Magnetics Example

Inclination and Declination

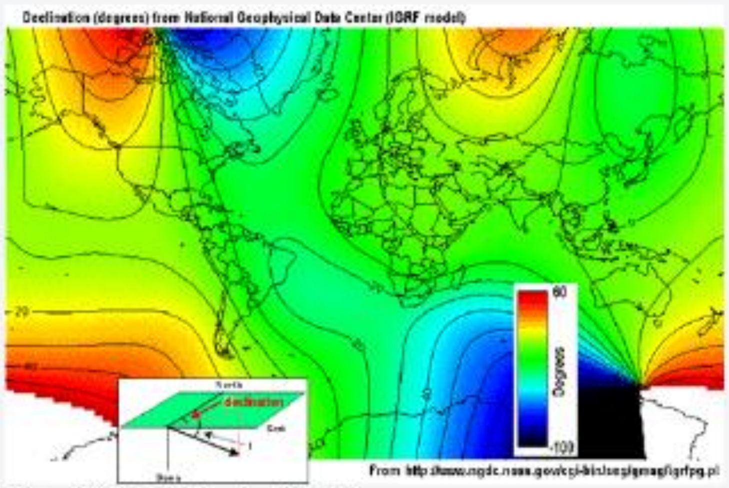


Fig. 26 Earth's declination.

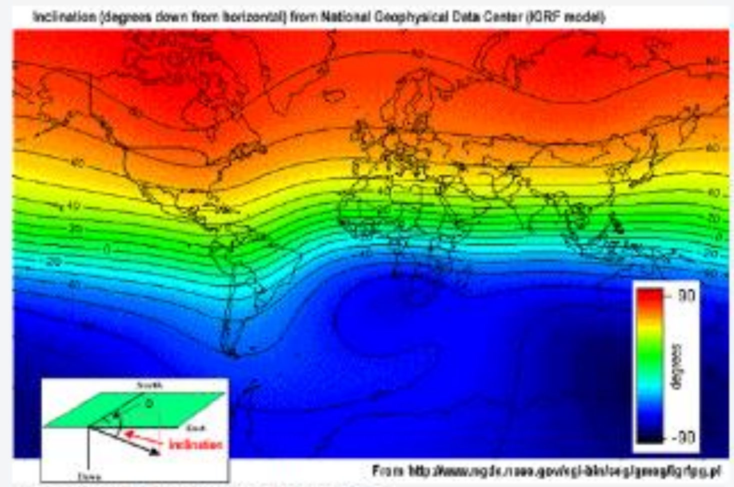


Fig. 27 Earth's inclination.

- If field direction is going **into** the ground, is inclination +ve or –ve?

  +ve

- What is the range of declinations the Earth can have?

  +/- 60 degrees (always South to North!)

- What direction is inclination = +60 and declination = -45?

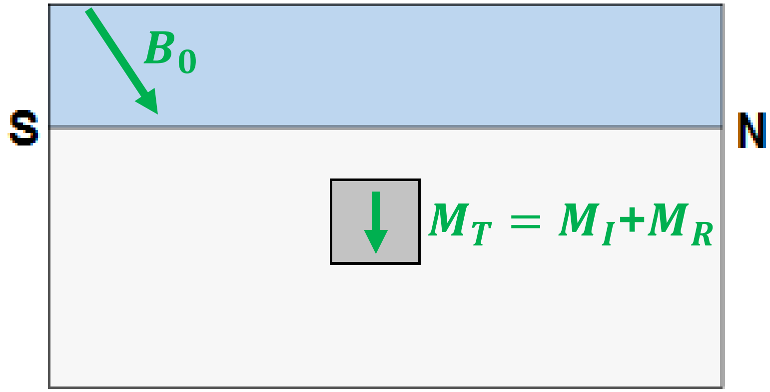
  Horizontal component is NW. Steeply dipping into the Earth at 60 degrees

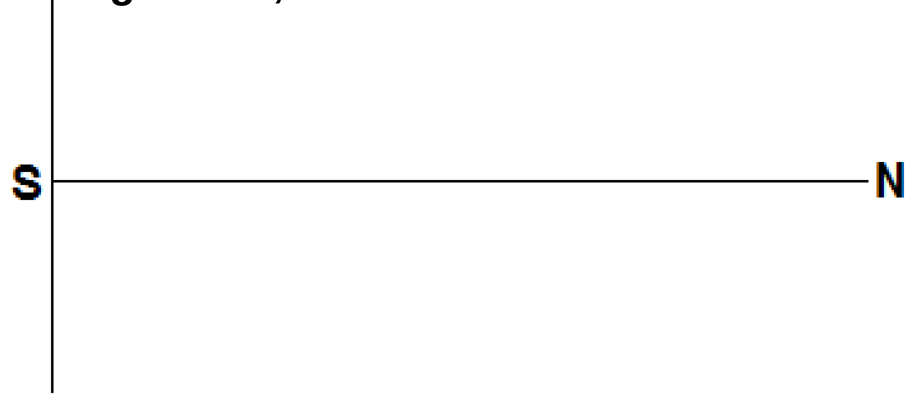
- What direction is inclination = -30 and declination 180?

  Horizontal component is toward the South. Shallowly coming out of the Earth

Magnetics as Dipoles or Charges

- **Inducing field has incl. = 60, decl. = 0 and strength = 50,000 nT. Draw and label Bo**





- **If the magnetic susceptibility is K=0.05 SI, compute the magnetization in the:**

Easting: **0 A/m**

Northing: **1 A/m**

Upward: **-1.7 A/m**

$$|M_I| = \frac{KB_0}{\mu_0} = 2.0\ A/m$$

$$Easting = 0\ (due\ to\ geometry)$$
$$Northing = |M_I|\cos(60)$$
$$Upward = -|M_I|\sin(60)$$

- **Block has remanence of 1.4 A/m at an incl = 45 and decl. = 180. Compute the total magnetization in the:**

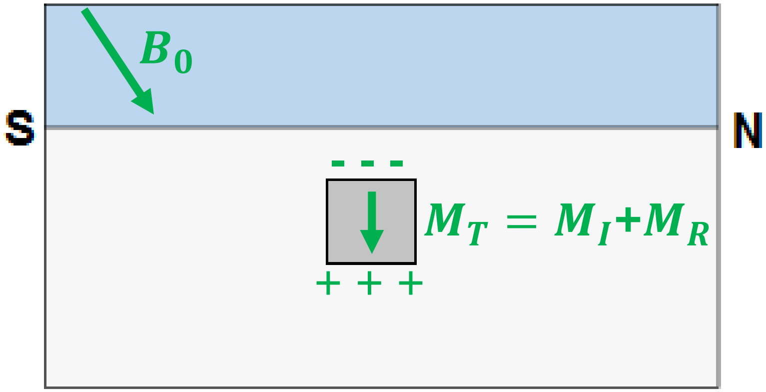
Easting: **0 A/m**

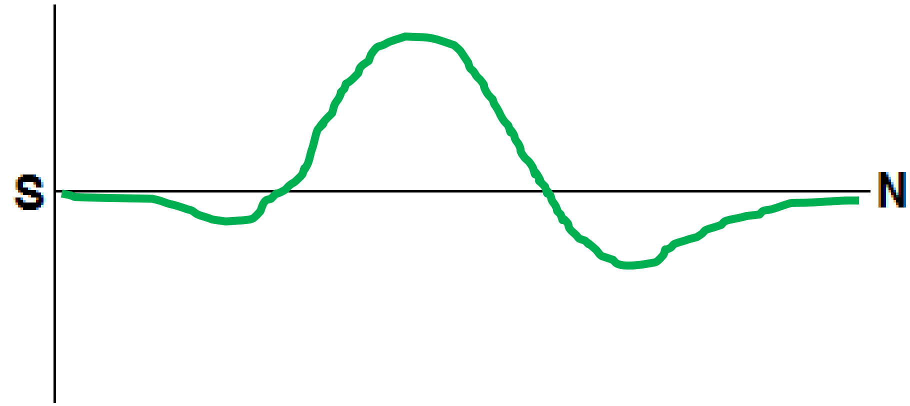
Northing: **0 A/m**

Upward: **-2.7 A/m**

$$Easting = 0 + 0\ (due\ to\ geometry)$$
$$Northing = |M_I|\cos(60) - |M_R|\cos(45)$$
$$Upward = -|M_I|\sin(60) - |M_R|\sin(45)$$

Magnetics as Dipoles or Charges





- If the block has a side length of 2 m, what is the total magnetic charge on the top of the block?

Total Magnetization

$$\vec{M} = -2.7\ A/m\ \hat{z}$$

Density of magnetic charge on top

$$\tau = \vec{M} \cdot \hat{n} = -2.7\ \hat{z} \cdot \hat{z} = -2.7\ A/m$$

Density time area

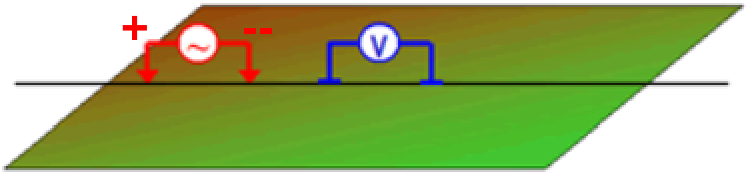
$$Q = \tau \times Area = -2.7 \times 2^2 = -10.8\ Wb$$

