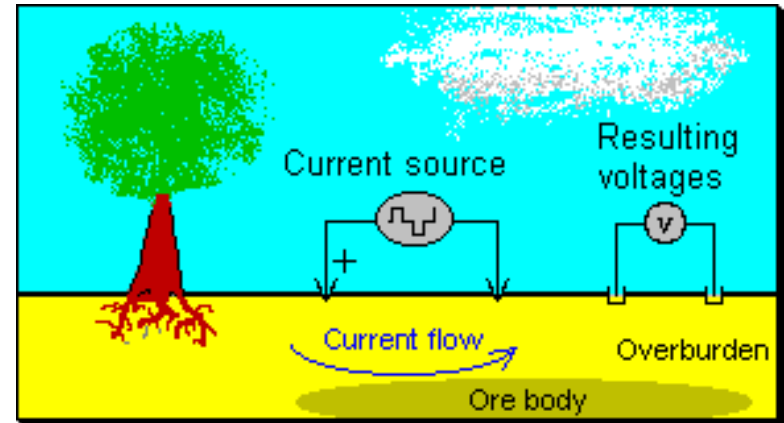

DC Resistivity

- Basic principles
- Pseudosections
- Data acquisition: Soundings and profilings
- Inversion

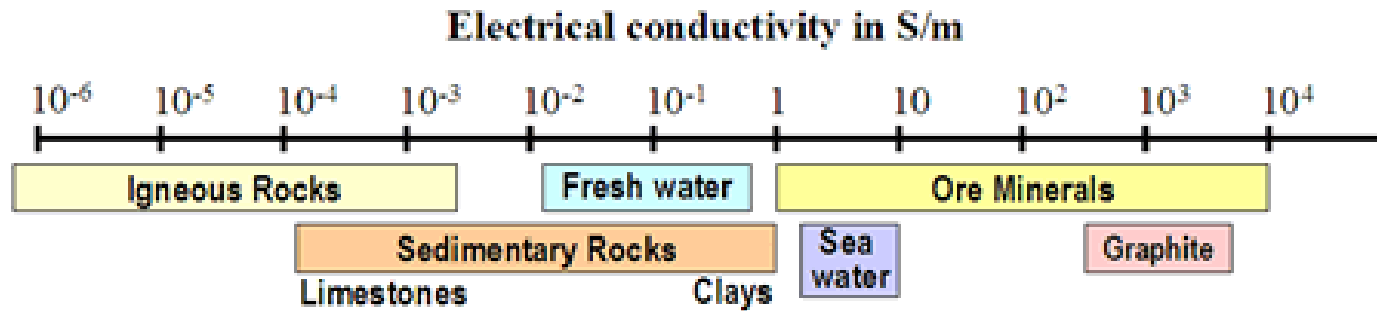


DC resistivity surveys and data

- Inject current.
- Measure potentials.
- Potentials depend upon the distribution of subsurface **resistivity**.
- Resistivity of geologic materials depends on:
 - rock type,
 - minerals,
 - porosity and fluid type.



Electrical Conductivity/Resistivity



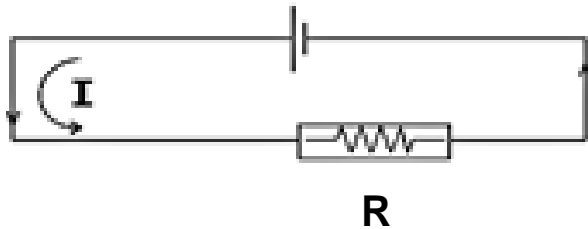
- porosity;
- hydraulic permeability, how pores are interconnected;
- moisture content;
- concentration of dissolved electrolytes;
- temperature and phase of pore fluid;
- amount and composition of colloids (clay content).

Remember: Resistivity (Ohm/m) = 1/Conductivity (S/m)

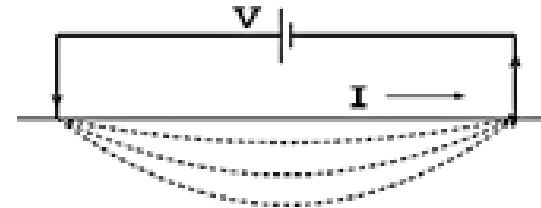


Basic Idea

Circuit

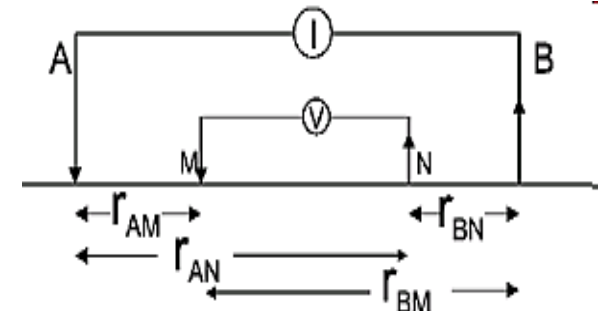


Earth circuit



I current put in by the transmitter
R is the resistance of the circuit
V is a measured voltage ($V=IR$)

For earth system: put the transmitter probes anywhere
Measure the voltage between two other electrodes

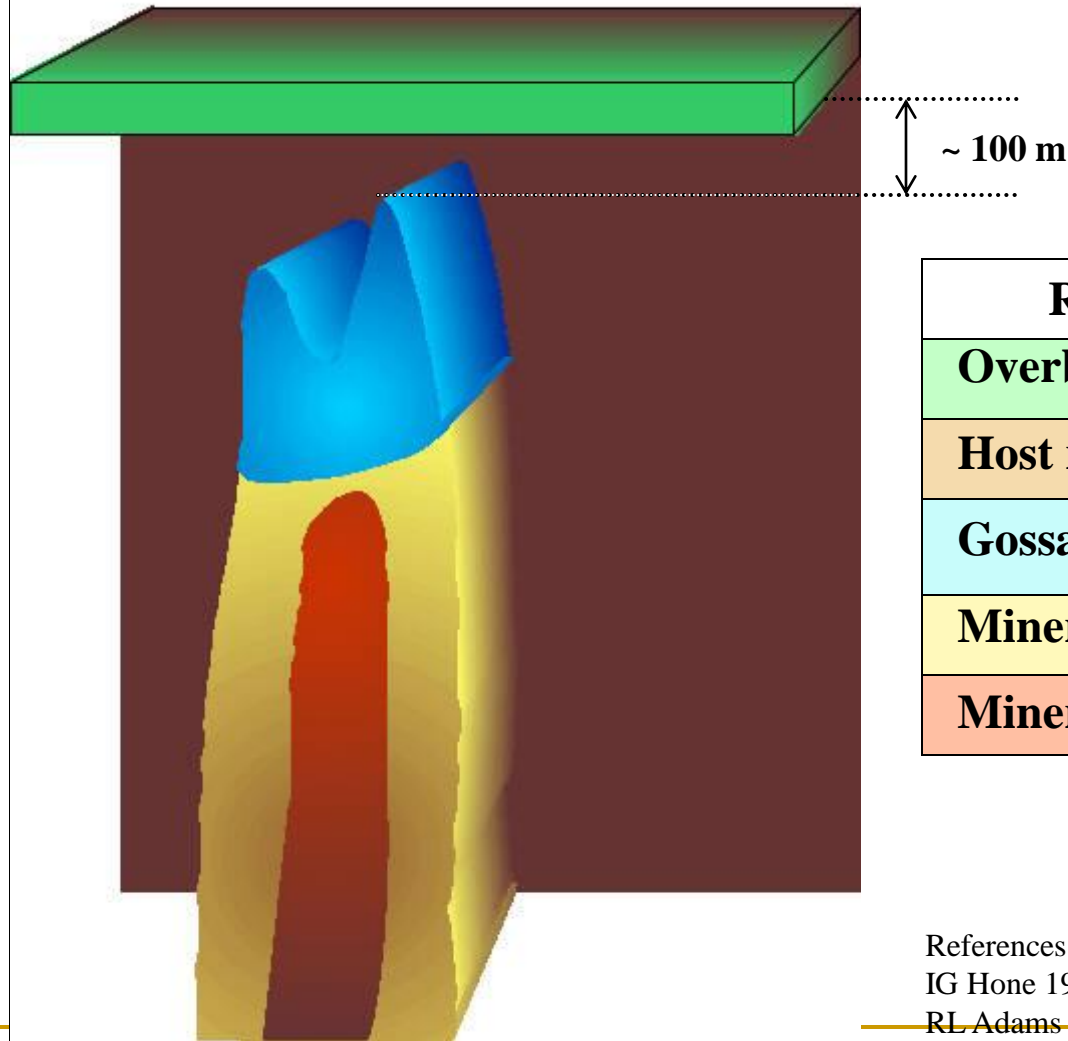


All geophysical systems use four electrodes



Current Flow: the Elura Orebody.

Elura orebody and conductive overburden.

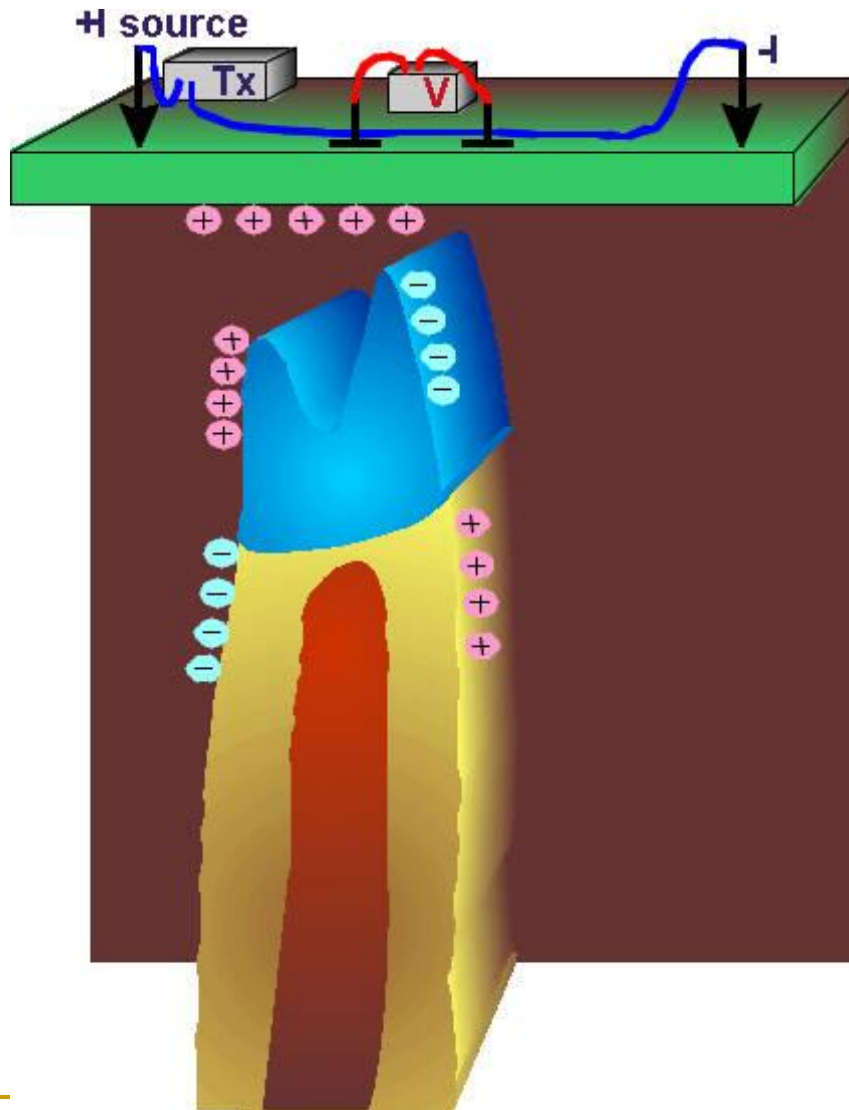


Rock type	Ohm-m
Overburden	12
Host rock	200
Gossan	420
Mineralization (pyritic)	0.6
Mineralization (pyrrhotite)	0.6

References:
IG Hone 1981
RL Adams & BL Schmidt, 1981



Current Flow: the Elura Orebody.



