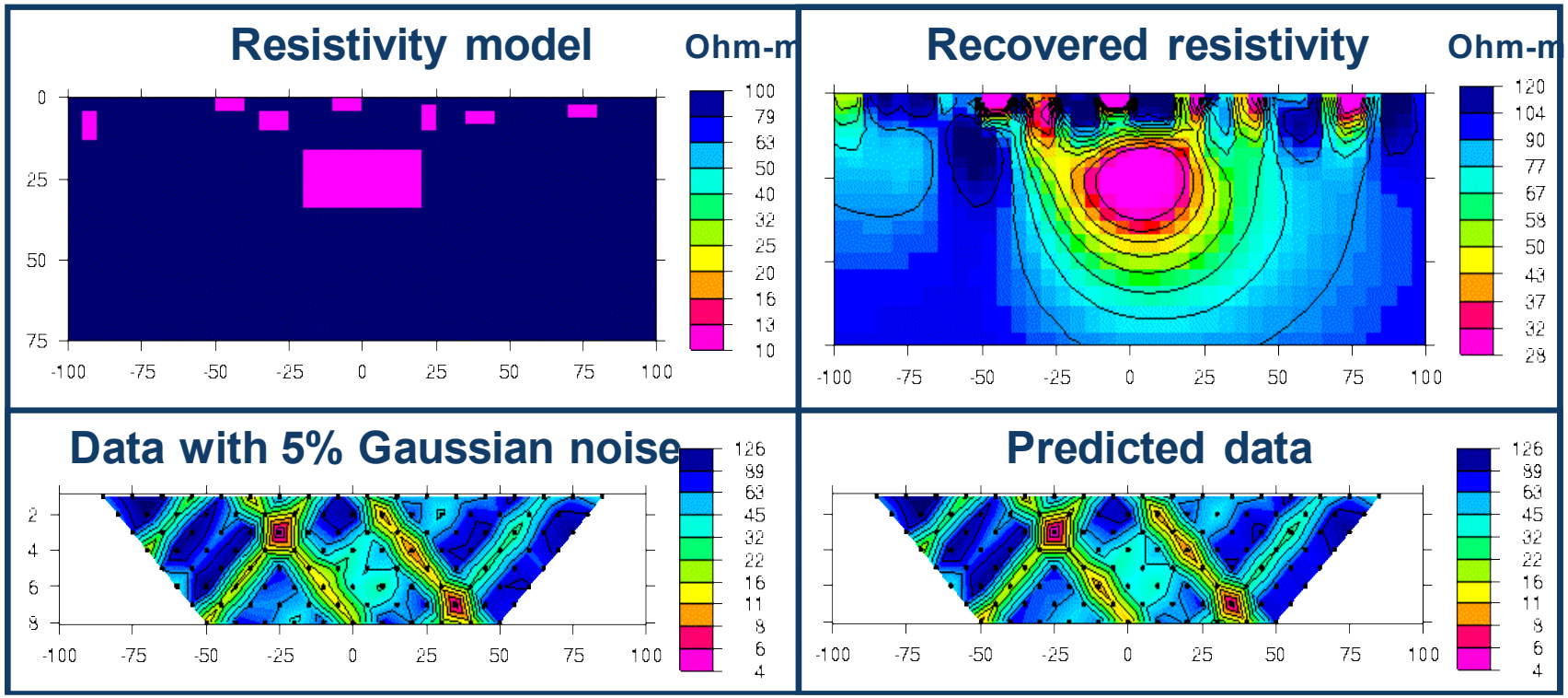


# Geophysical Inversion

**GOAL: Recover a physical property model that:**

**1) Explains the data**

**2) Is geologically approximate**



# Geophysical Inversion

**Requirements:**

1) A physical model (respect physics)

2) Field observations (must fit data)