- Draw the anomaly

DC Resistivity Example

Physics Review

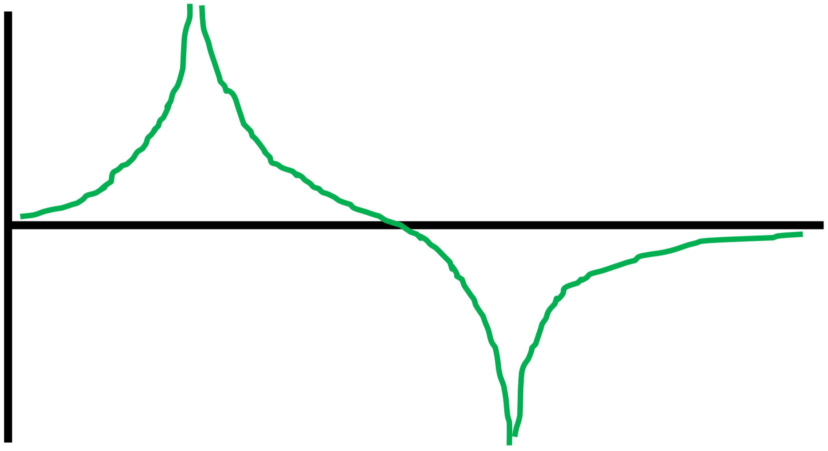
You are doing a dipole-dipole survey



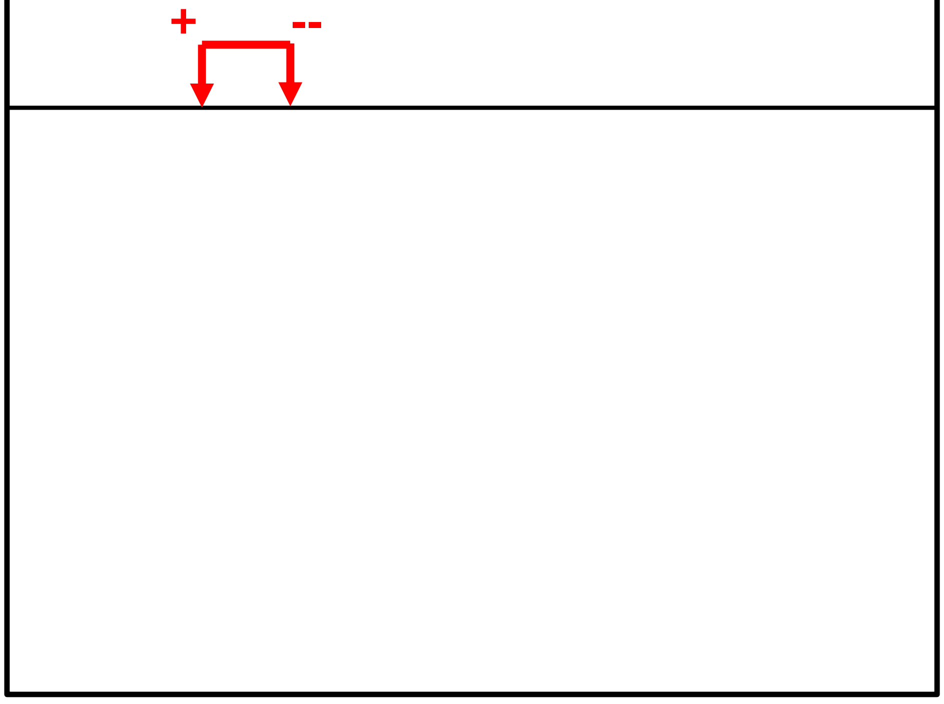
Voltage due to current electrode: $V = \frac{\rho I}{2\pi r}$

Electric potential and electric field: $\mathbf{E} = -\nabla \mathbf{V}$

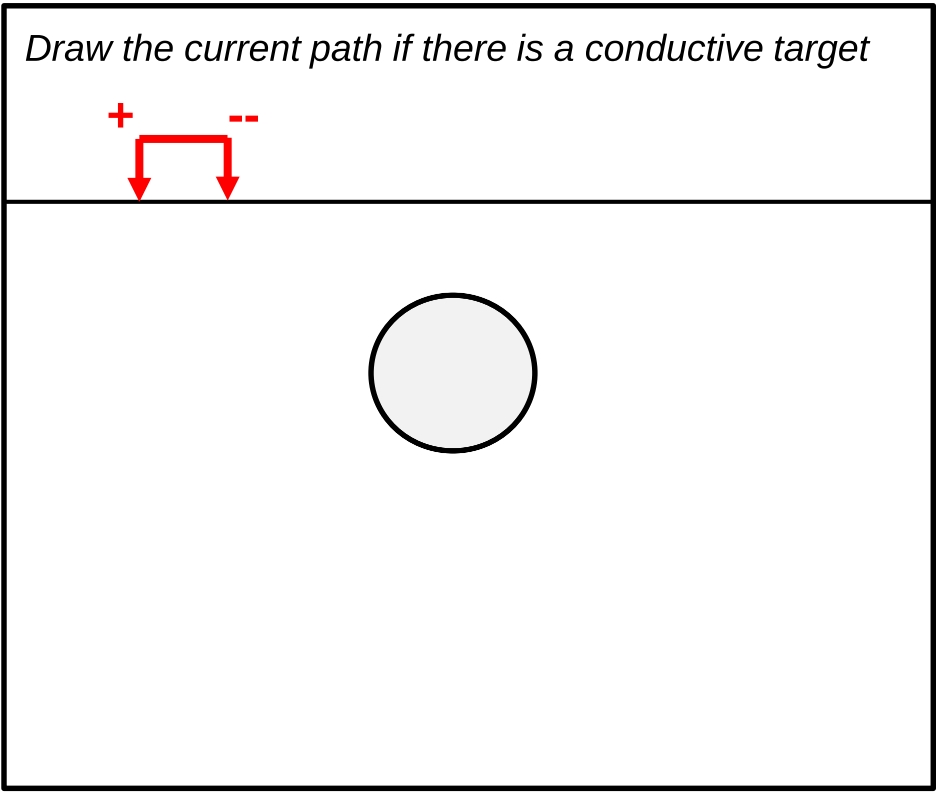
Draw potential on Earth's surface due to a dipole current electrode

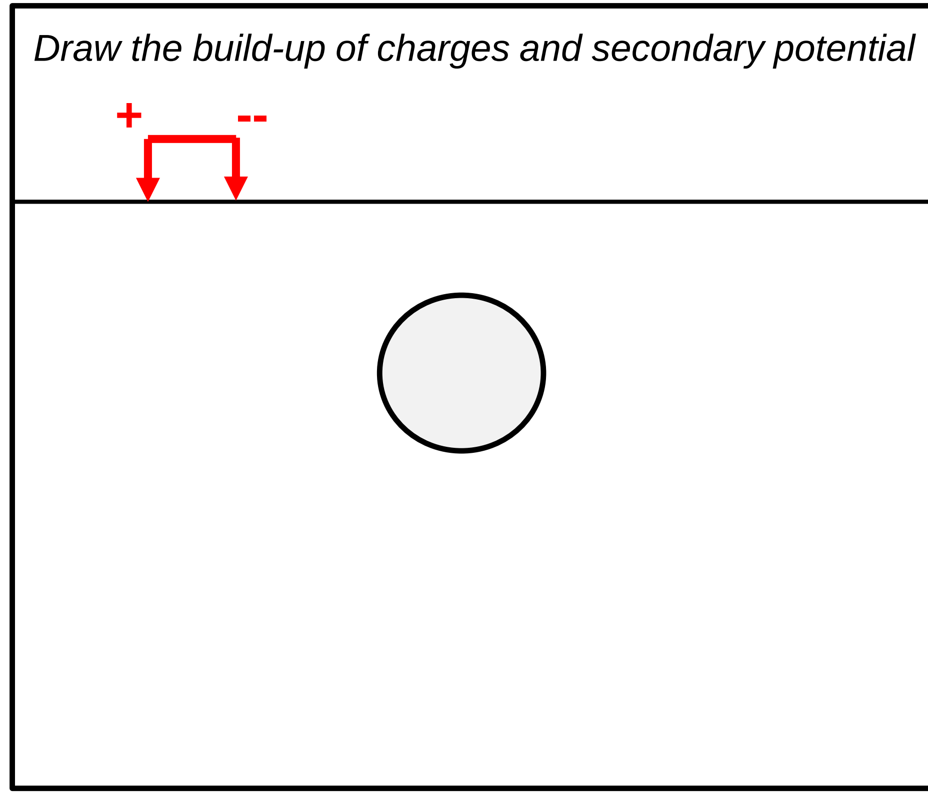


Draw the equi-potentials and current path in ground



Physics Review





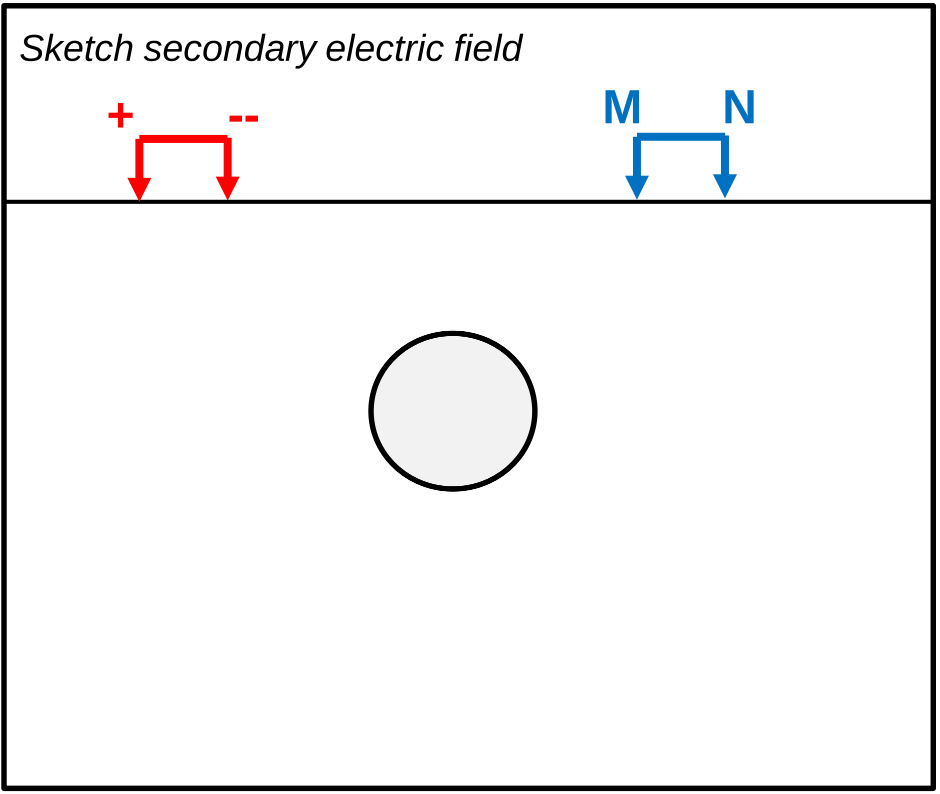
Boundary condition for normal currents

$$\left(\frac{\mathbf{1}}{\sigma_{\mathbf{2}}} - \frac{\mathbf{1}}{\sigma_{\mathbf{1}}}\right)\mathbf{J_n} = (\rho_{\mathbf{2}} - \rho_{\mathbf{1}})\mathbf{J_n} = \frac{\tau}{\varepsilon_{\mathbf{0}}}$$