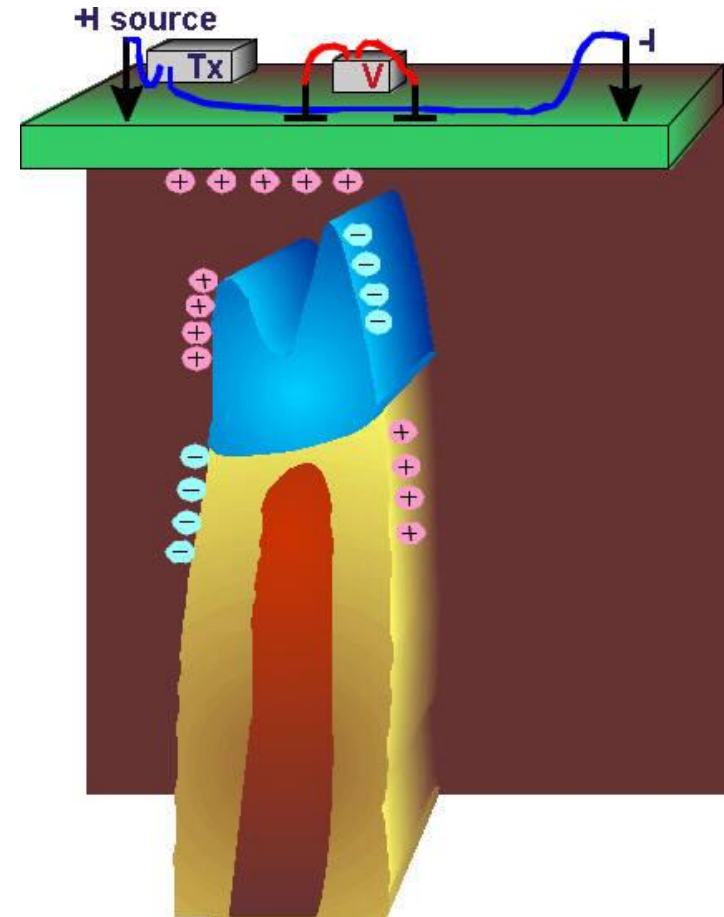
- Resistivity and IP survey configuration.
- Current converges on conductors, diverges from resistors.
- Charges accumulate.
- Charge distribution affects recorded potentials.

$$V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$$

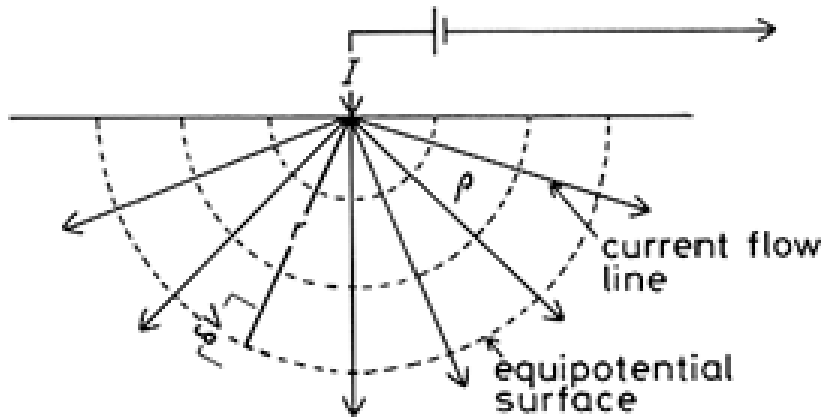


Some important elements

- Currents need to couple with the target
- Charges will exist on horizontal layers as well as on buried targets
- The voltage depends upon the location and separation of the potential electrodes.



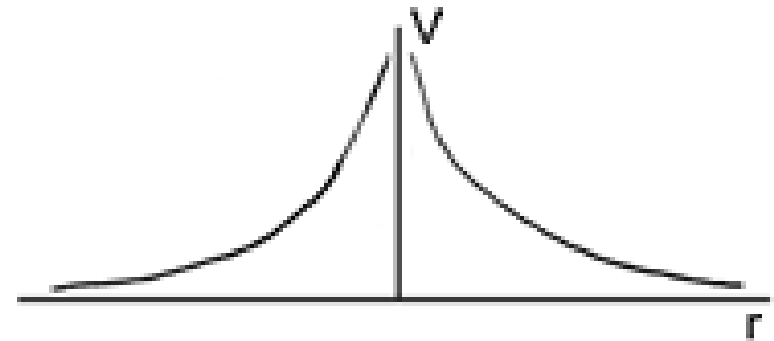
Potential for a homogeneous earth



Current flows radially outwards

Electrical potential decays as $1/r$

$$V(r) = \frac{I}{2\pi\sigma r} = \frac{I\rho}{2\pi r}$$

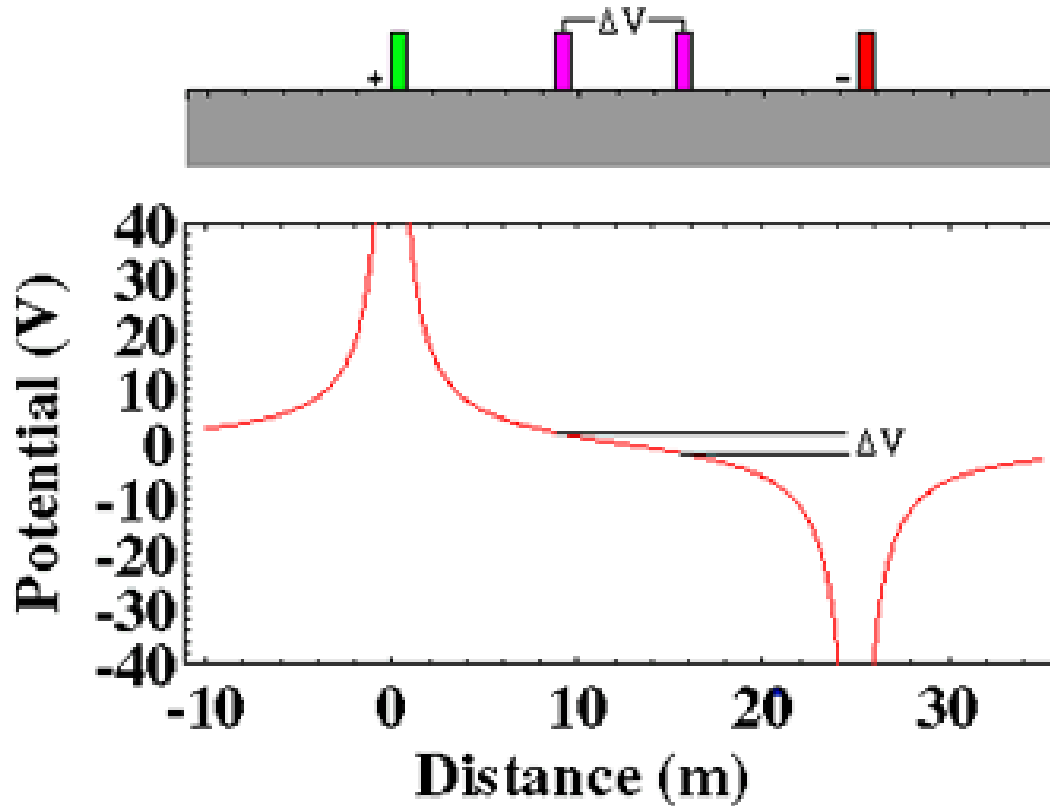


Measure V at any r . Compute $\rho = 2\pi r V(r) / I$

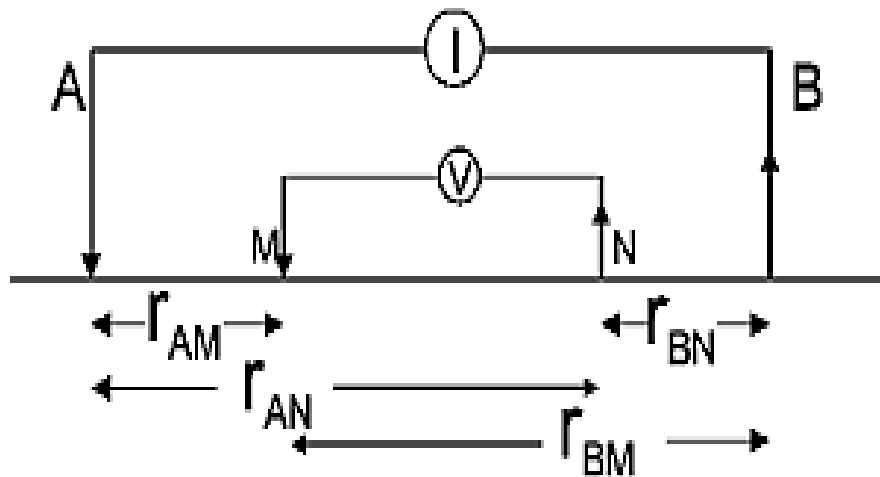


Measuring potentials

- GPG 3b (Principles)



Apparent Resistivity



Convention:
 AB are current electrodes
 MN are potential electrodes

Apparent resistivity

$$\Delta V = \frac{I\rho}{2\pi} \left\{ \frac{1}{r_{AM}} - \frac{1}{r_{BM}} - \frac{1}{r_{AN}} + \frac{1}{r_{BN}} \right\}$$