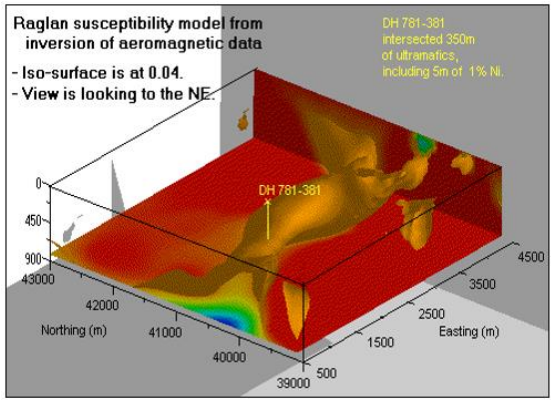
3) A starting model (initial guess)

4) Reference model (impose structures)

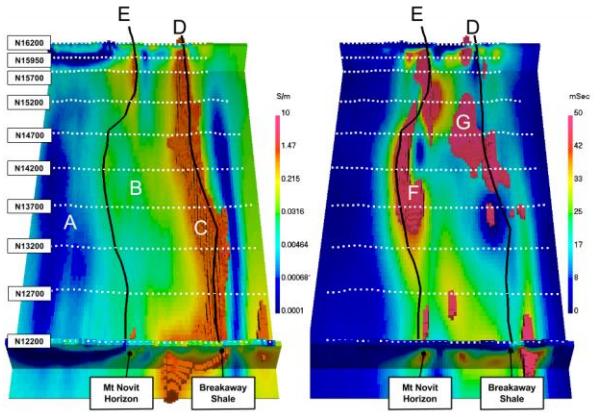
5) Constraints (other solution requirements)

