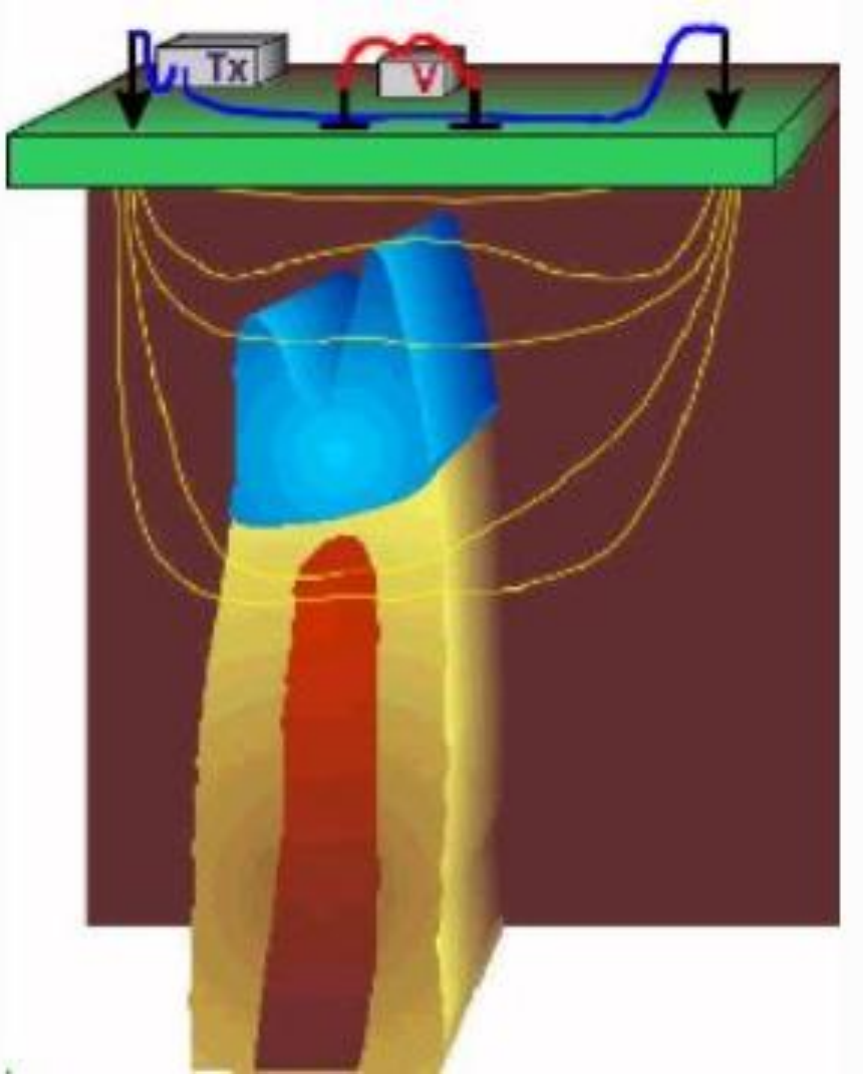
From Last Time

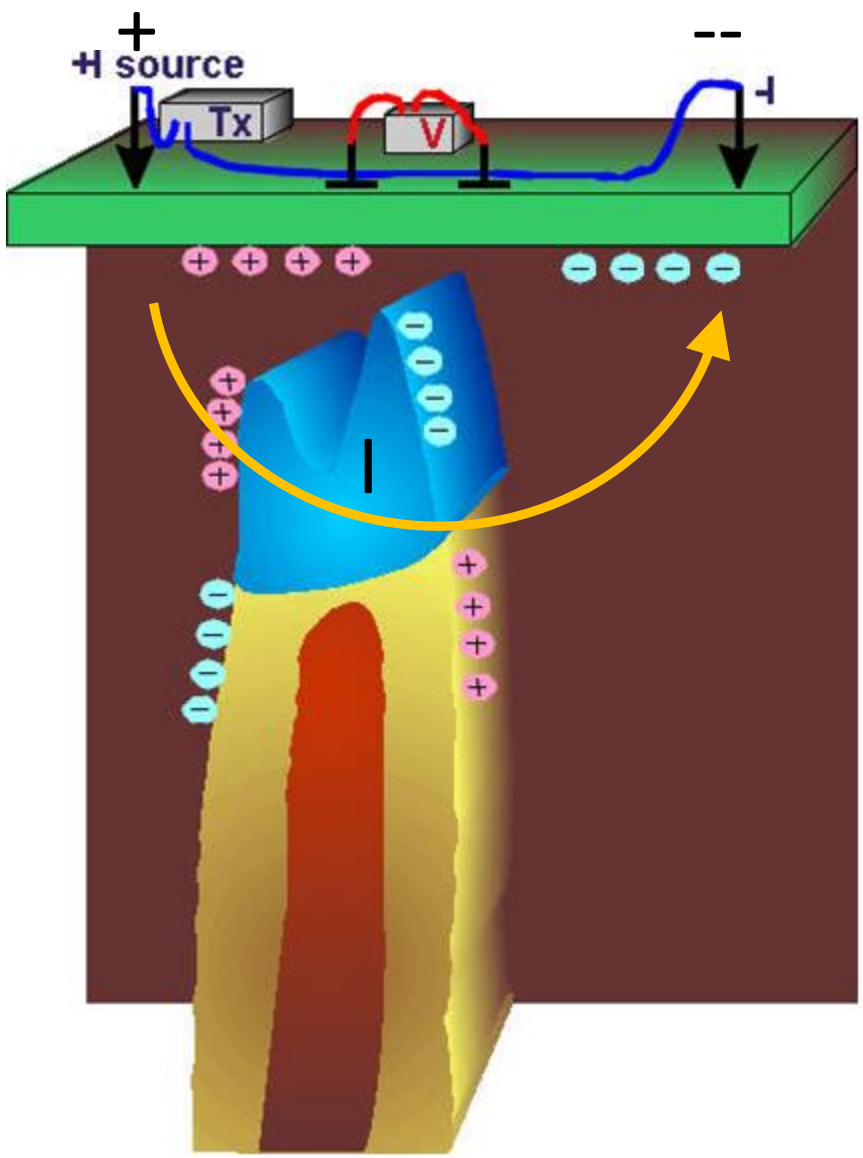
- Current converges on conductors and diverges at resistors
- More current flows deeper if current electrodes are more spaced



From Last Time

- Current converges on conductors and diverges at resistors
- More current flows deeper if current electrodes are more spaced
- Charges accumulate on boundaries normal to current flow

$$\left(\frac{1}{\sigma_2}-\frac{1}{\sigma_1}\right)\mathbf{J_n}=\left(\rho_2-\rho_1\right)\mathbf{J_n}=\frac{\tau}{\varepsilon_0}$$