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

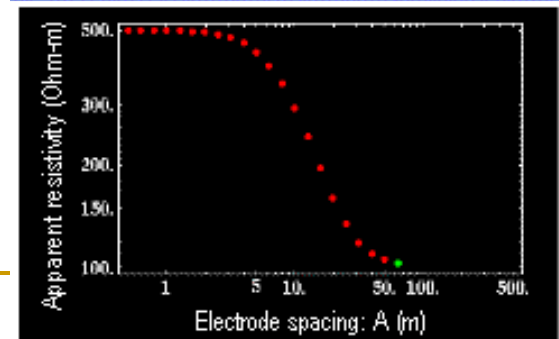
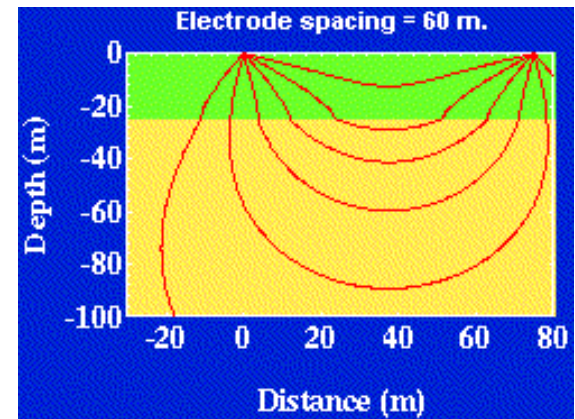
$$\Delta V = I\rho G$$

G: Geometric Factor



Data acquisition: Sounding (GPG 3b)

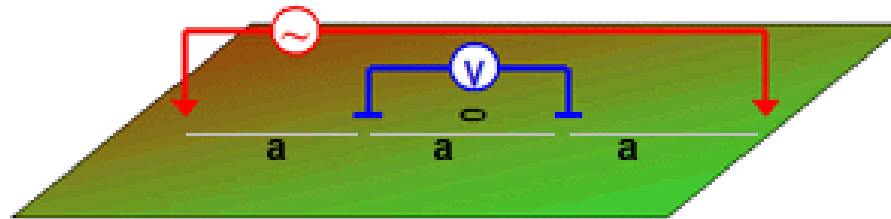
- Current penetration depends upon current electrode separation
- To estimate conductivity directly beneath a point
 - expand current electrodes symmetrically
 - measure potentials
- Compute apparent resistivity (Apparent resistivity is not the true resistivity)



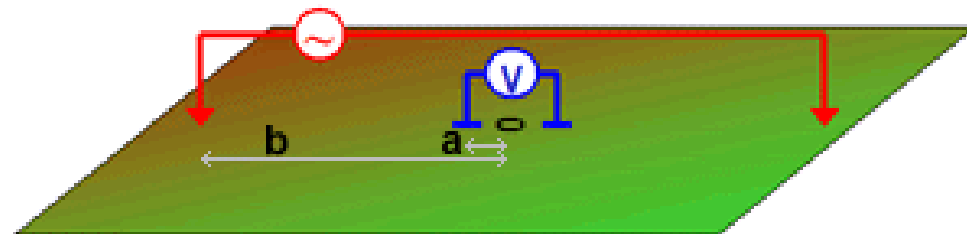
Data acquisition: Sounding

- Acquiring data symmetrically about a point is referred to as a “sounding”

- Wenner:



- Schlumberger:



$a \ll b$



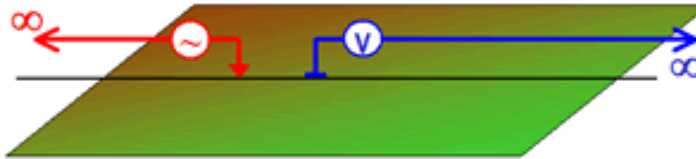
Data acquisition: Profiling

- A particular electrode geometry moved laterally is referred to as “profiling”
- This can help see lateral changes in conductivity

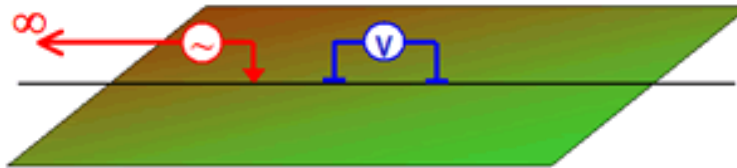


Data acquisition: Profiling

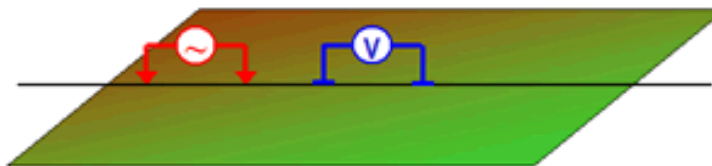
- Pole-pole



- Pole-dipole



- Dipole-dipole

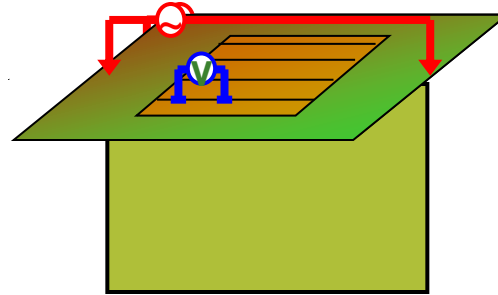
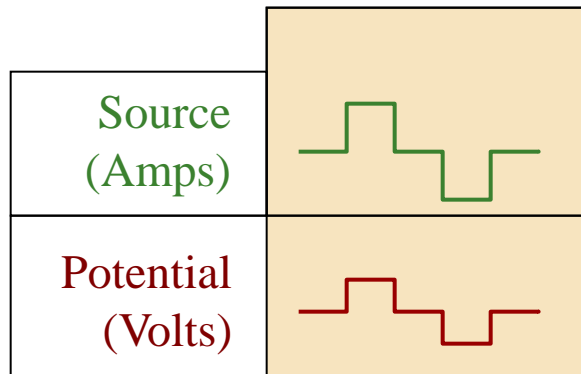


Putting it all together

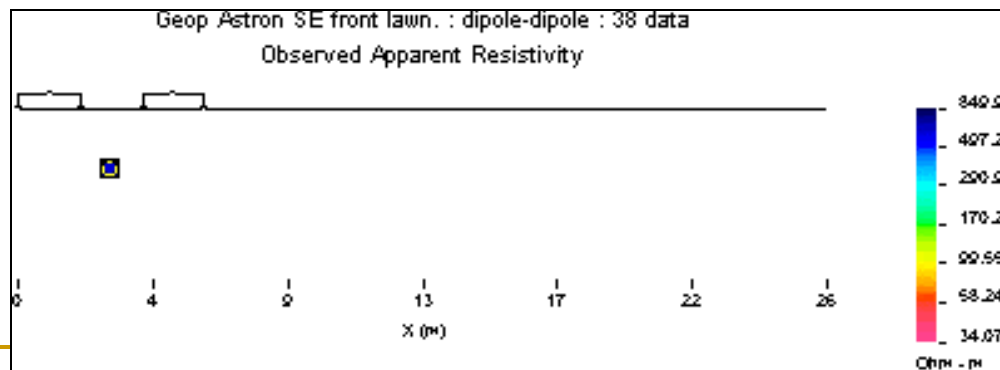
- Generally we want to see in depth and laterally
- Combine sounding and profiling
- Create an array geometry
 - expand it (sounding)
 - move it (profiling)



DC resistivity data



Each data point is an *apparent* resistivity: $\rho_a = \frac{2\pi\Delta V}{IG}$



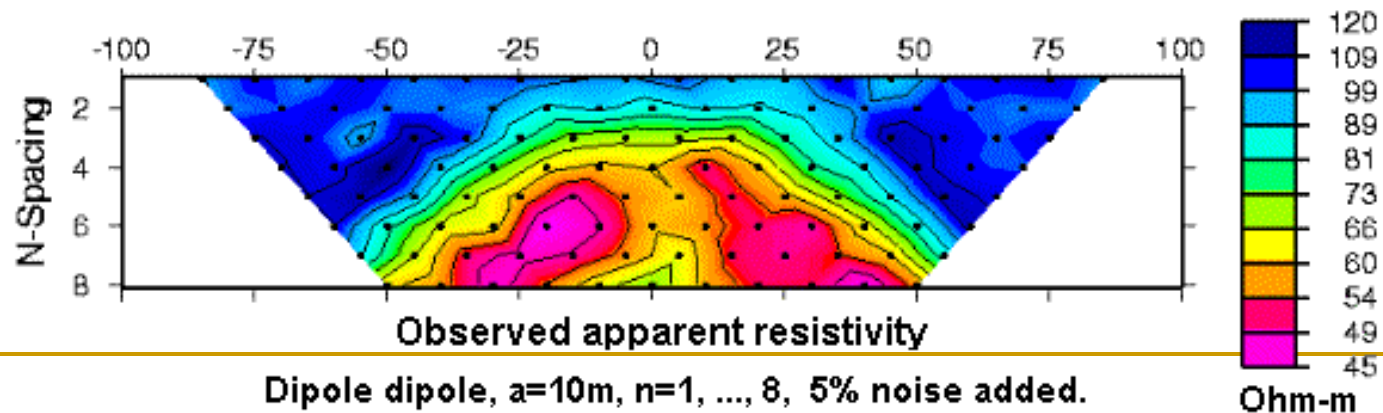
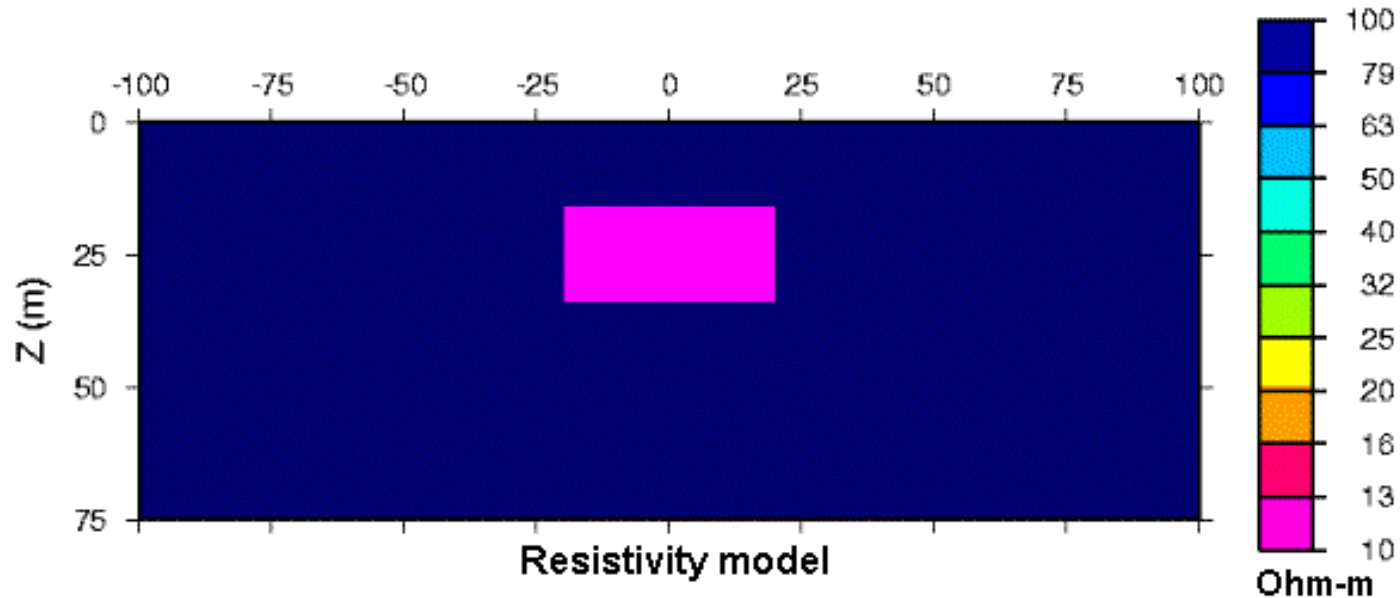
This is only a plot of the data