Geologically representative physical property model

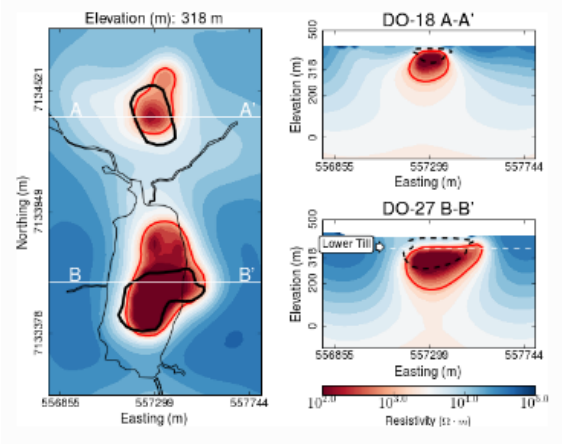
**Magnetics Example**




**DCIP Example**



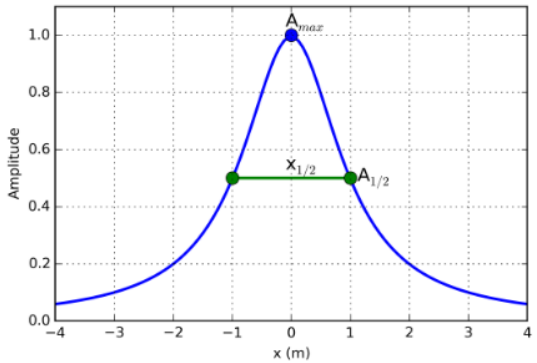

**EM Example**

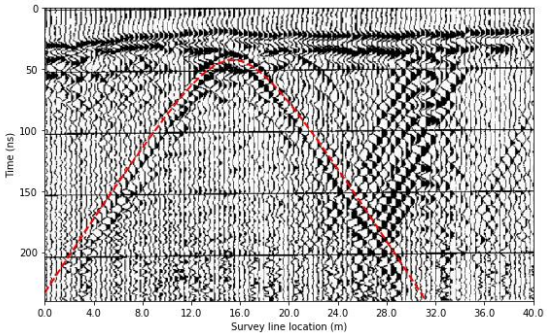


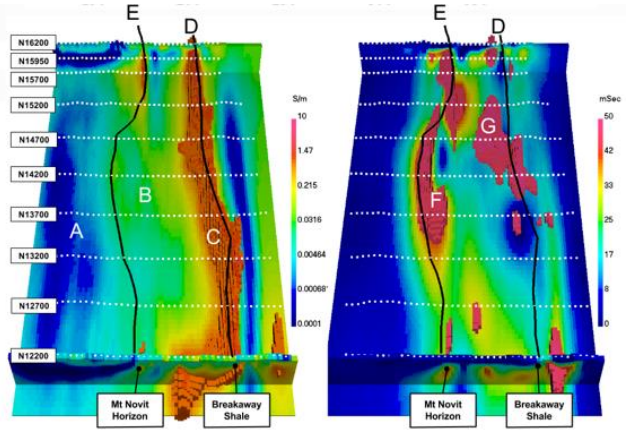
# Interpretation

# Interpretation

- **Try to answer your geoscientific question**
- **Make conclusions:**
  - Directly from processed data → (e.g. half-width formula)
  - By fitting the anomaly with simple model →
  - From inversion results →
  - Using any other information



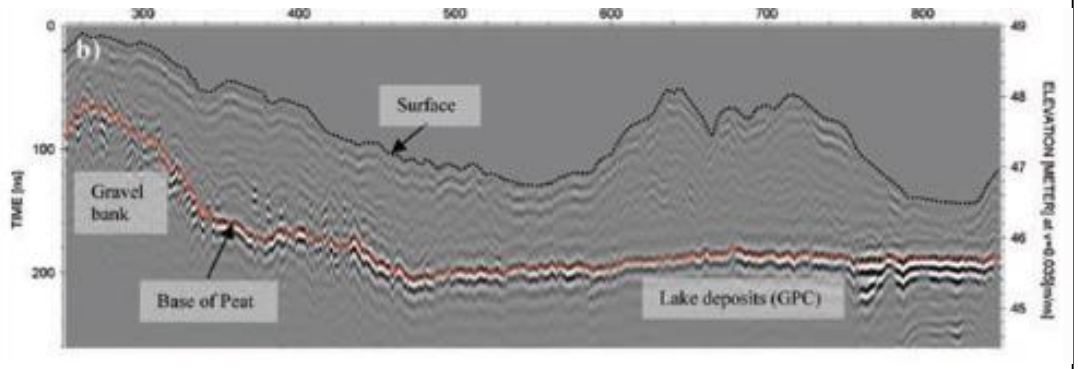



# Interpretation Examples

**Estimate Peat Resources with GPR**

- Base of peat bogs produce strong reflector
- Infer location of gravel bank and lake deposits
- Arrival time to depth conversion gives me peat thickness profile