From Last Time

- Current converges on conductors and diverges at resistors
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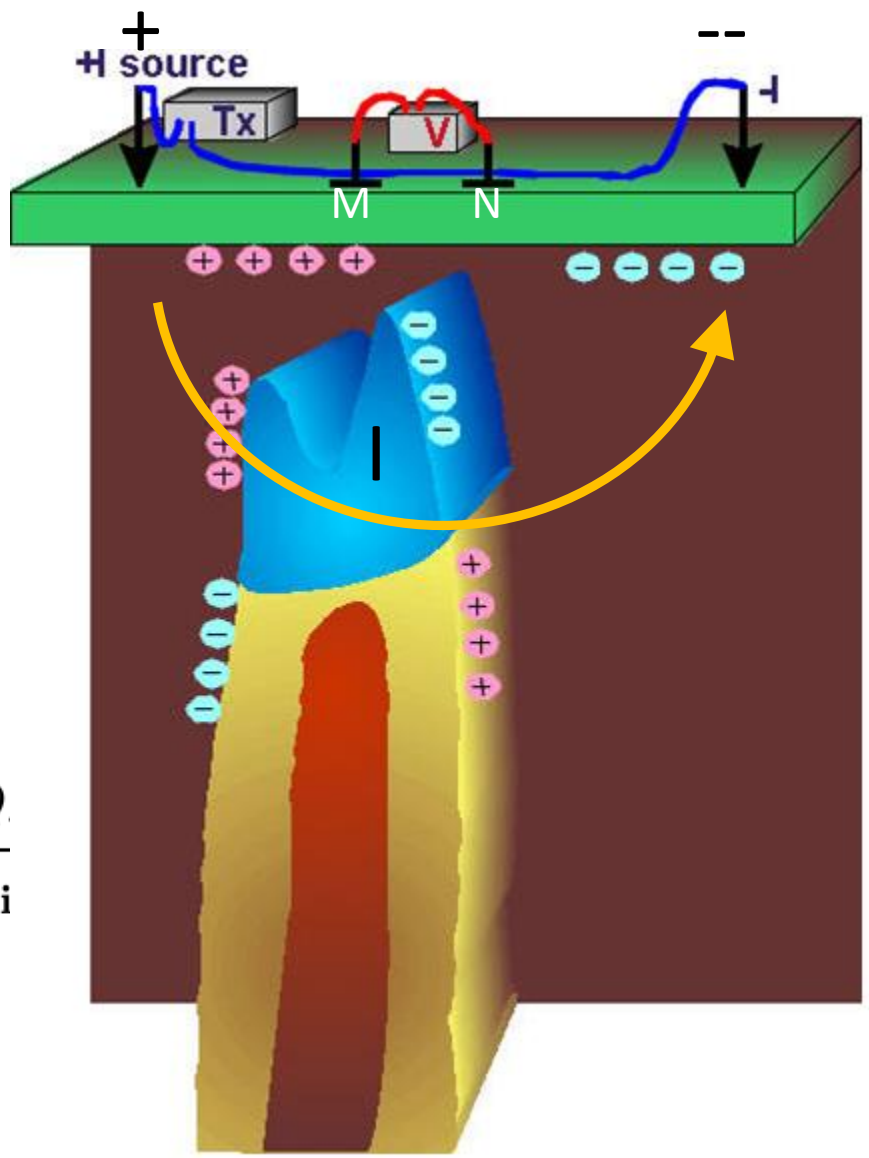
$$\left(\frac{1}{\sigma_2}-\frac{1}{\sigma_1}\right)\mathbf{J_n}=\left(\rho_2-\rho_1\right)\mathbf{J_n}=\frac{\tau}{\varepsilon_0}$$

- Accumulation of charges changes the secondary potential

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

- Differences in potential measured by potential electrodes

$$\Delta\mathbf{V}=\mathbf{V_N}-\mathbf{V_M}$$



Today's Topics

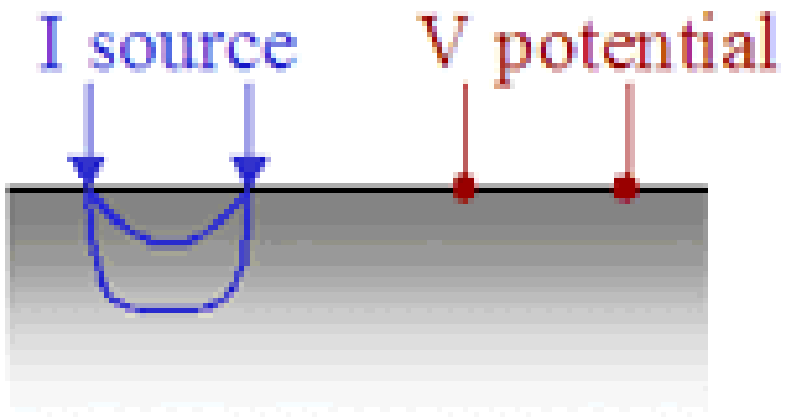
- Survey
  - Source and receiver
  - Survey configurations
  - Sounding measurements
  - Profiling measurements