Electric potential due to charges

$$\mathbf{V}(\mathbf{r}) = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{Q_i}{\mathbf{r_i}}$$

Physics Review



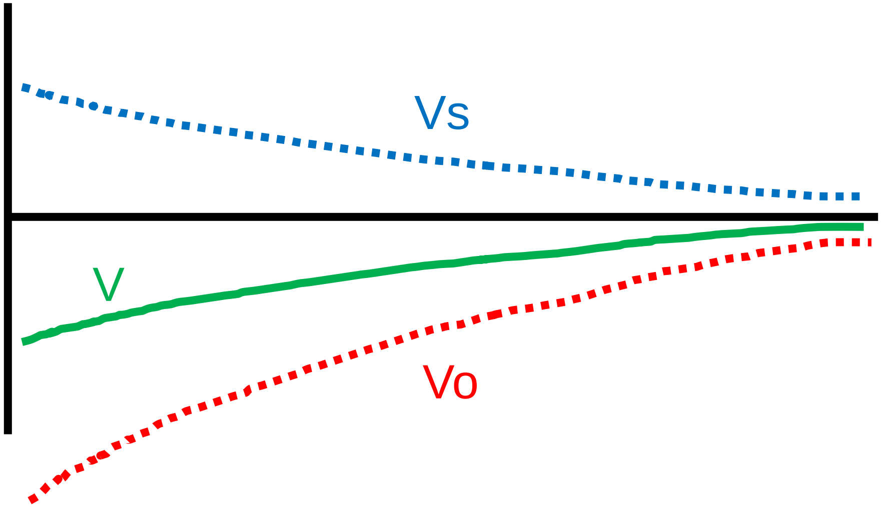
Voltage measurement

$$\Delta V = V_N - V_M$$

Apparent resistivity

$$\rho_a = \frac{\Delta V}{IG}$$

Sketch primary and secondary potentials near receiver

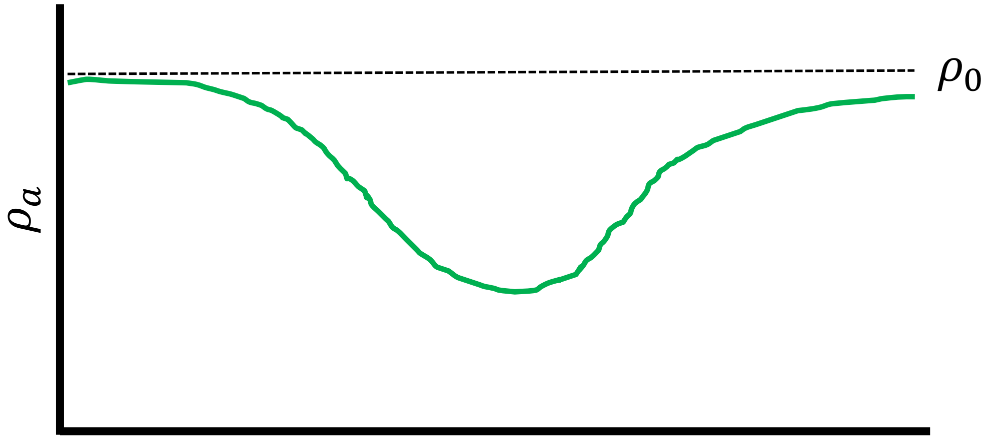


- *Is Vs adding to or opposing Vo?*
  Opposing

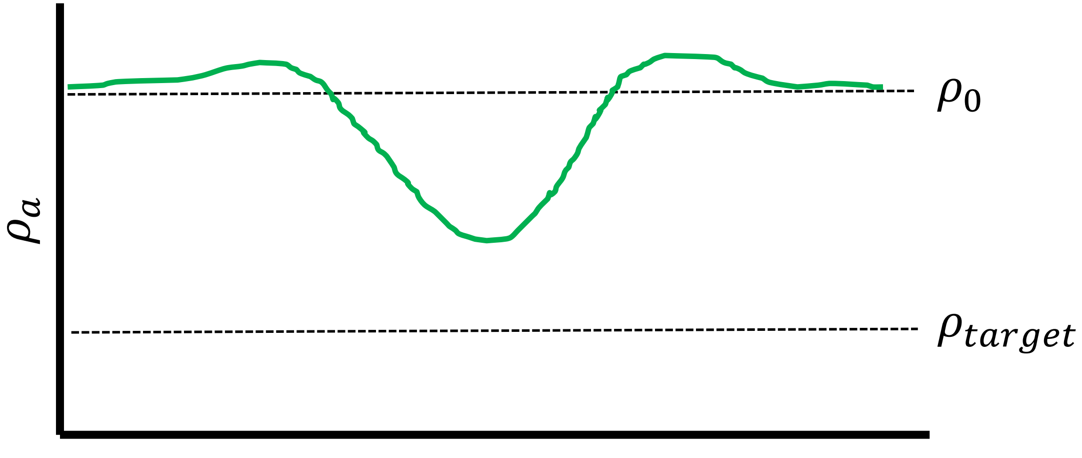
- *How does this impact apparent resistivity?*
  - *Smaller drop in potential across electrodes*
  - *Lowers apparent resistivity*

Physics Review

Sketch sounding data over this conductor



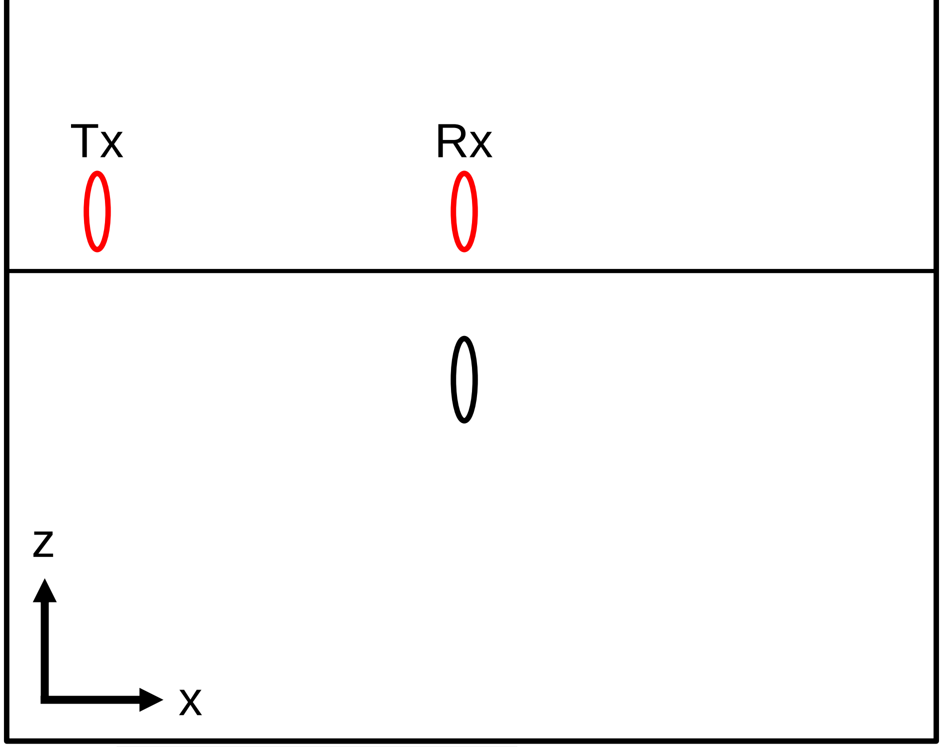
Sketch profiling data over this conductor

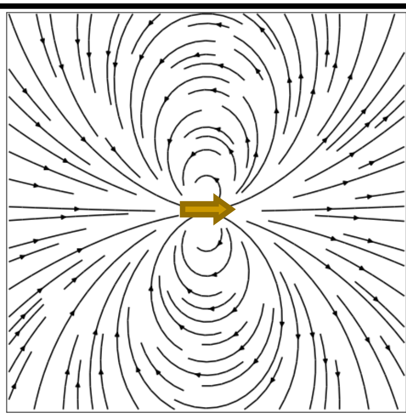


Electromagnetics

Vertical Coaxial Example

Sketch the primary and secondary fields. Define the transmitter to have a dipole moment in the x-direction





We have a vertical coaxial survey geometry over a target

The target is modeled as an LR circuit

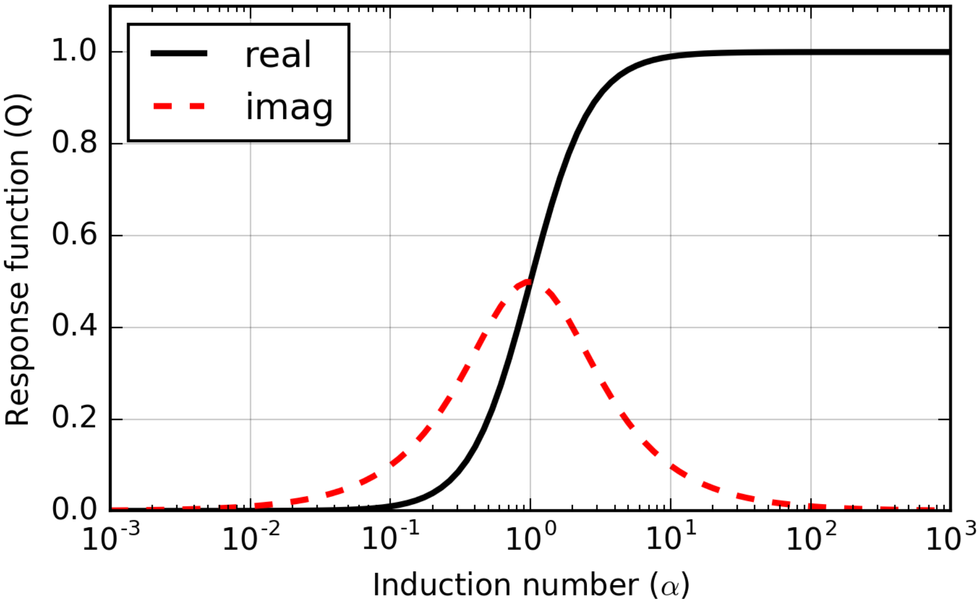
If the radius of the transmitter loop is 50 cm, the amplitude of the current is 2 A and the coil has 5 turns, what is its dipole moment?

$$m = NIa = 5(2\ A)(\pi\ 0.5^2) = 7.85\ Am^2$$

Is the transmitter and receiver well-coupled or null-coupled?