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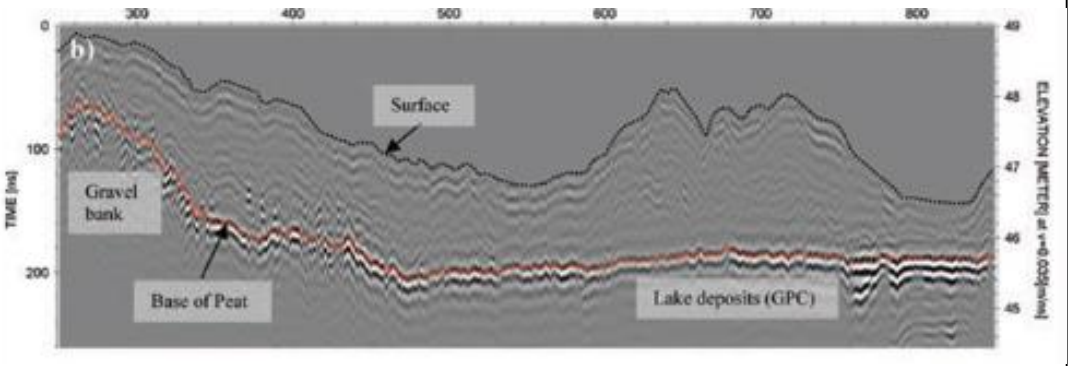
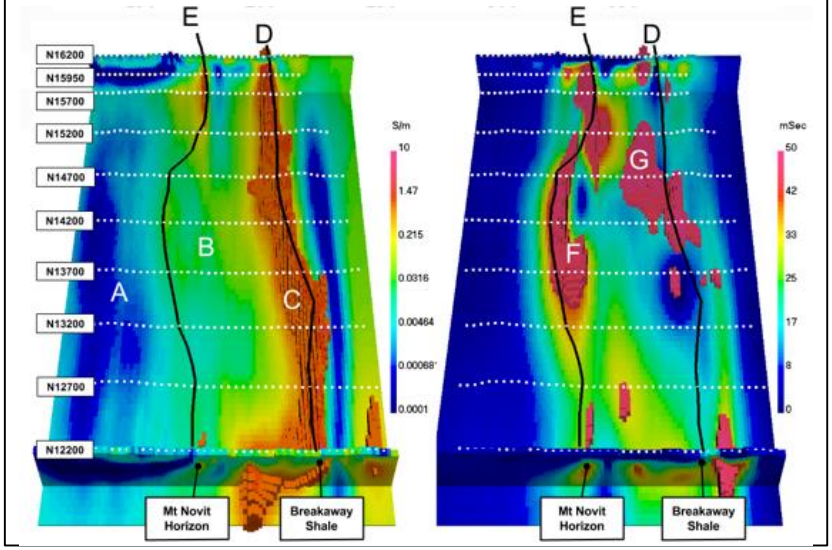



**Mineral Exploration with DCIP**

- Sulphides are conductive **and** chargeable
- Other units are not
- **G** most likely sulphide mineralization



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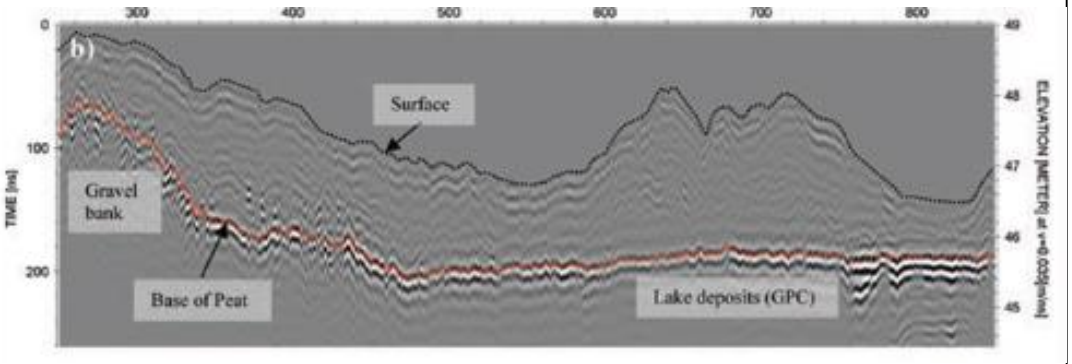