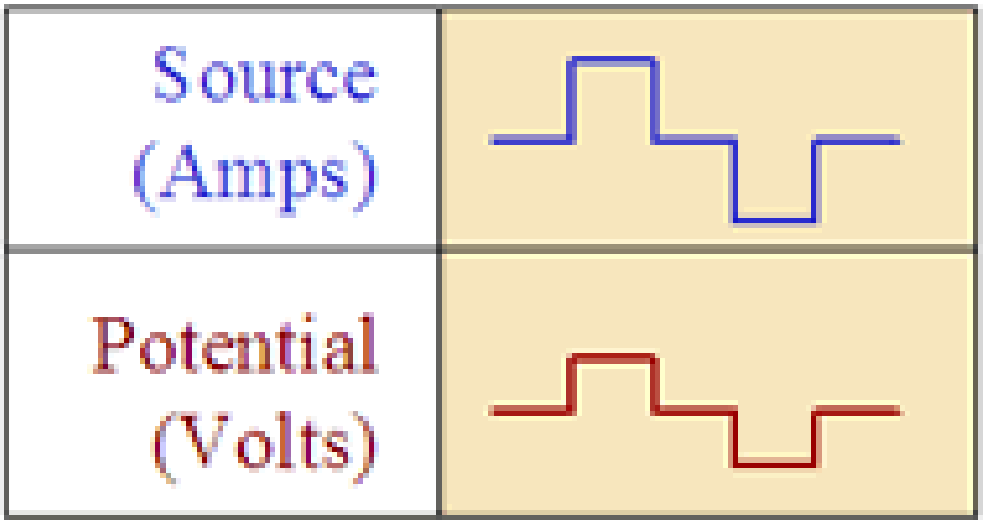
- Data
  - Raw data and apparent resistivity data
  - Pseudo-sections

Survey

Survey (Source and Receiver)

- Alternating square waveform used for current source (T=2s)
- Potential electrodes measure during the on-time
- Many repetitions averaged to reduce noise

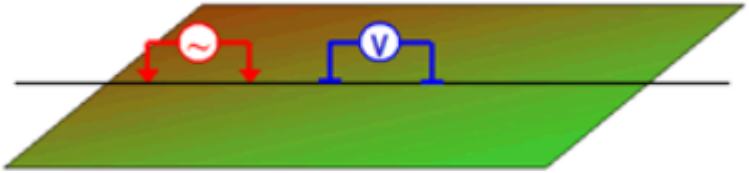




Survey Configurations

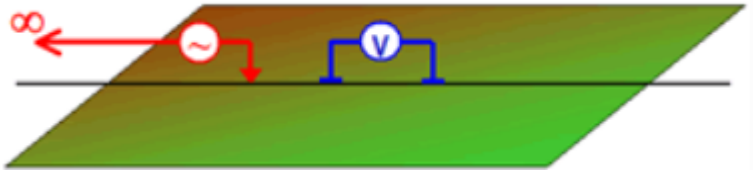
- Various electrode configurations exist
- Some configurations used for specific applications
- 3 main types:

Dipole-Dipole



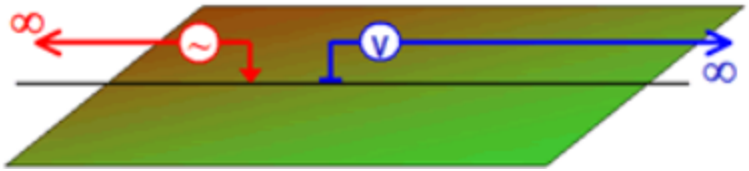
- Most common
- Multiple V measurements per Tx location

Pole-Dipole



- More efficient than dpdp
- Deeper penetration
- Lower resolution

Pole-Pole

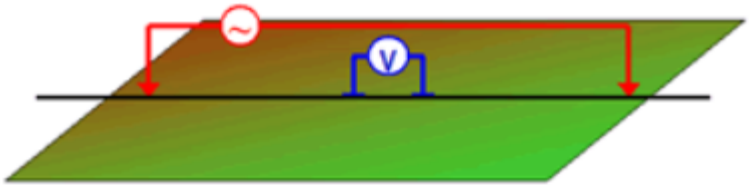


- Most efficient
- Deepest penetration
- Lowest resolution

Survey Configurations

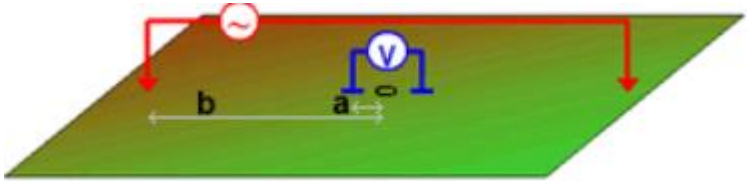
- Some configurations use specific dimensions