(Click for animation)



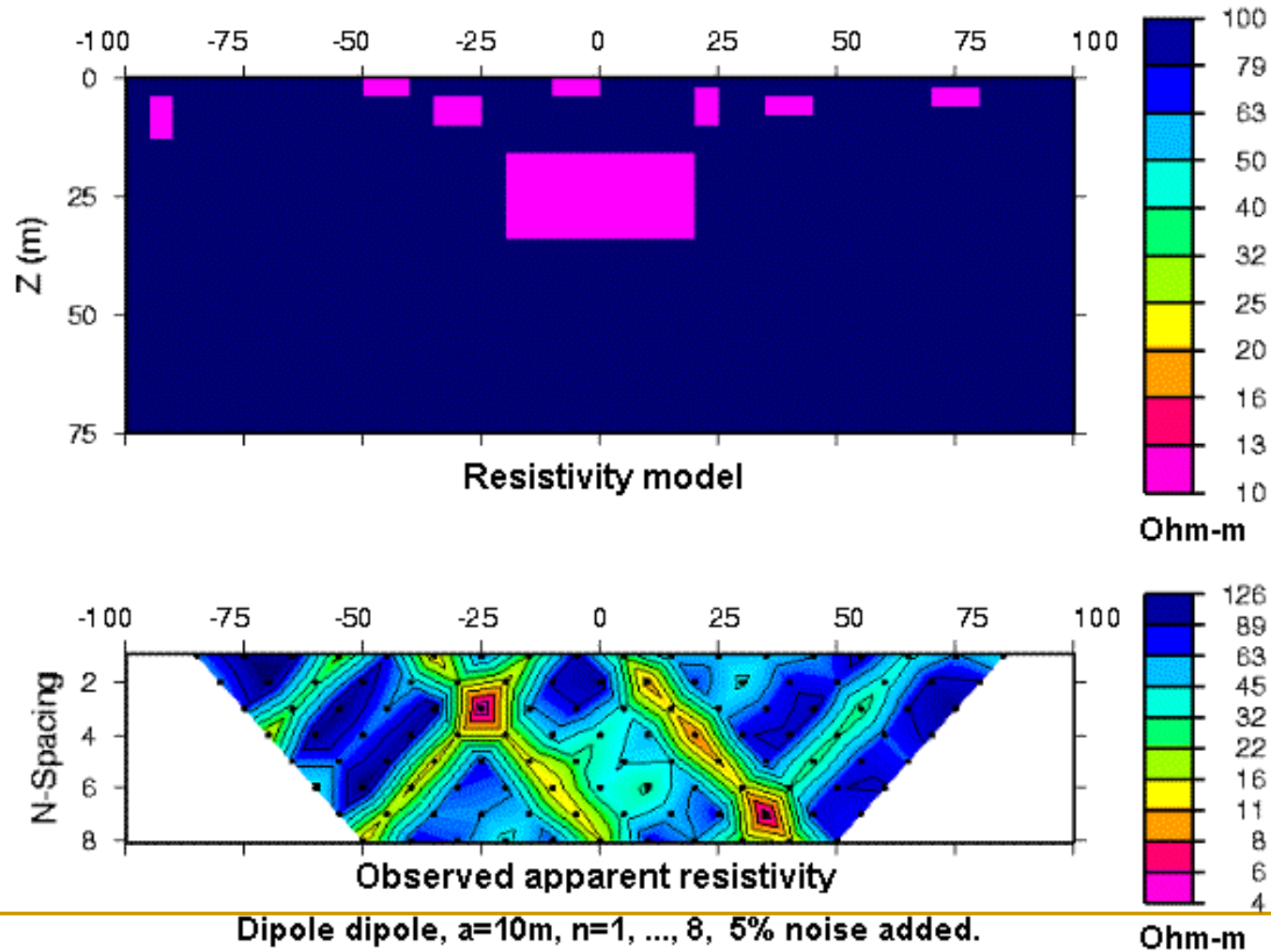
Example pseudosections

1) A single buried conductive block



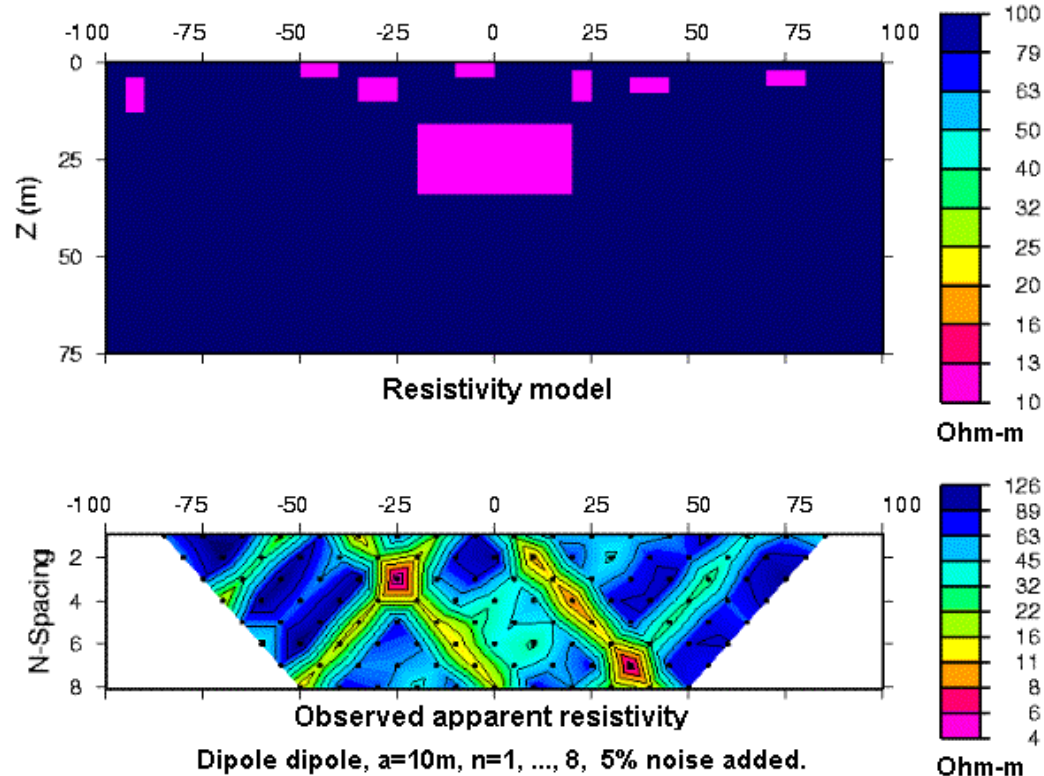
Example pseudosections

2) The conductive block with geologic noise.

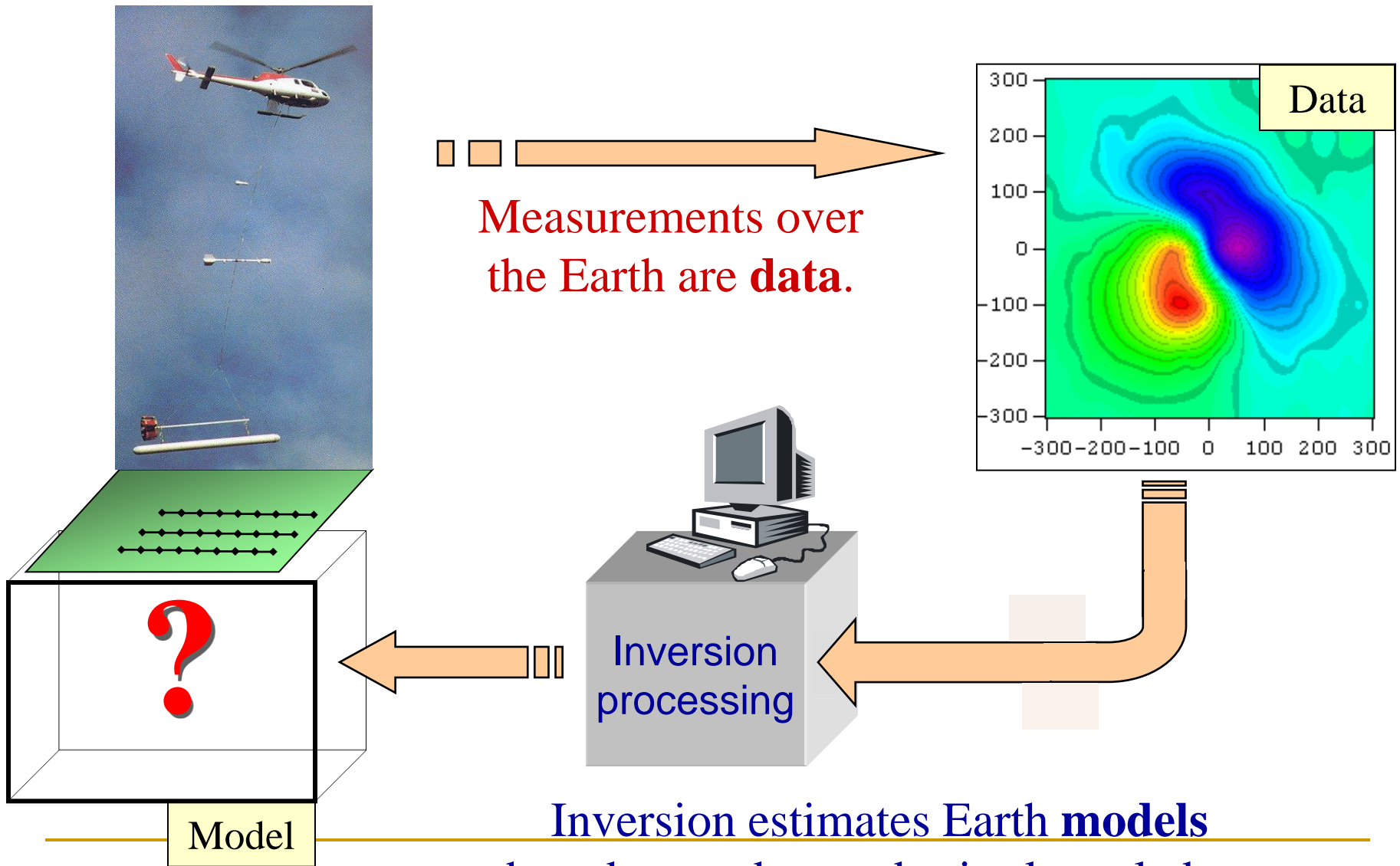


Pseudosections can rarely be interpreted geologically

- Remember each point in the pseudosection is the result of charges distributed in a volume
- It is now common to invert these data



What is Inversion?