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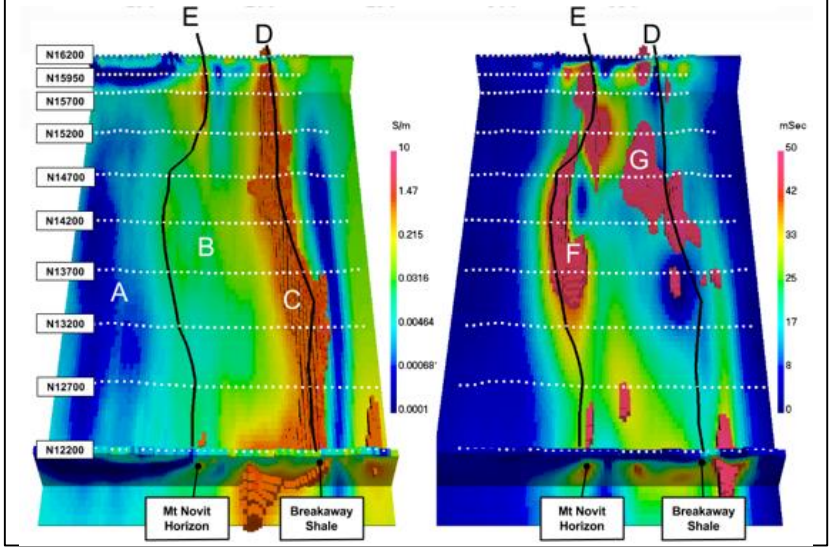
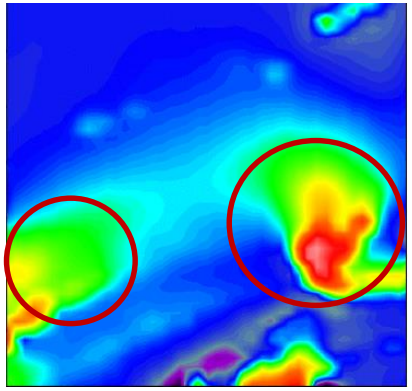
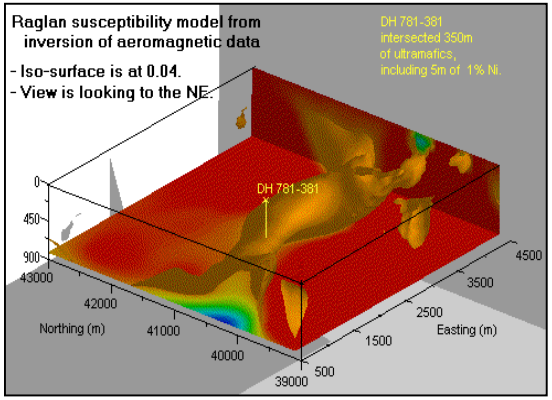



## Mineral Exploration with Airborne Magnetics

- Outcropping units associated with mineralization (associated magnetic high circled)
- Inversion indicates outcropping units connected
- Possible new deposits





# Synthesis

# Concept

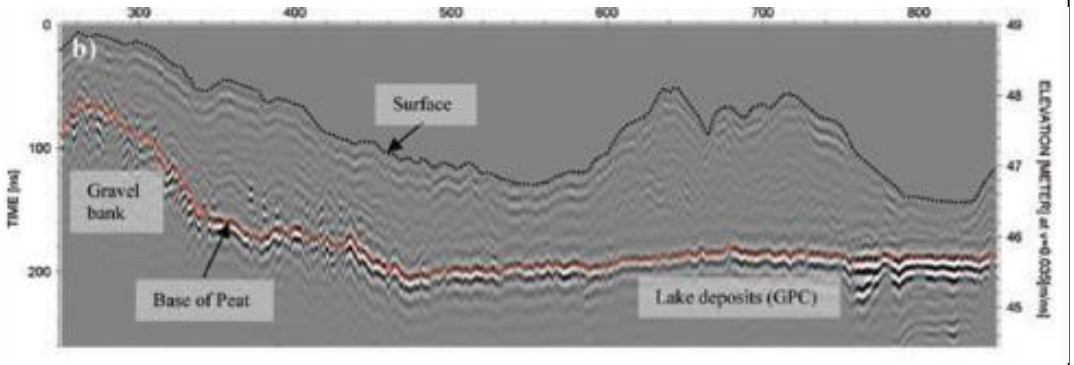
**Evaluating your interpretation and comparing with others:**

- Did I answer my geoscientific questions?
- How confident am I in my result?
- How does this compare to interpretations by others?
- Can I validate my result?
- Further work needed?