Real Section



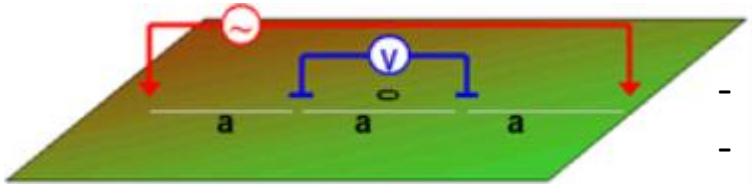
- Measurements in between current electrodes

Schlumberger



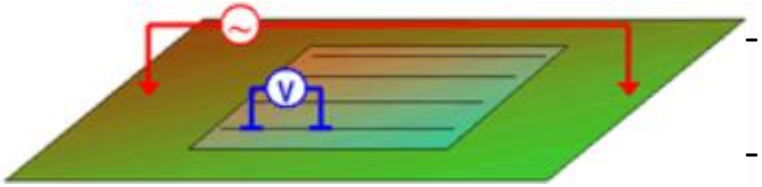
- a<<b

Wenner Sounding



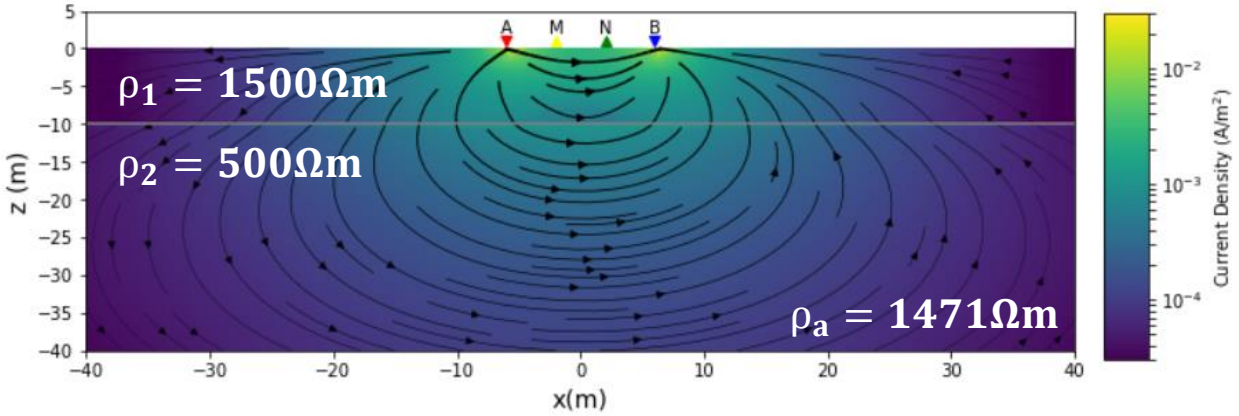
- Dimensions fixed
- Moved every sounding