Both are well coupled

Vertical Coaxial Example



The transmitter carries an oscillating current. The frequency and the properties of the target loop are such that the ***inductance is 0.5***

What is the phase lag between the primary and induced current?

$$\frac{\pi}{2} + tan^{-1}(0.5) = 117°$$

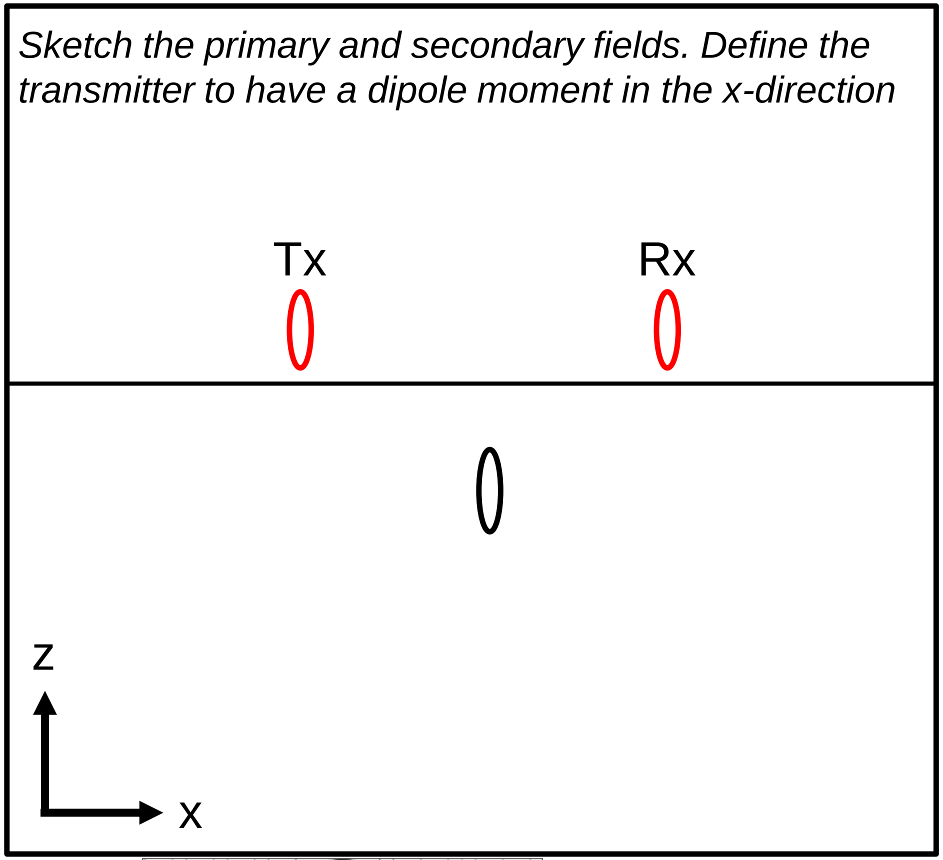
$$\alpha = \frac{\omega L}{R}$$

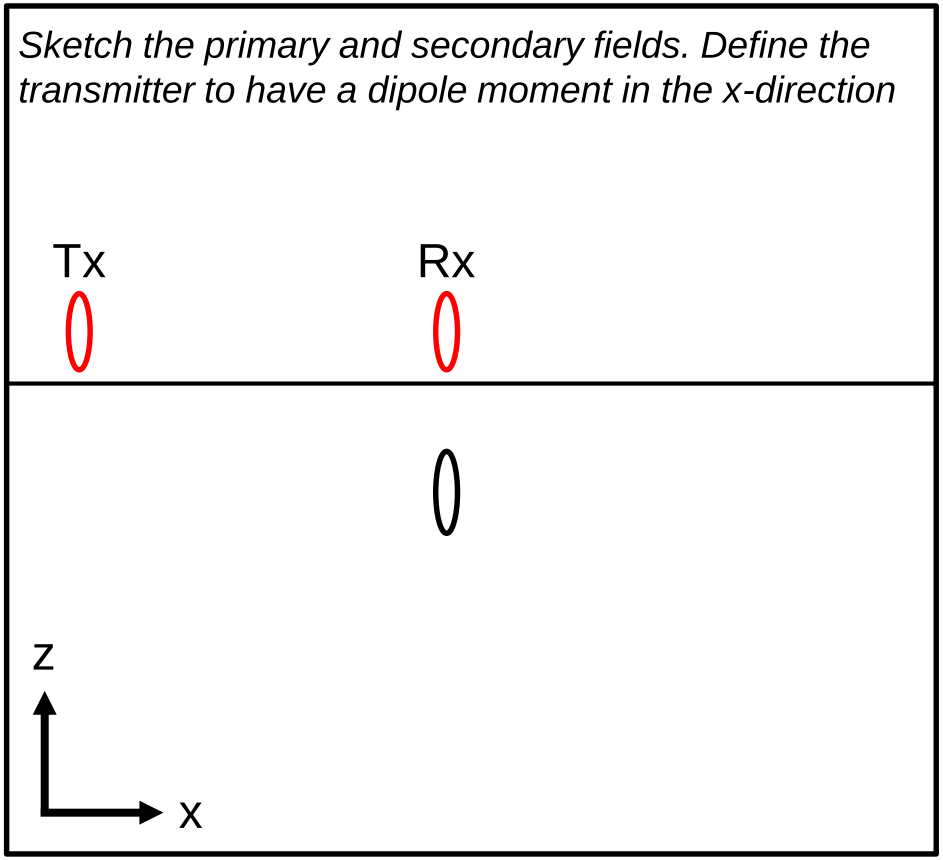
$$\psi = \frac{\pi}{2} + \tan^{-1}\left(\frac{\omega L}{R}\right)$$

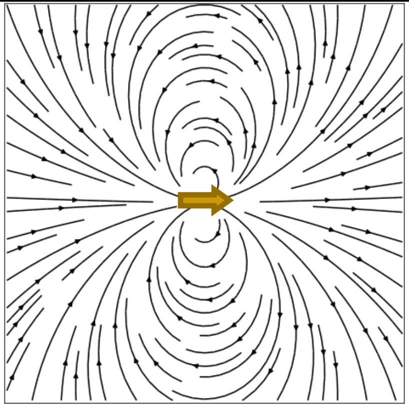
Will the response have a large in-phase or quadrature component?

Quadrature component

Vertical Coaxial Example

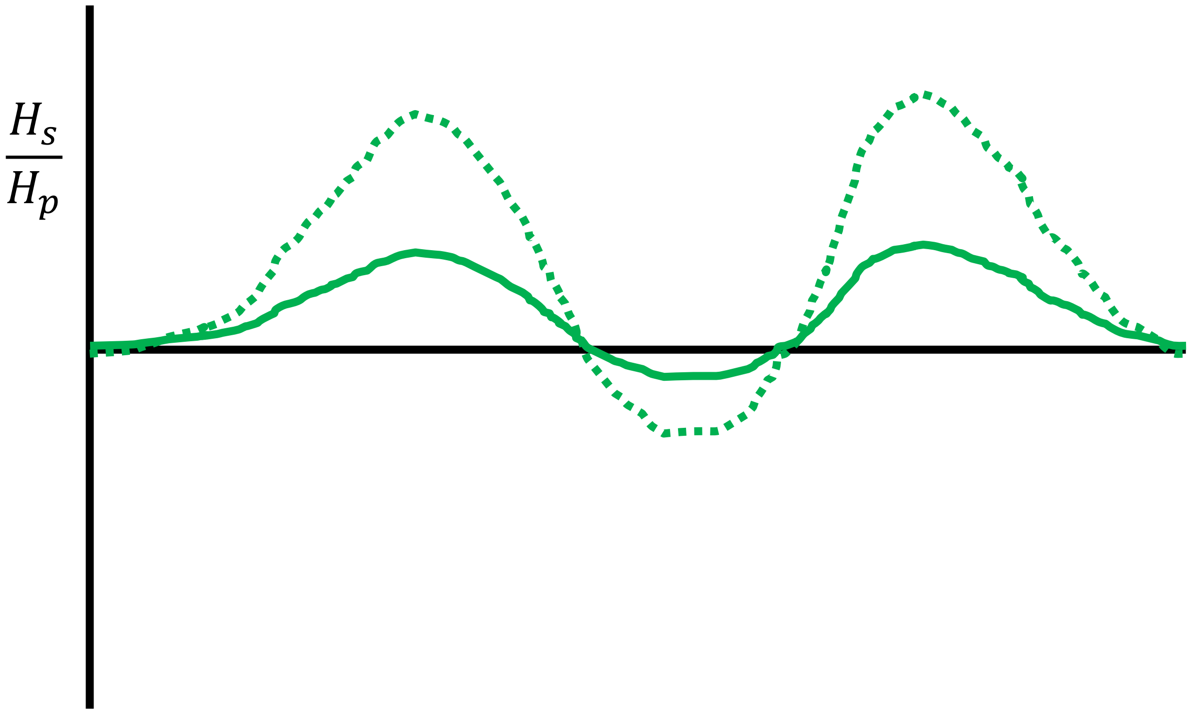






Vertical Coaxial Example

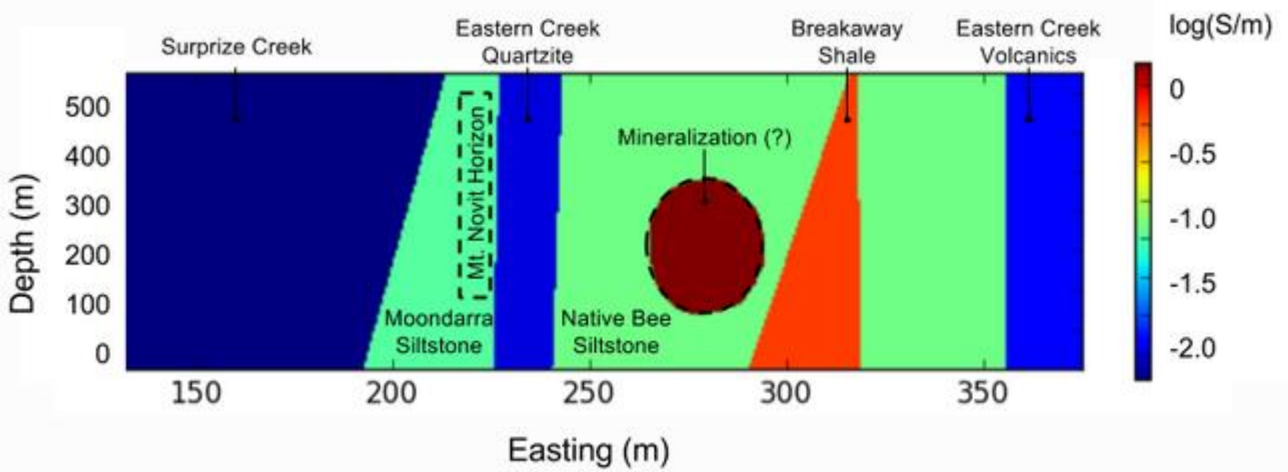
Sketch the anomaly. They halfway point between Tx and Rx is the data location