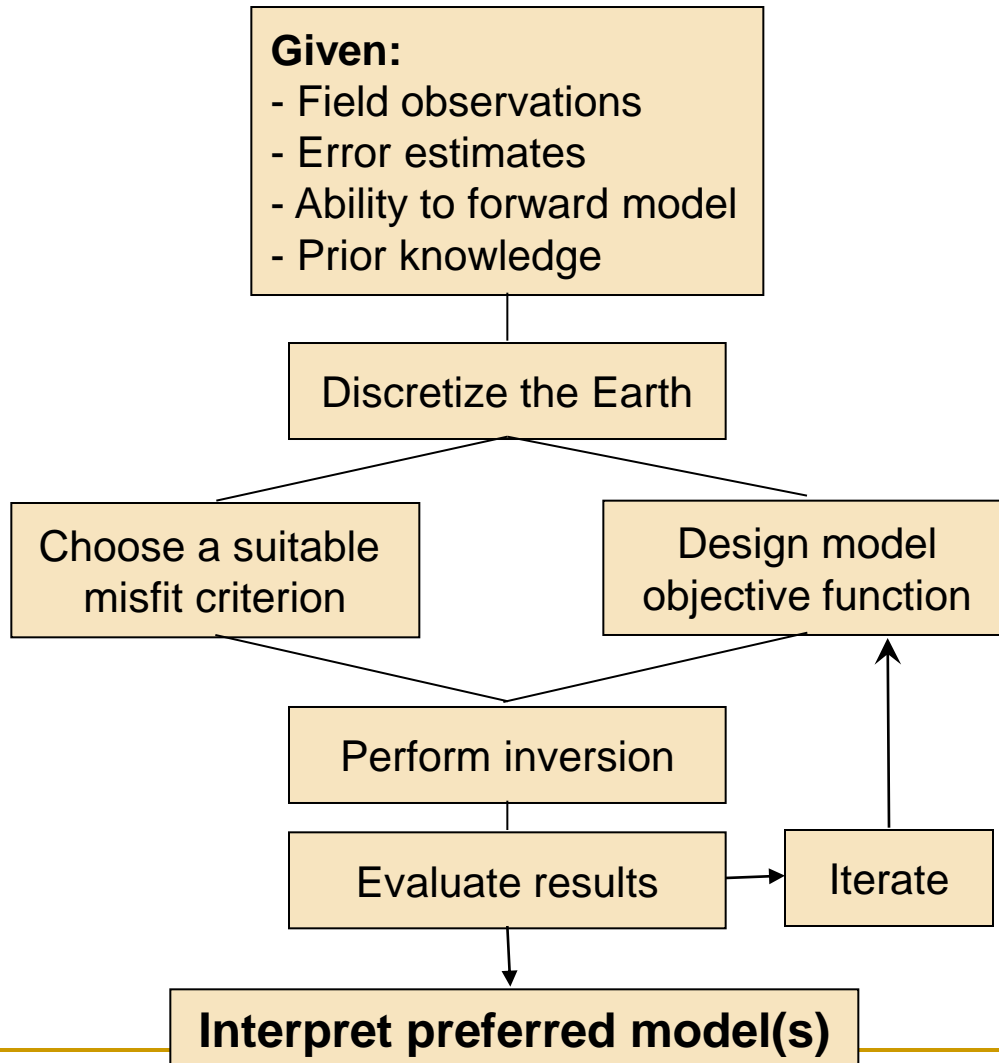


Measurements over the Earth are **data**.

Inversion estimates Earth **models** based upon data and prior knowledge.



Summary: what is needed to invert a data set?



$$\phi_m = \alpha_s \int (m - m_0)^2 dx$$

$$+ \alpha_x \int \left(\frac{d}{dx} (m - m_0) \right)^2 dx$$

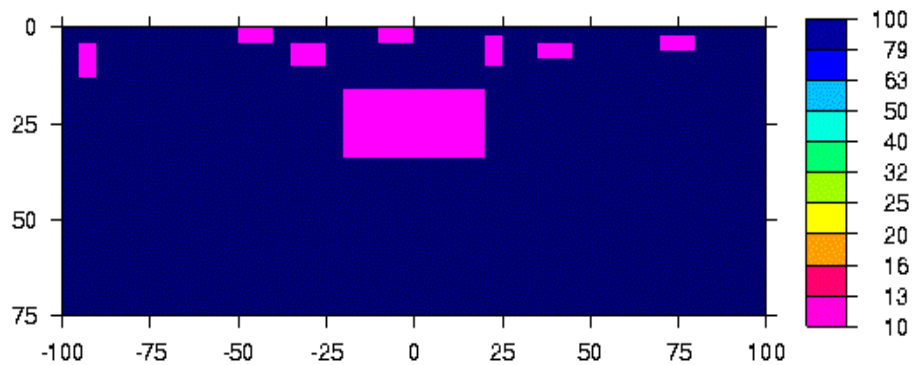
$$+ \alpha_z \int \left(\frac{d}{dz} (m - m_0) \right)^2 dz$$



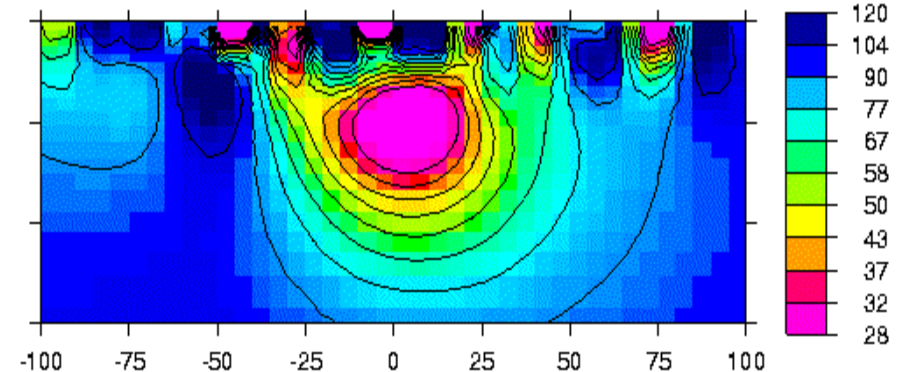
Example 2: prism with geologic noise.

- Pole-dipole; $n=1,8$; $a=10\text{m}$; $N=316$; $(\alpha_s, \alpha_x, \alpha_z)=(.001, 1.0, 1.0)$