Gradient Array

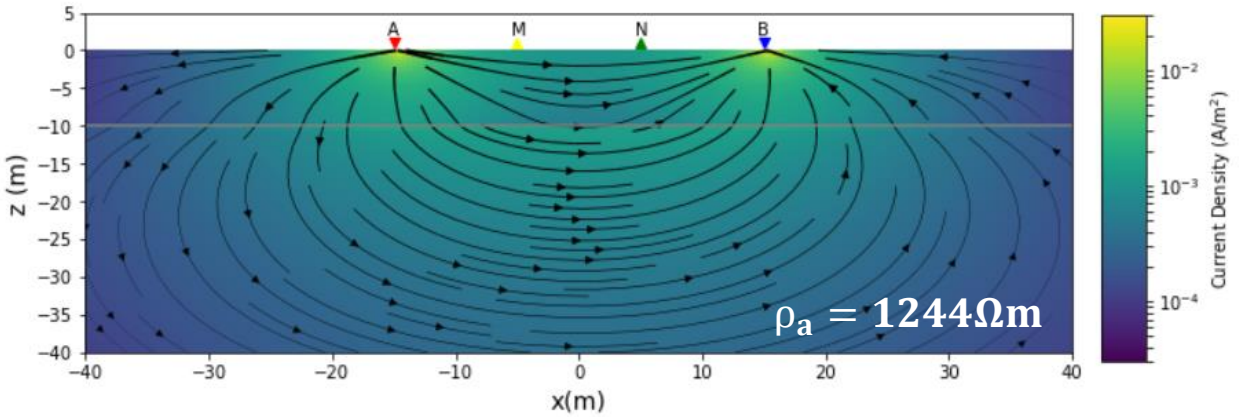


- Off-line measurements collected
- Poor depth
- Rapid acquisition of large areas