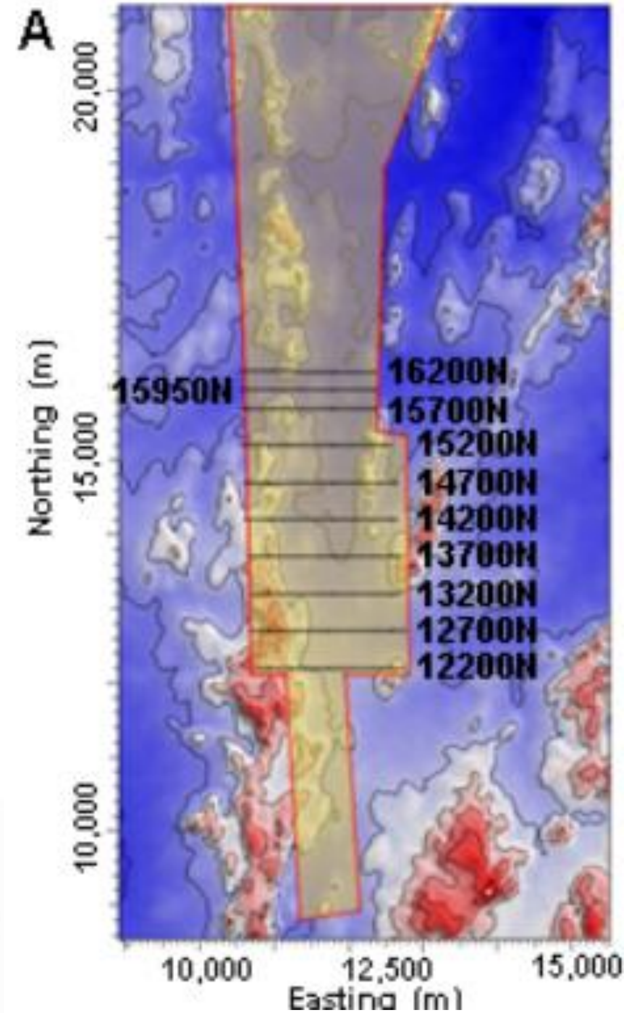
The Return of Mt. Isa

Mt. Isa (Setup)

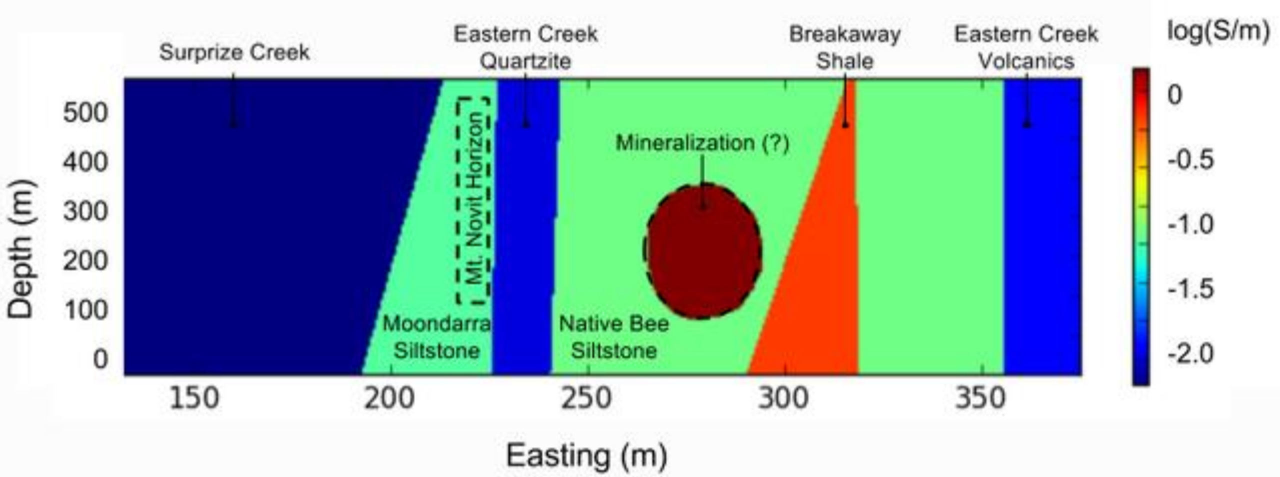
- **Objective:** Local sulphide mineralization within Native Bee Siltstone
- **Other info:** A geological cross-section



Simplified (log) conductivity distribution expected at Mount Isa (N:12200m).



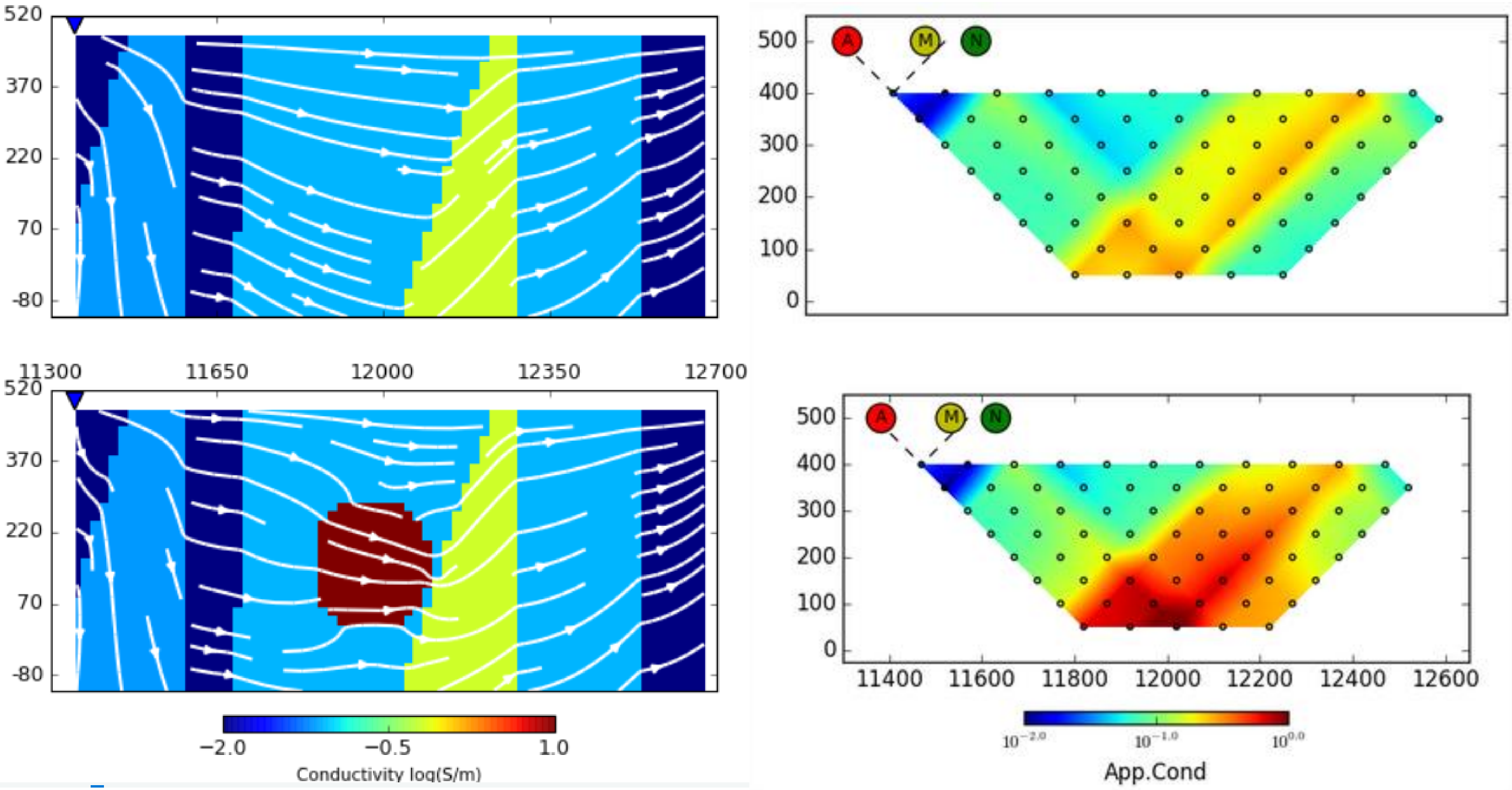
Mt. Isa (Properties)