# Synthesis Examples

**Estimate Peat Resources with GPR**

- Soil sampling confirmed the peat thickness profile inferred from data
- Confident in results
  → can estimate peat resources



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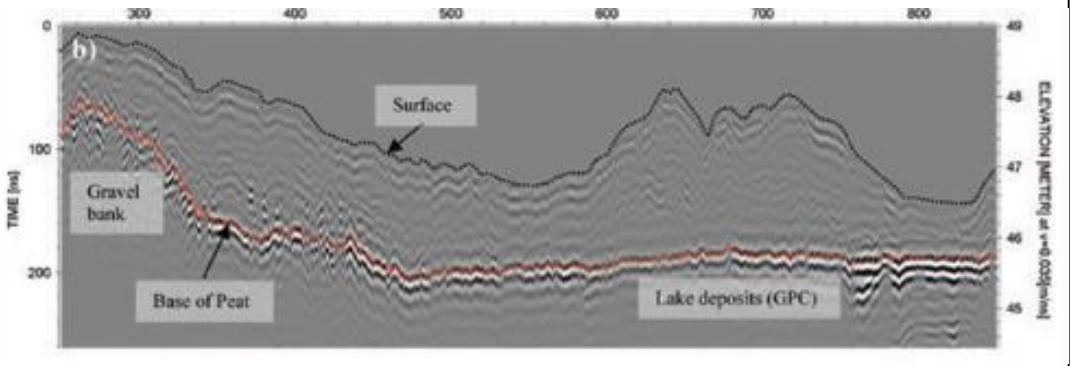
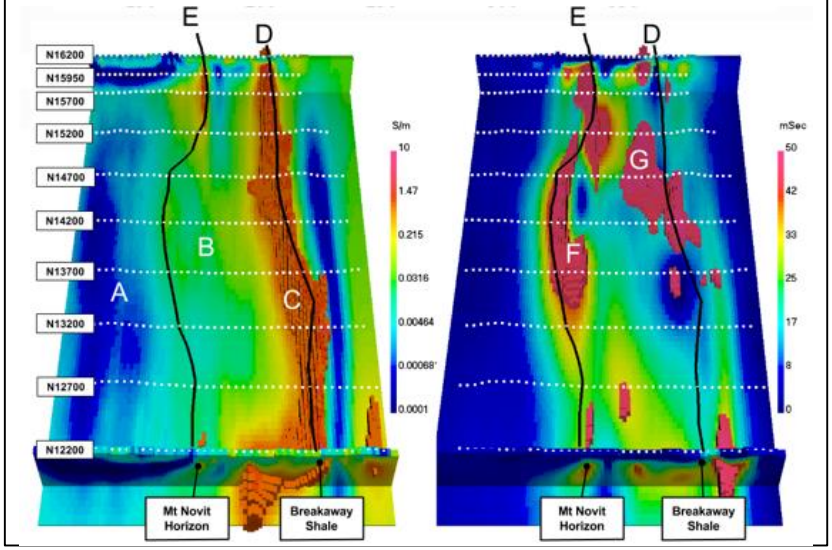



**Mineral Exploration with DCIP**

- 3D DCIP inversion can be used to delineate conductive and chargeable units
- Drilling required to confirm if ore-bearing



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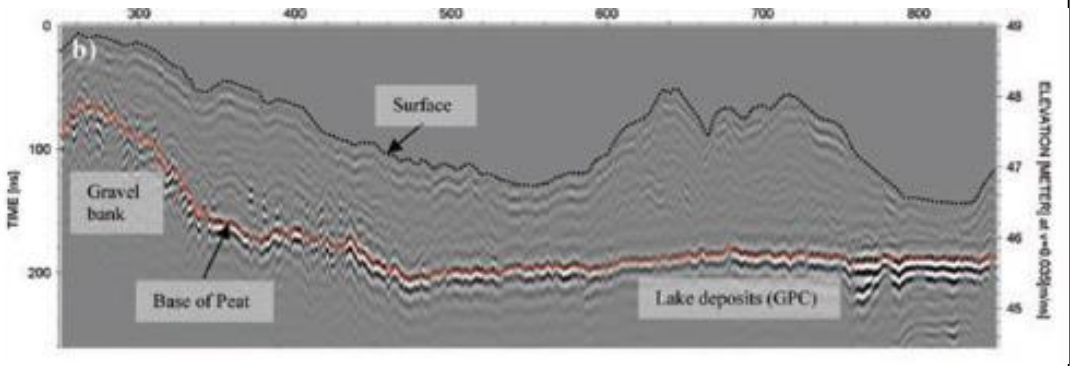