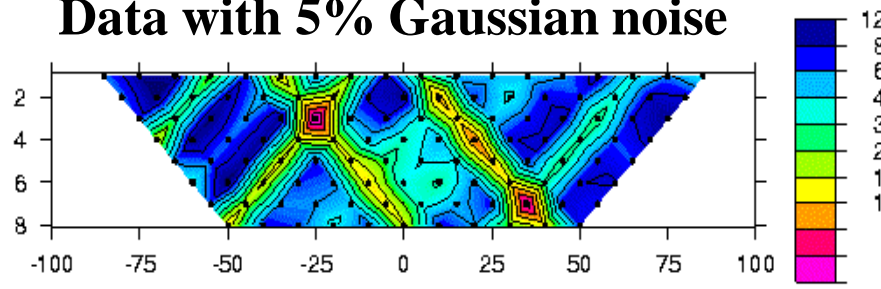
Resistivity model



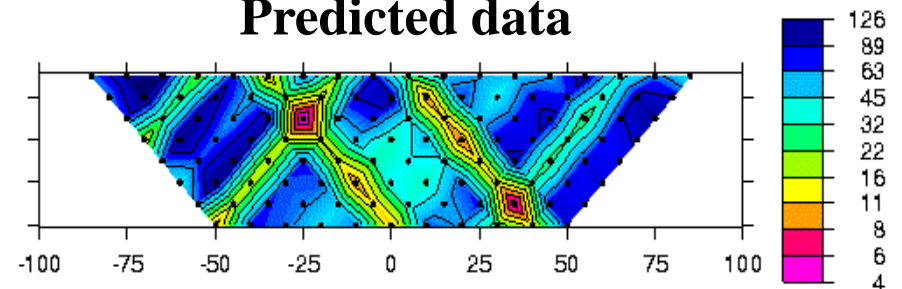
Recovered resistivity



Data with 5% Gaussian noise



Predicted data

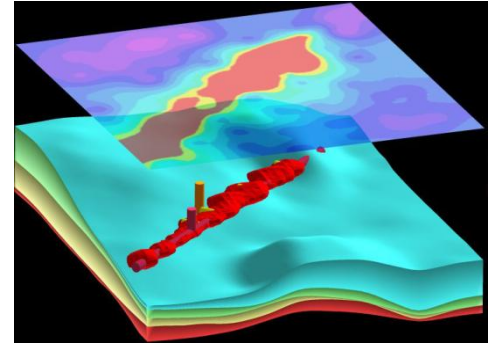


Most Geology is 3D

- Host



- Orebody



- Topography

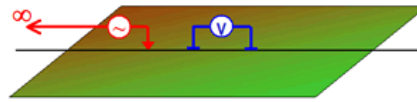


Solve the inverse problem in 3D



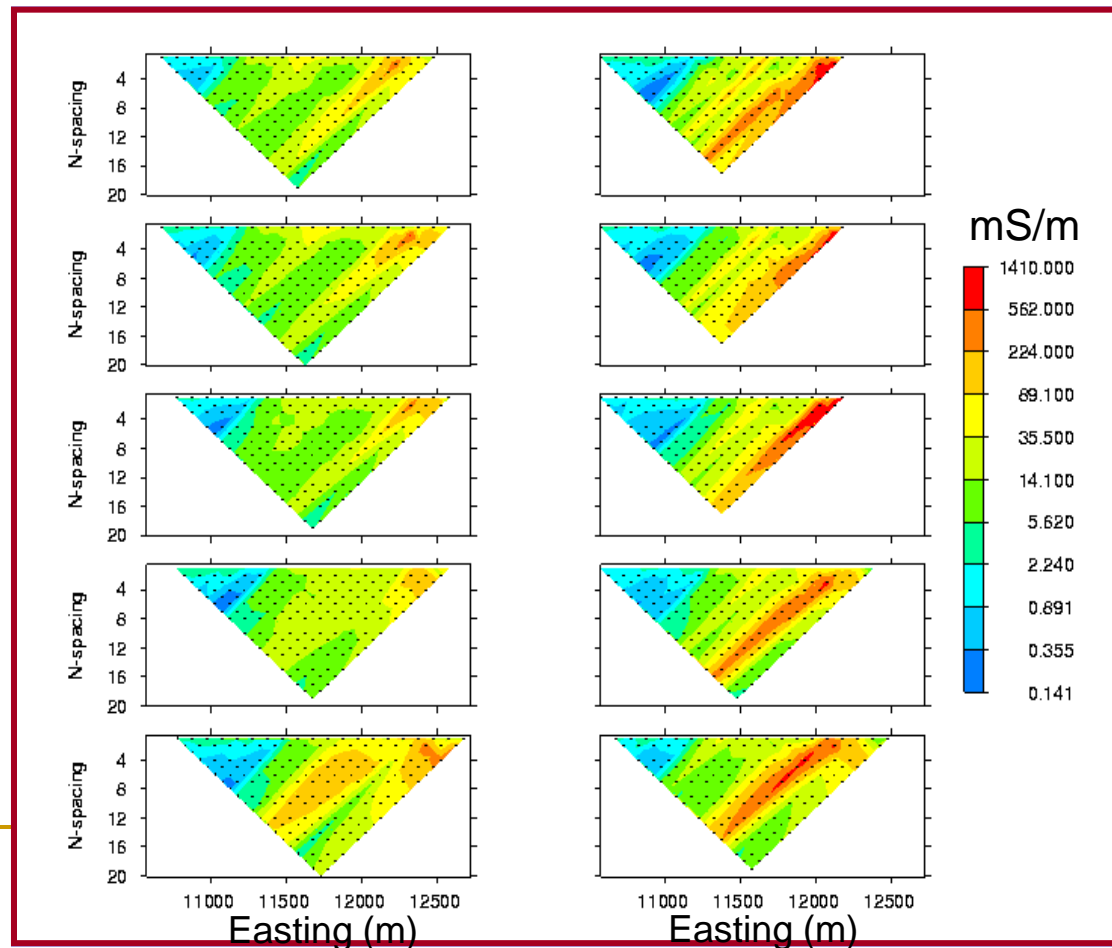
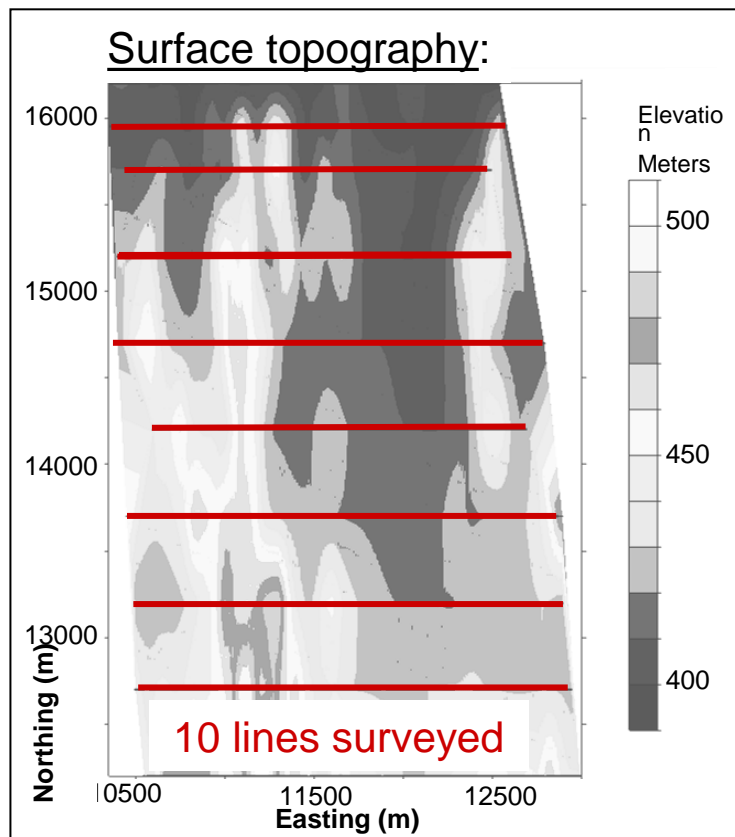
Cluny: 3D resistivity

- Eight survey lines
- Two survey configurations.

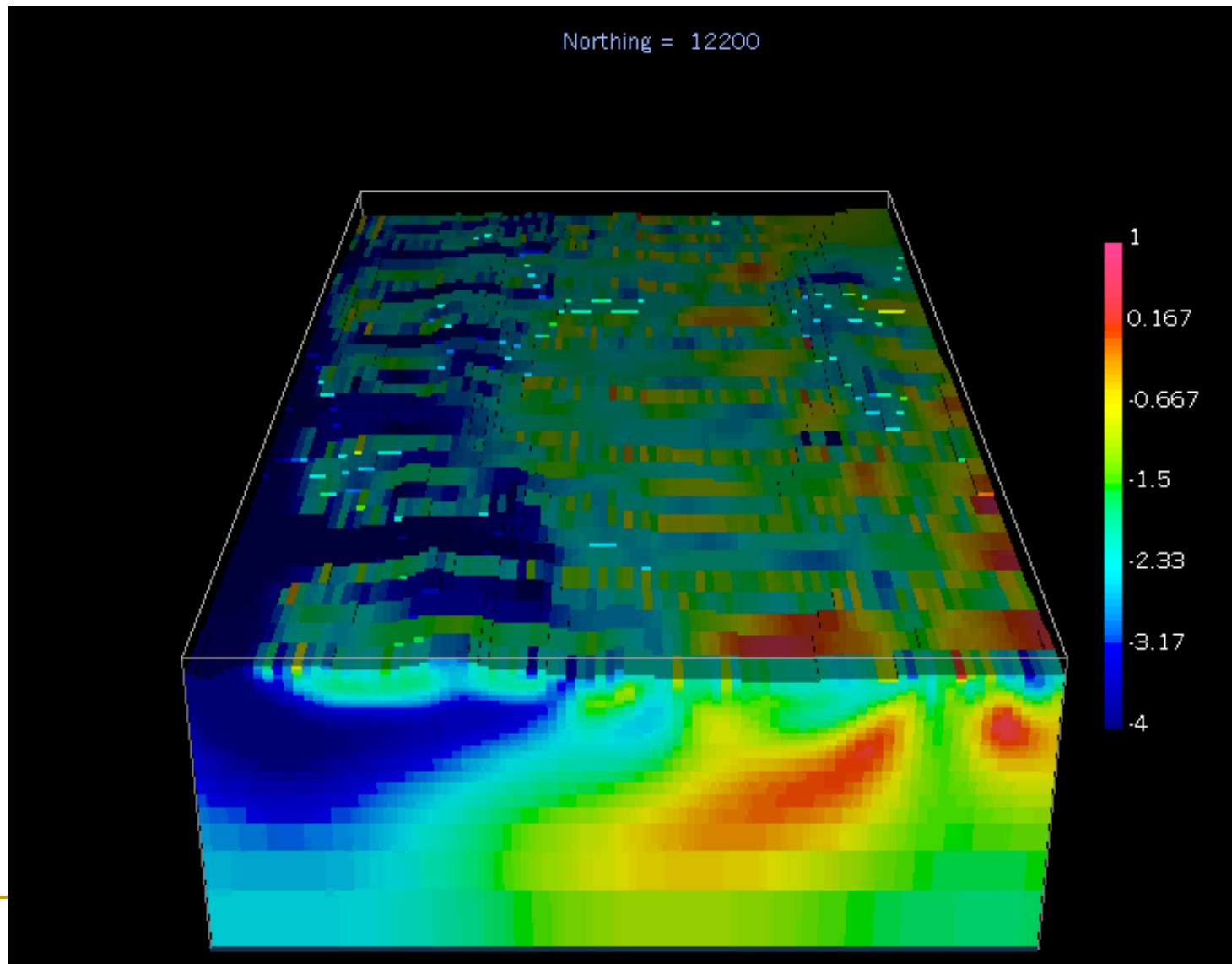


Data set #2:

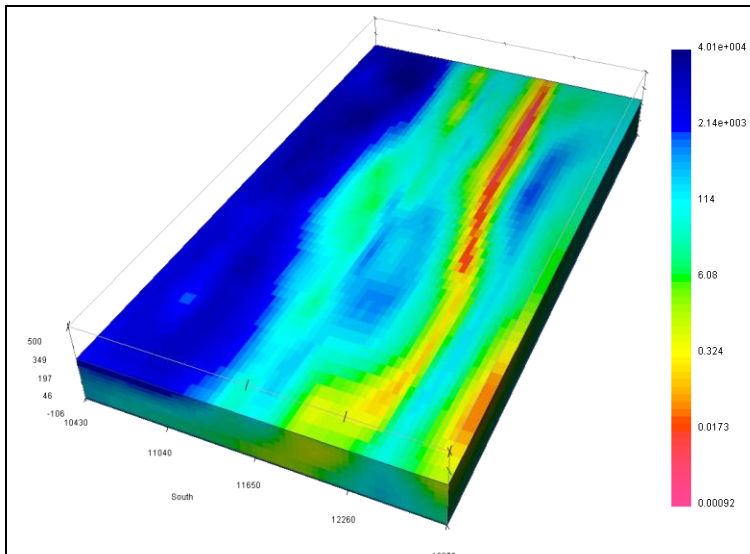
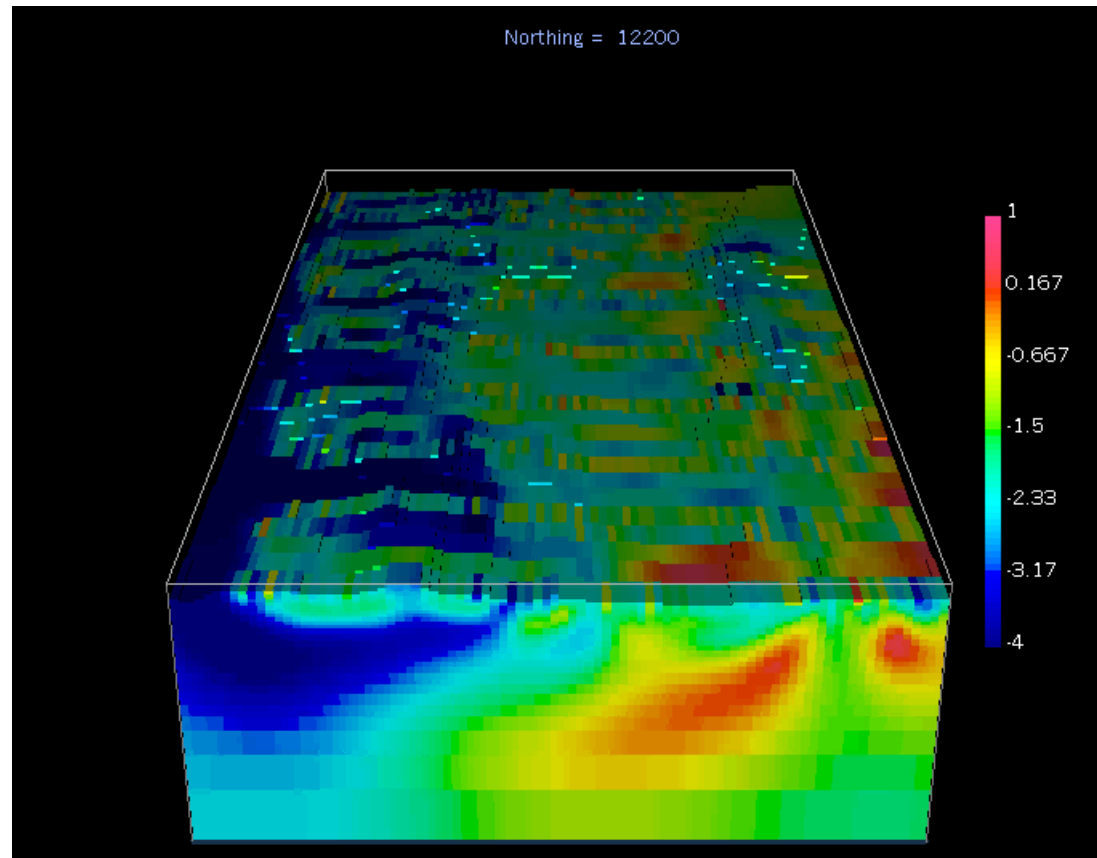
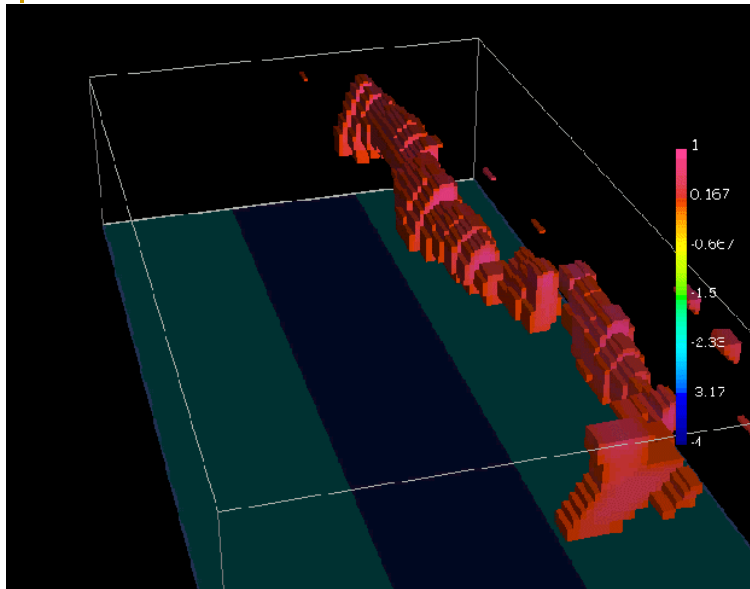
Apparent resistivity,
pole - dipole.



Conductivity model from 3D inversion of DC



Conductivity model from 3D inversion of DC





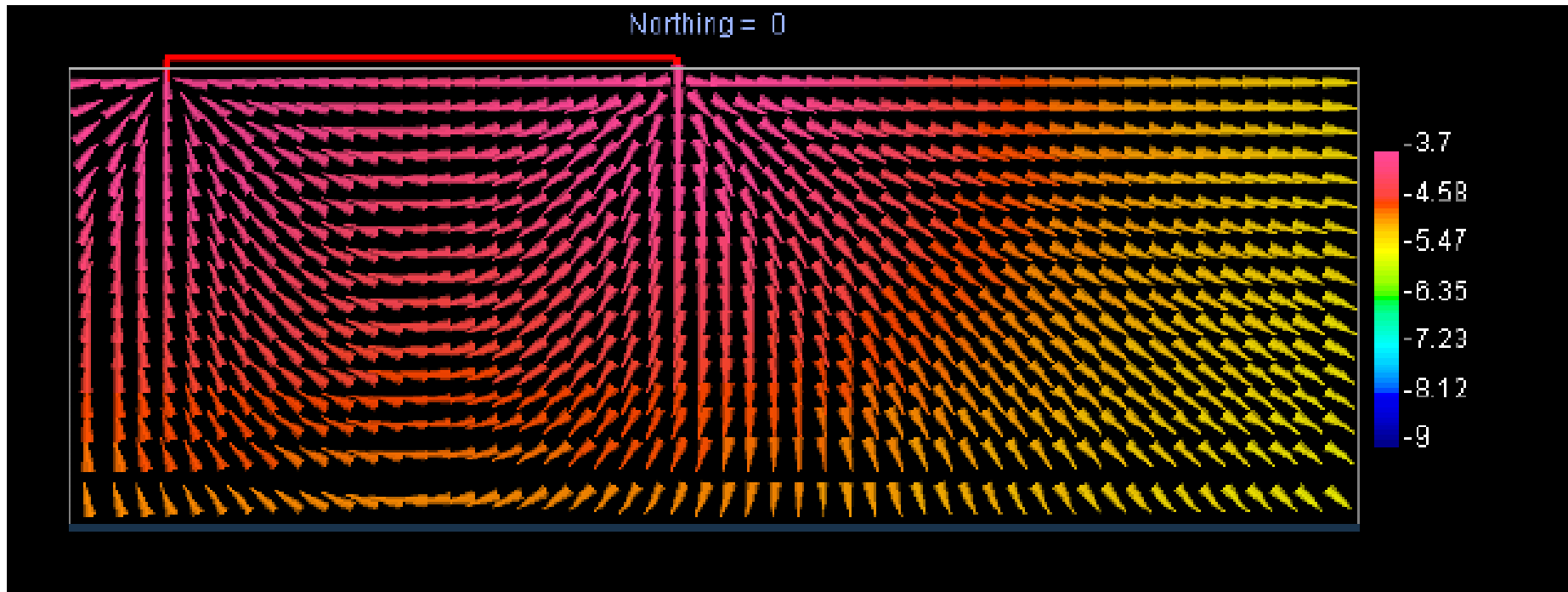
- Currents and charges in a DC resistivity survey

Numerical simulation of currents

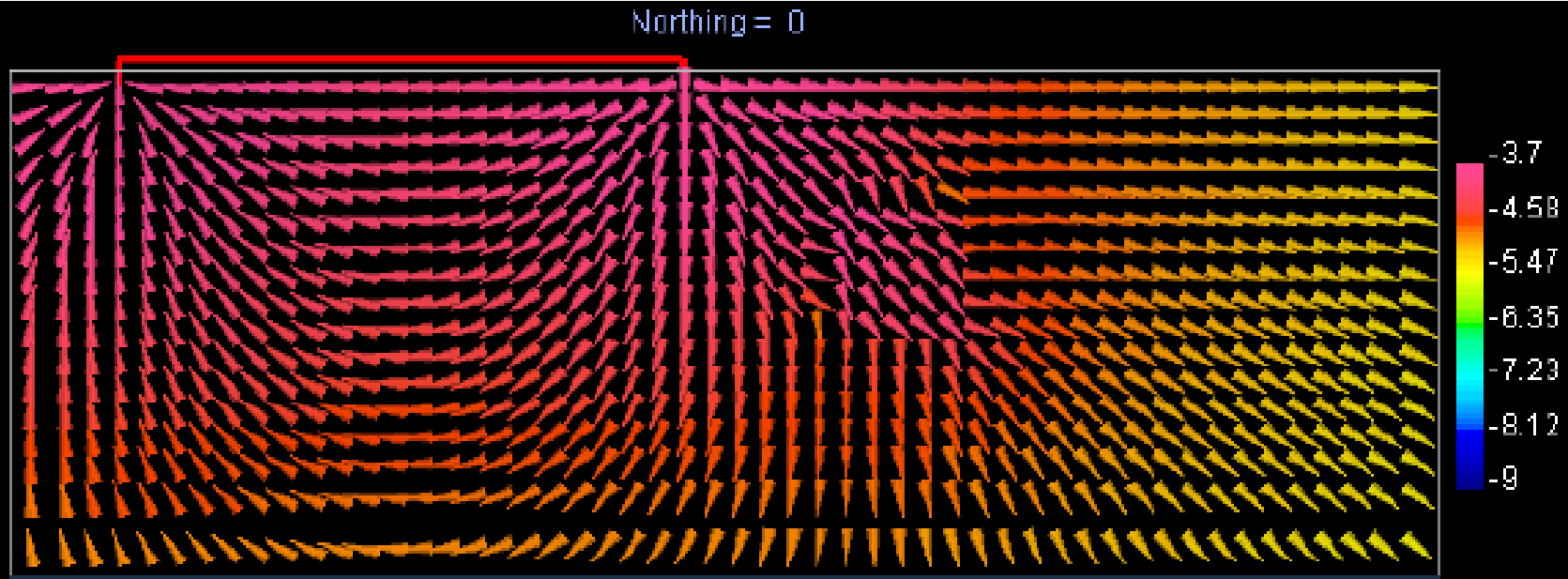
- Primary currents (uniform earth)
- Total currents
- Secondary currents (associated with a buried conductor)