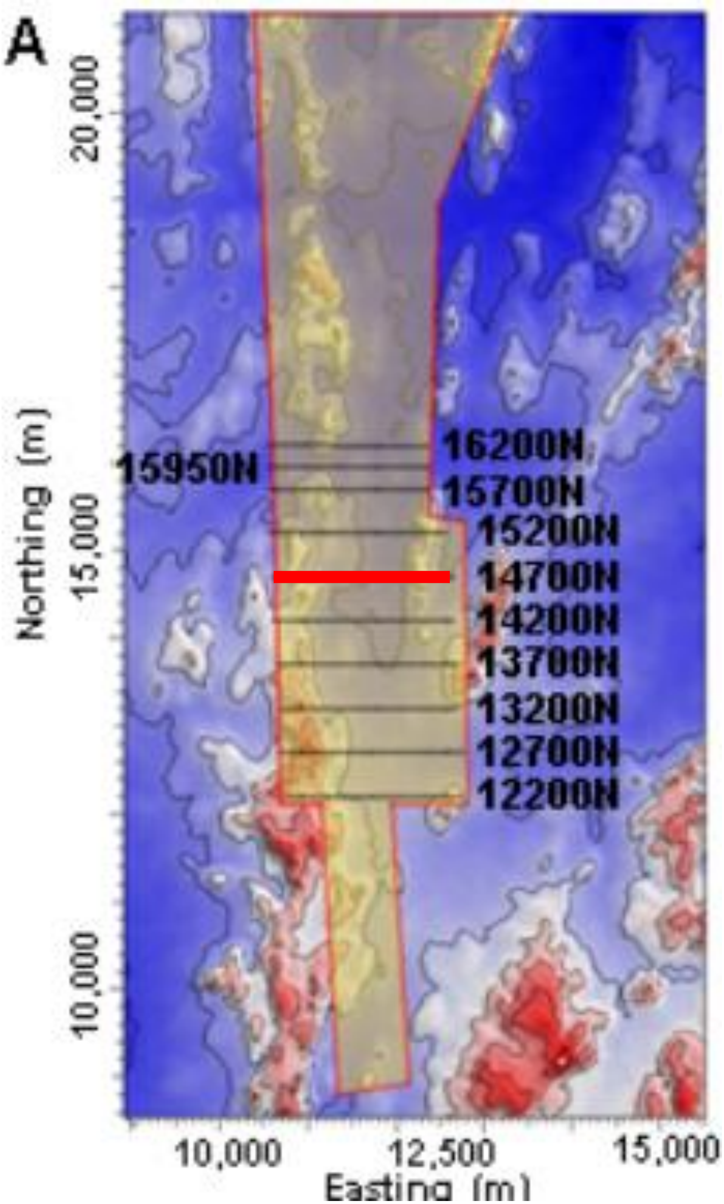
Simplified (log) conductivity distribution expected at Mount Isa (N:12200m).

Rock Unit	Conductivity	Resistivity ($\Omega \cdot m$)	Chargeability
Native Bee Siltstone	Moderate	Moderate (~10)	Low
Moondarra Siltstone	Moderate	Moderate (~10)	Low
Breakaway Shale	Very High	Very Low (~0.1)	Low-None
Mt Novit Horizon	High	Low (~1)	High
Surprise Creek Formation	Low	High (~1000)	None
Eastern Creek Volcanics	Low	High (~1000)	None

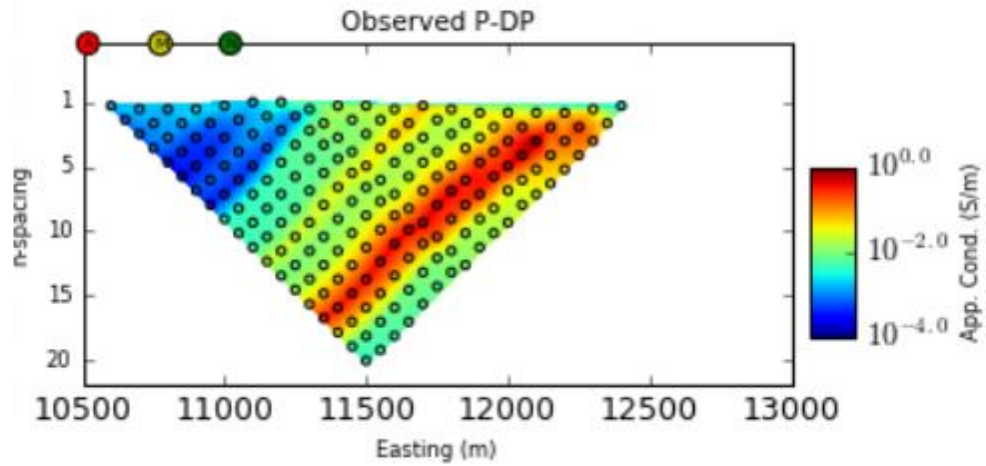
Planning my survey (Synthetic Modeling)



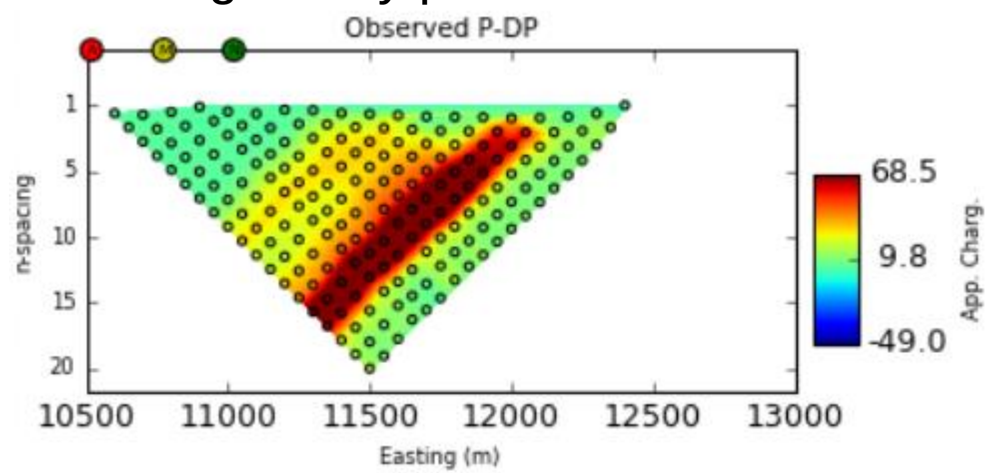
Mt. Isa (Survey and Data)



Conductivity pseudo-section



Chargeability pseudo-section



Q: What trends seen in data?

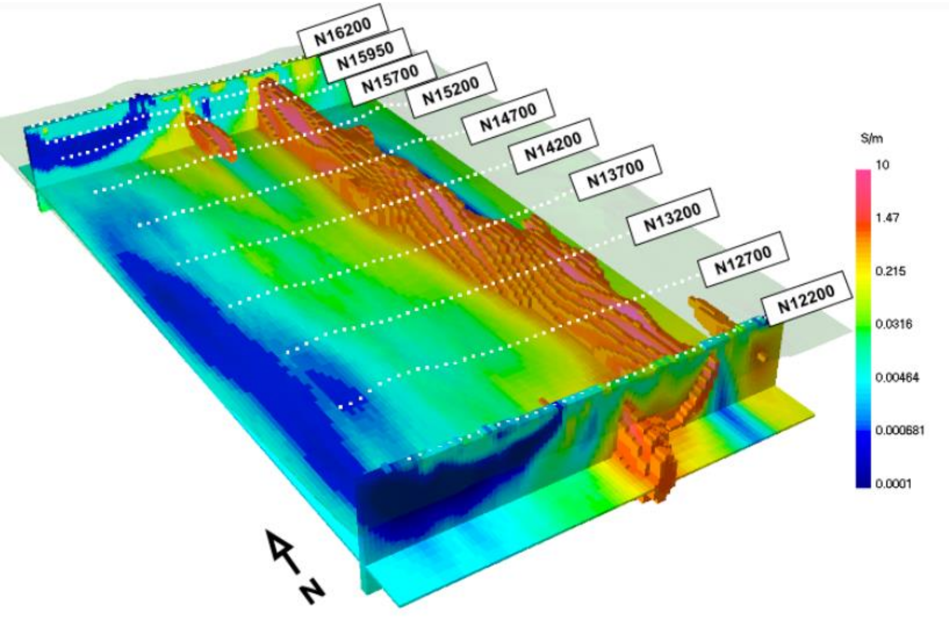
Mt. Isa (Processing)

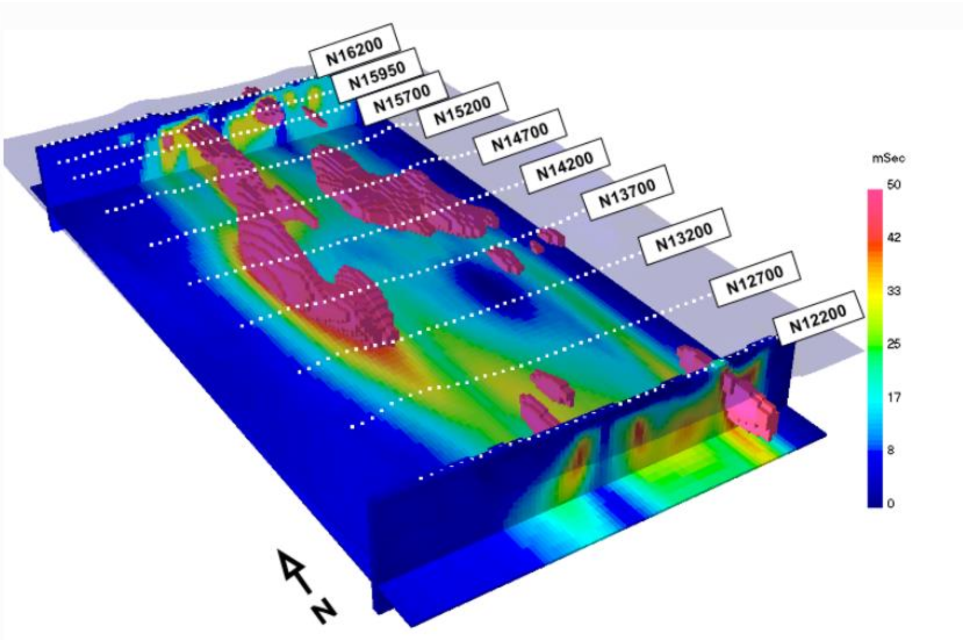
Apparent resistivity data (ρ_a)

Resistivity model (ρ)