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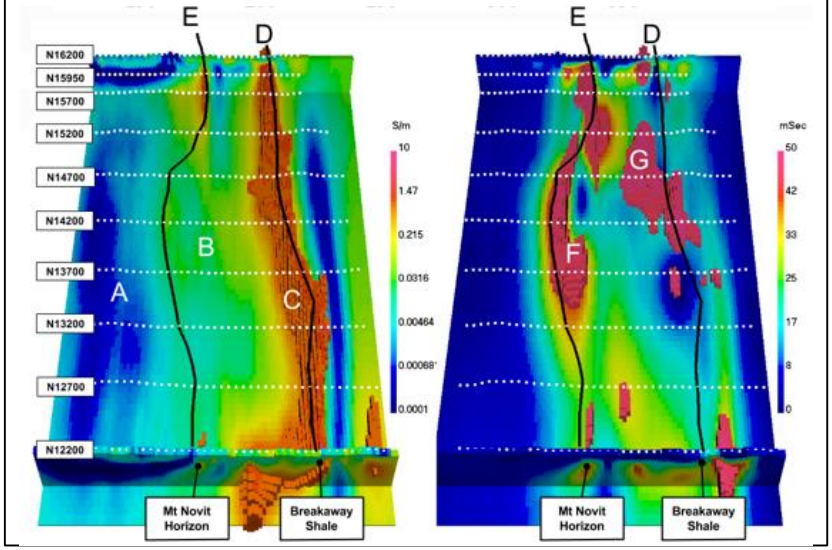
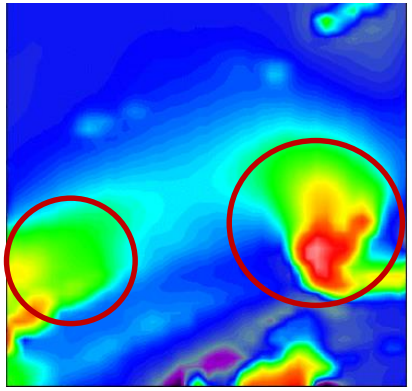
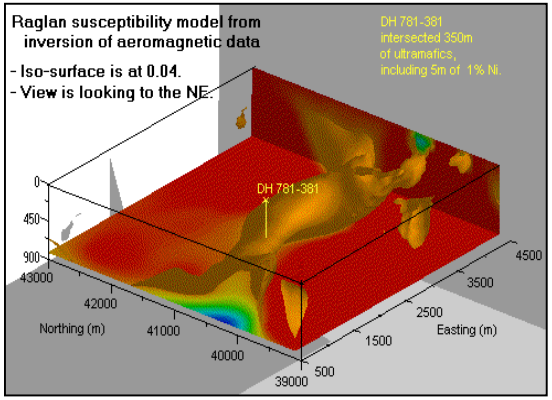



## Mineral Exploration with Airborne Magnetics

- Drilling confirmed that the outcropping units are connected at depth (inversion result correct)
- More work so see if viable for development





# Final Thoughts

1) Geophysics has **many applications**

2) If applied correctly, geophysics is a **cheap** and **efficient** way to get information about the subsurface

3) Geophysics is a **tool** that can help answer geoscientific questions but it is **not a magic bullet**

4) I hope you consider using geophysics in the future

# Plan for Next Week

**Monday:**

- Teaching evaluation
- Comment on final exam
- What do you want to review?

**Wednesday:**

- Review lecture

**Friday:**

- Review lecture
- Last day to hand stuff in!!!