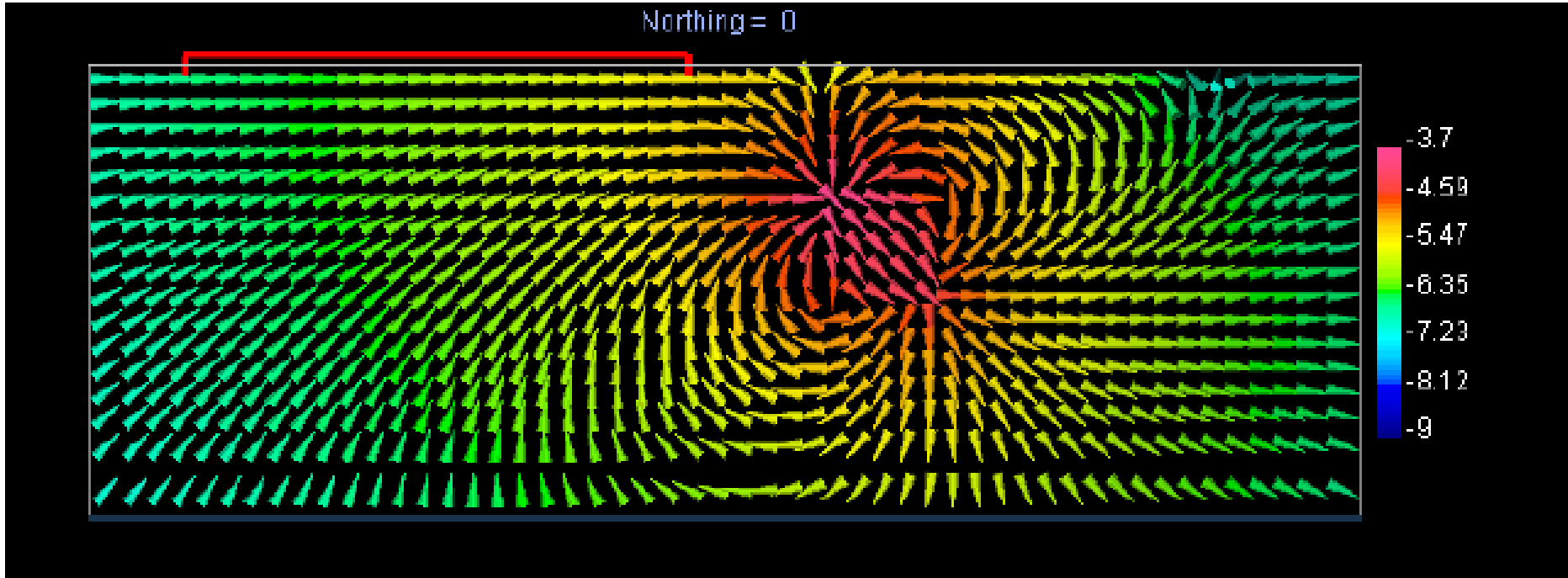
J Primary (uniform earth)



J Total (earth with conductive block)



$$J_{\text{Secondary}} = J_{\text{(Total)}} - J_{\text{(Primary)}}$$

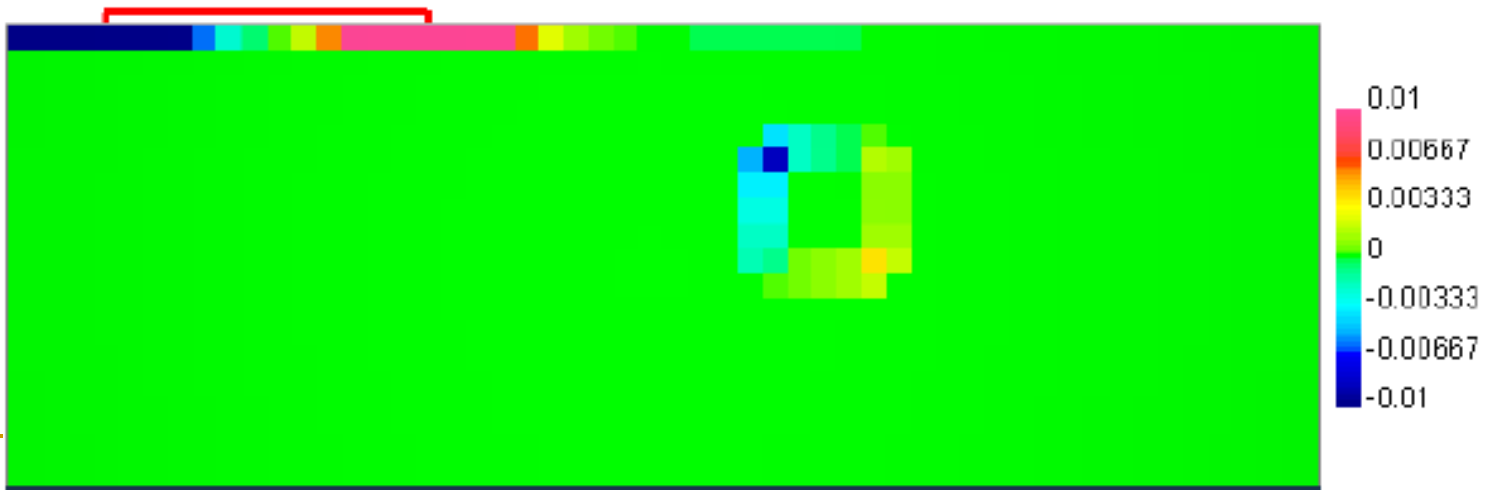
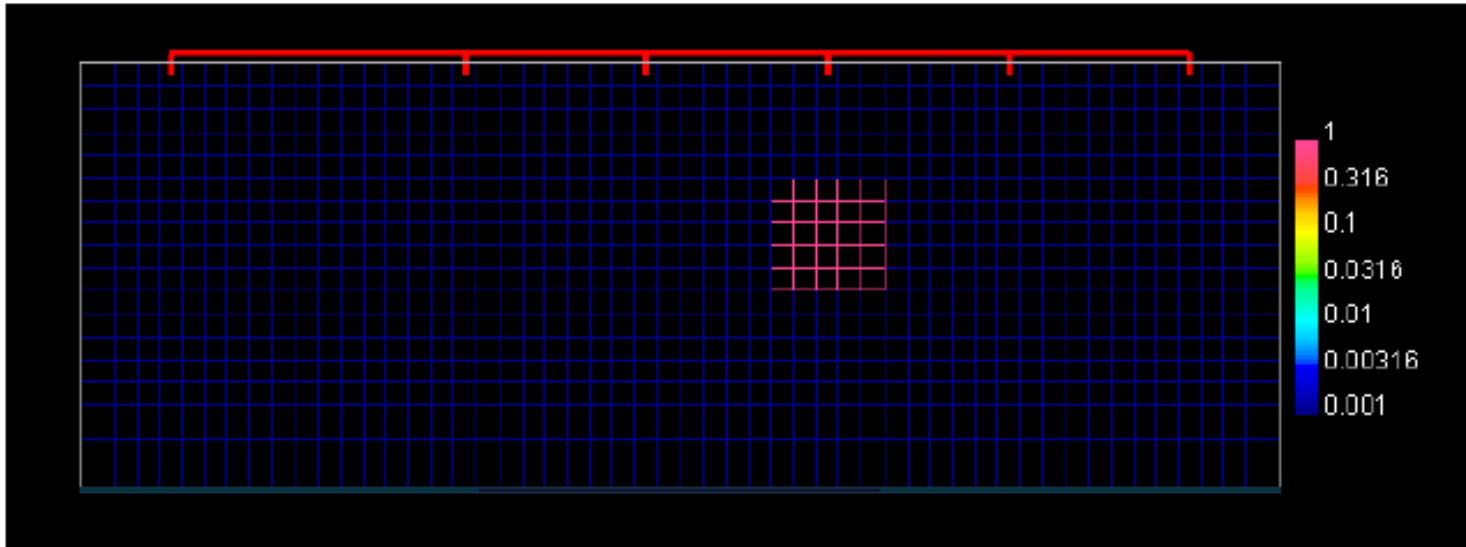


Visualizing the “illumination” of the target

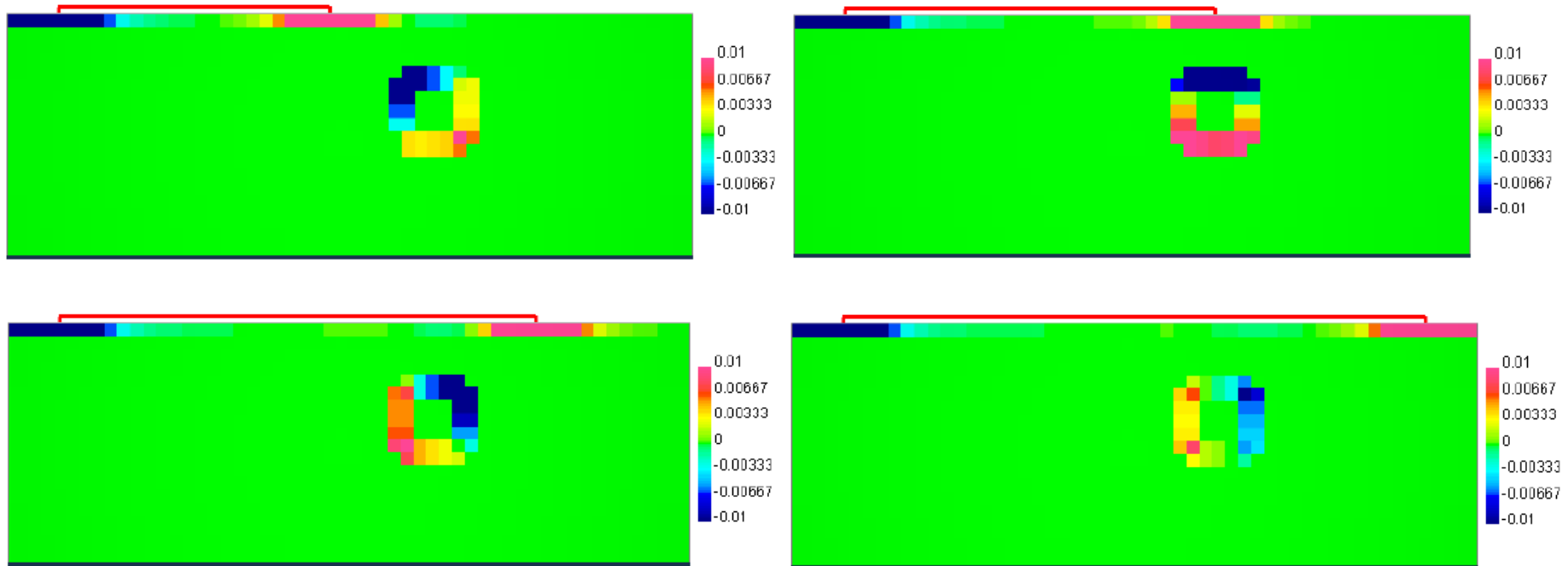
- Conductive prism
- Currents in the prism depend upon the transmitter location
- Electric charges are set up so that normal component of current is continuous across a boundary
- Next slides show how the electric charges, and hence measured data, are related to the transmitter location.



Effects of source location



Effects of source location



Data depend upon

- (a) Coupling (Transmitter and target)
- (b) Location and orientation of receiver