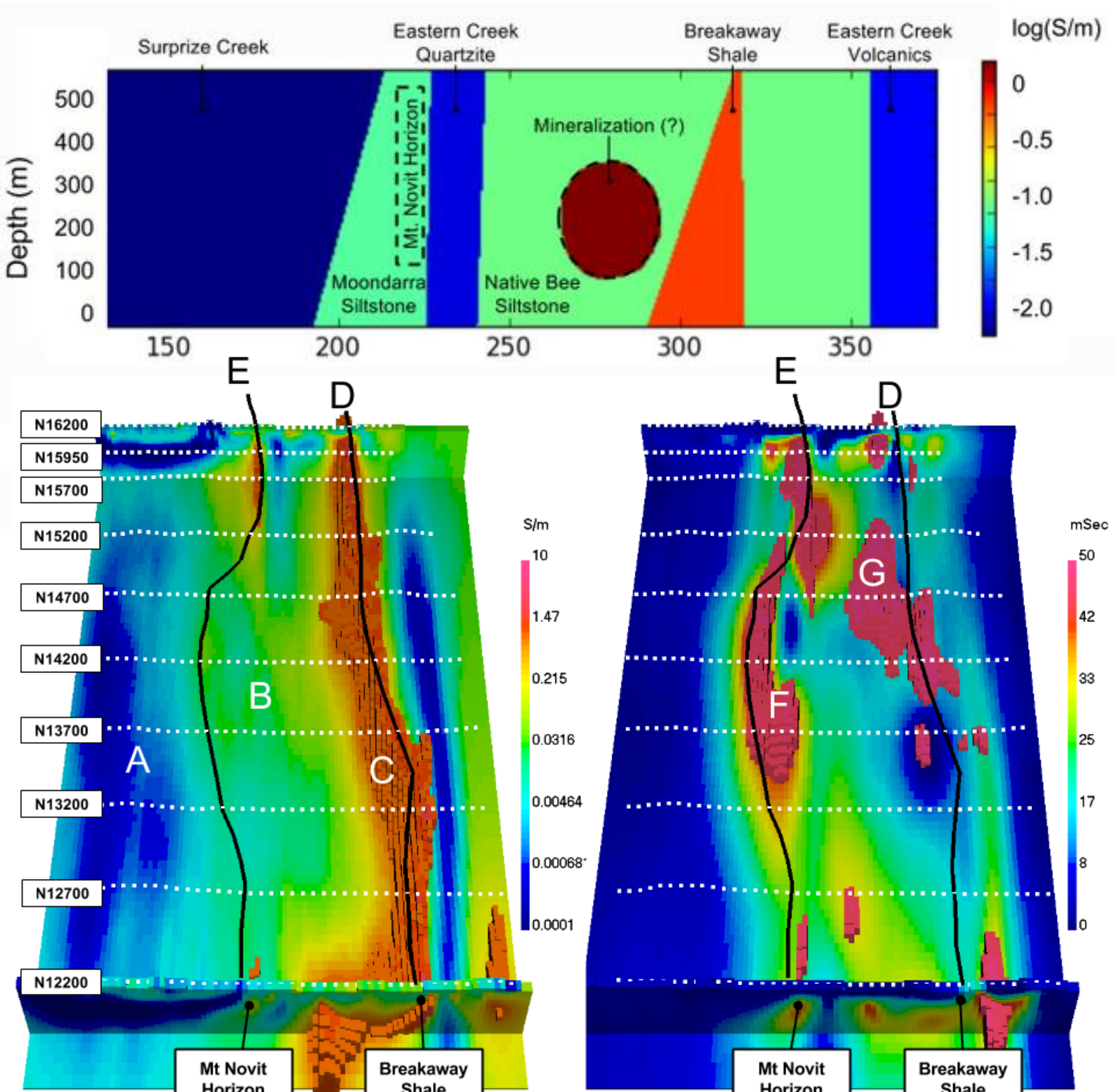
Integrated chargeability data (d_{IP})

Chargeability model (η)



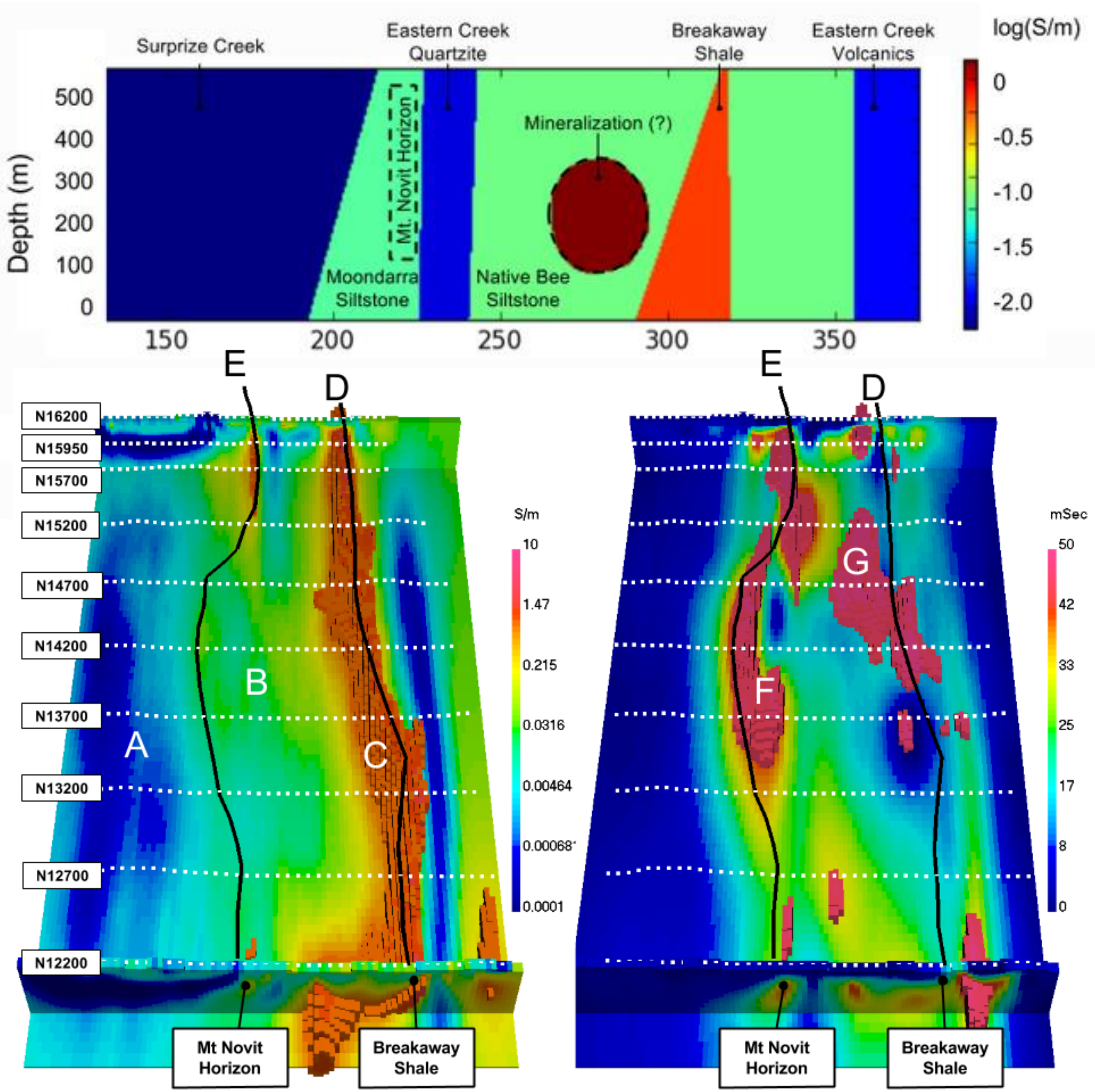


Mt. Isa (Interpretation)



A: Surprise creek
(low σ, low η)

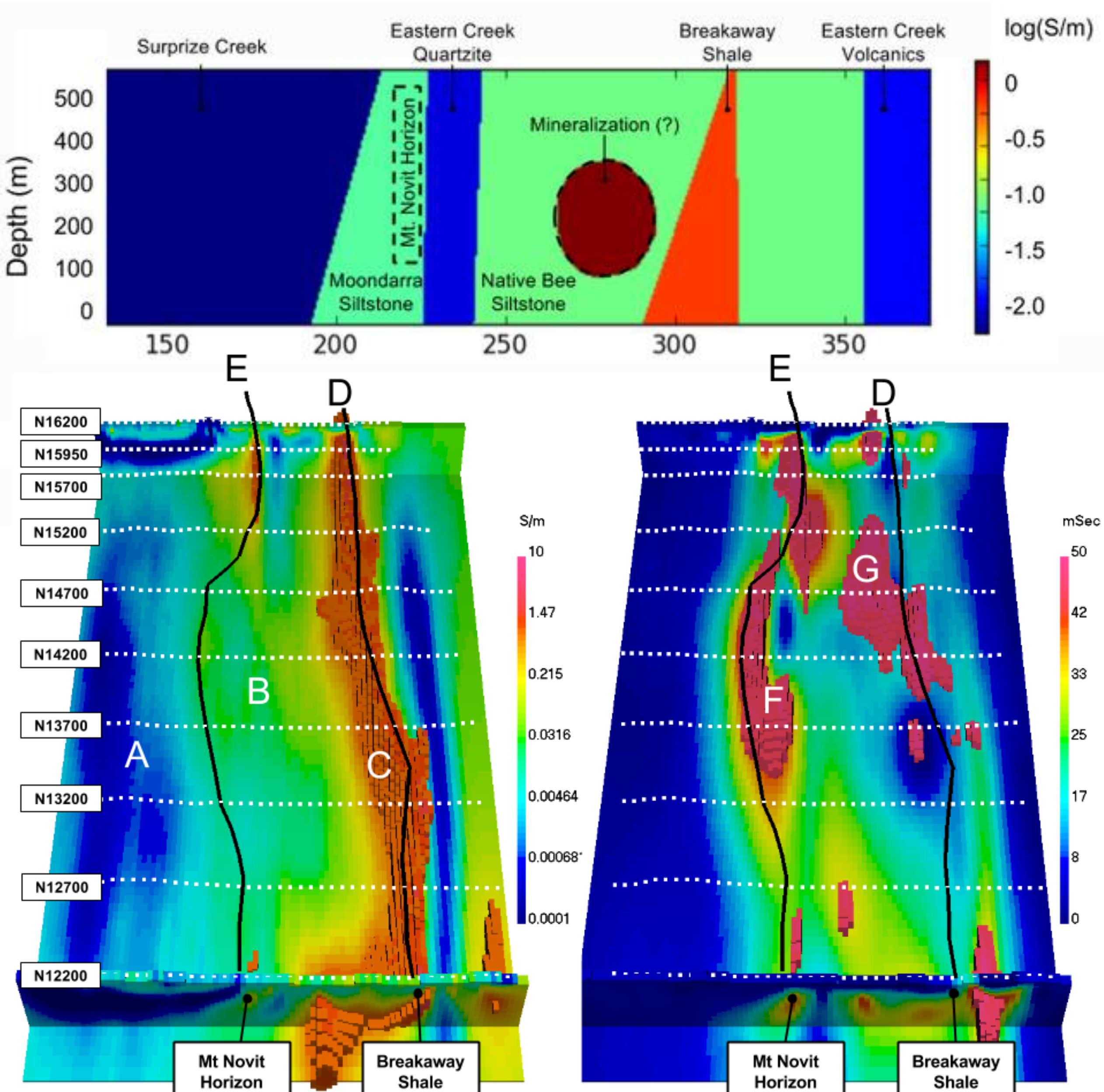
Mt. Isa (Interpretation)



A: Surprise creek
(low σ, low η)

B: Moondarra and Native Bee siltstones
(moderate σ, low η)

Mt. Isa (Interpretation)

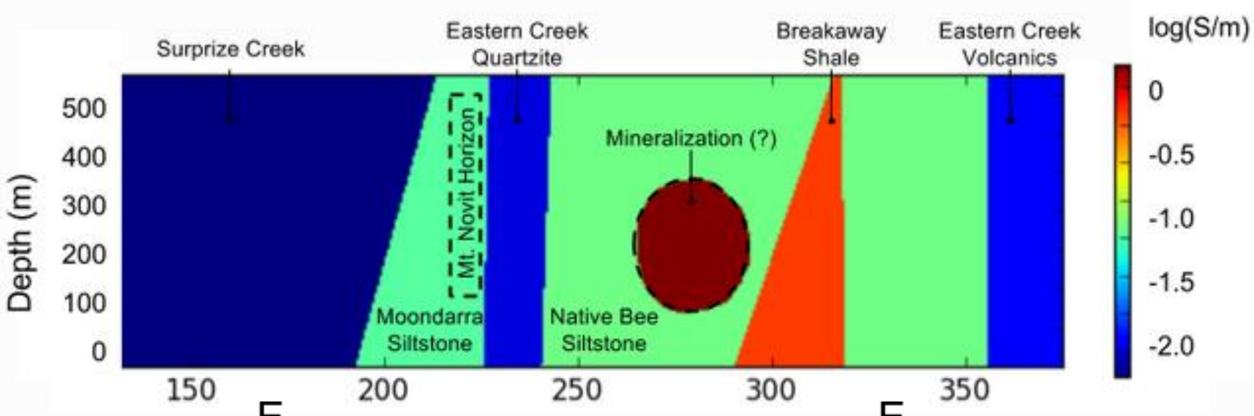


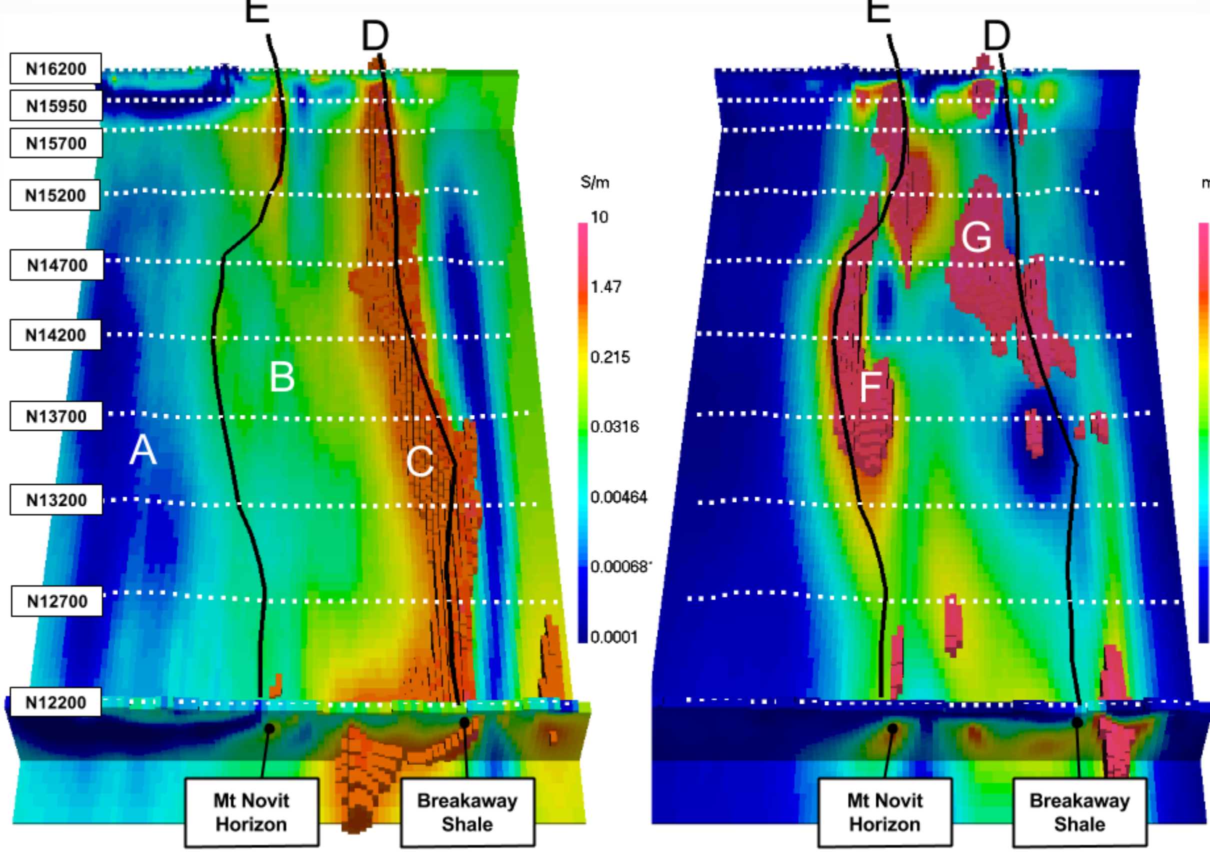
A: Surprise creek
(low σ, low η)

B: Moondarra and Native Bee siltstones
(moderate σ, low η)

C and D: Breakaway shales
(high σ, low η)

Mt. Isa (Interpretation)





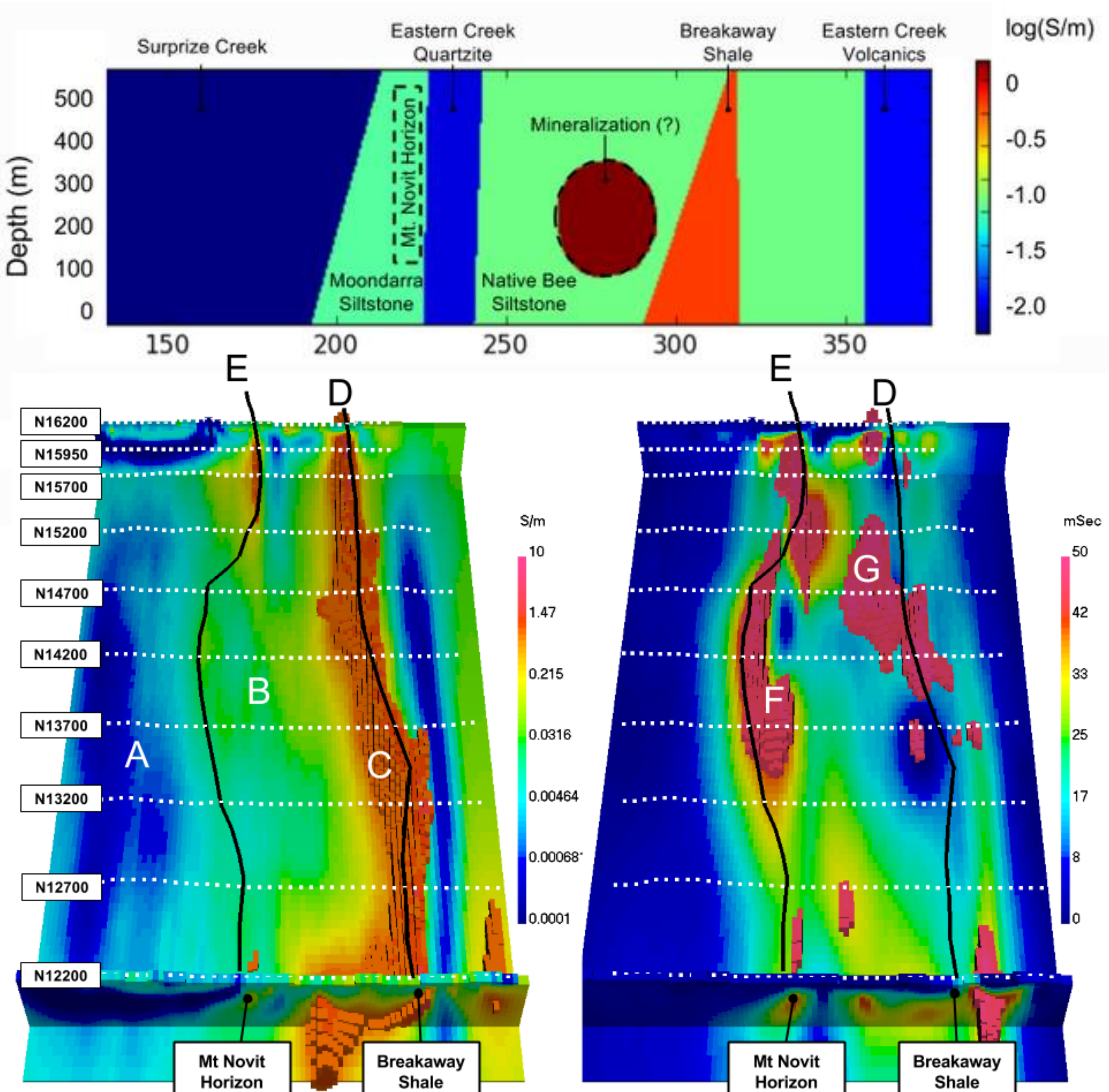
A: Surprise creek
(low σ, low η)

B: Moondarra and Native Bee siltstones
(moderate σ, low η)

C and D: Breakaway shales
(high σ, low η)

E and F: Mt. Novit horizon
(high σ, high η)

Mt. Isa (Interpretation)



A: Surprise creek
(low σ, low η)

B: Moondarra and Native Bee siltstones
(moderate σ, low η)

C and D: Breakaway shales
(high σ, low η)

E and F: Mt. Novit horizon
(high σ, high η)

G: Possible mineralization
(high σ, high η)