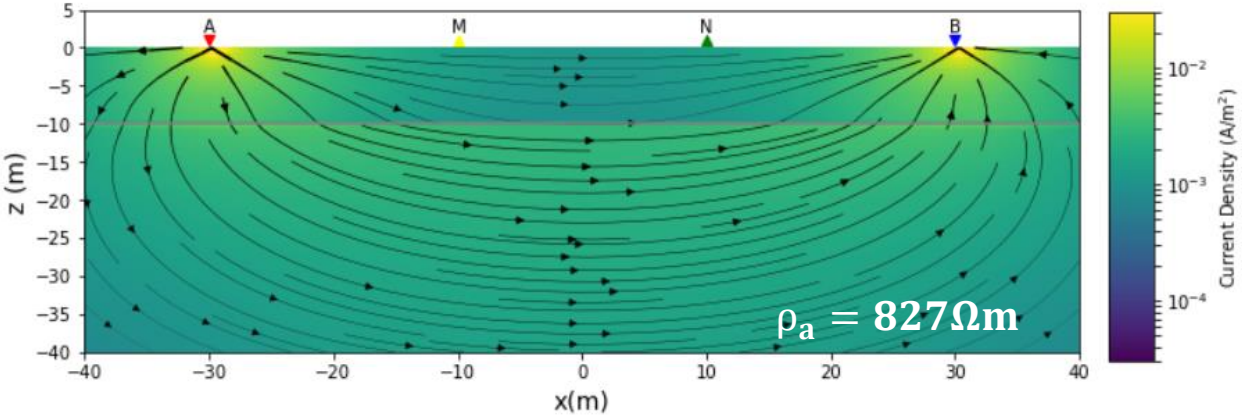
Sounding: Layered Earth



- Most currents near electrodes
- Only sees top layer

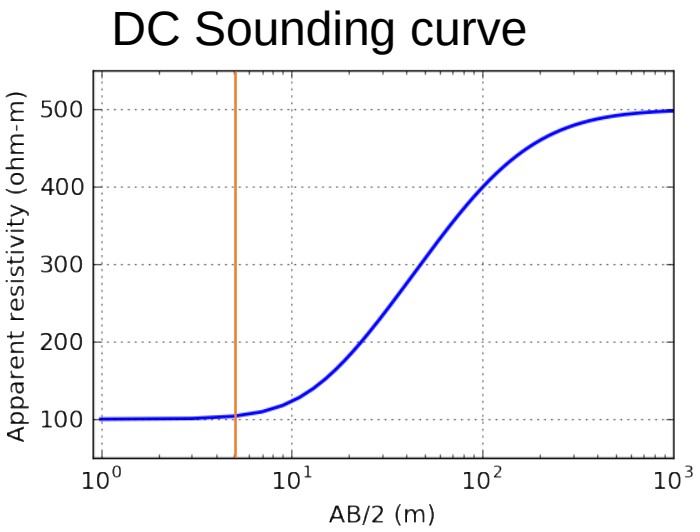


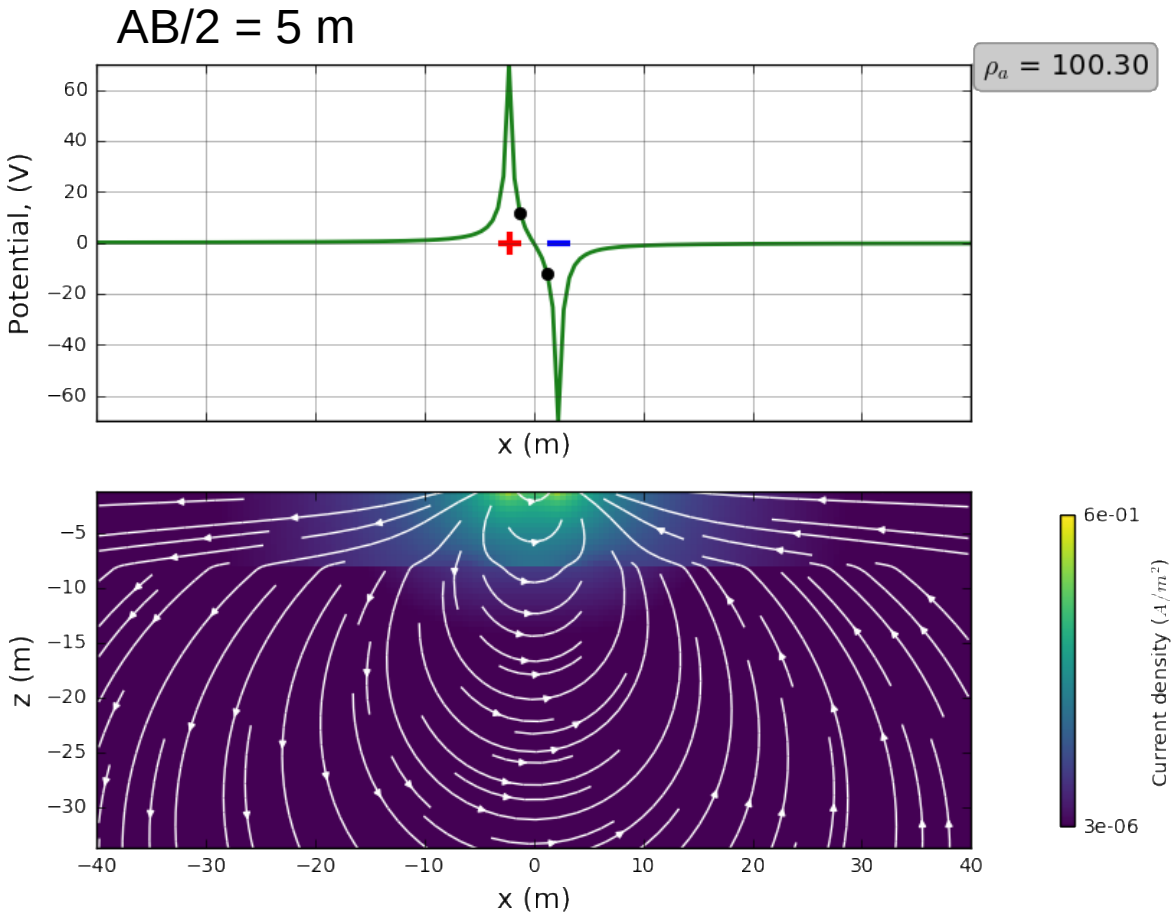
- Currents in lower layer
- Lower apparent resistivity



- Apparent resistivity sensitive to lower layer

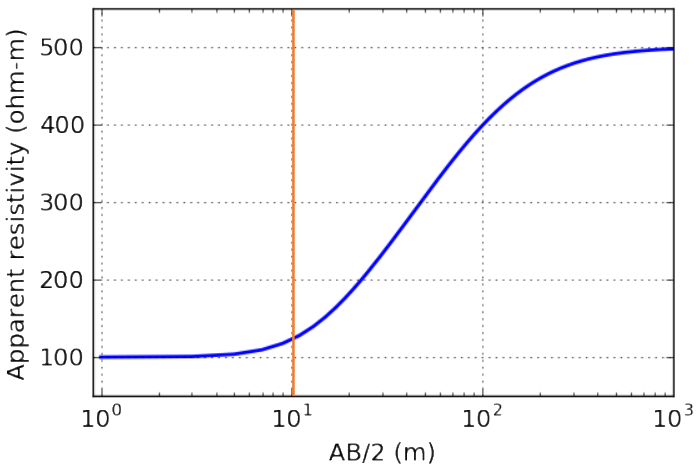
Sounding Measurements



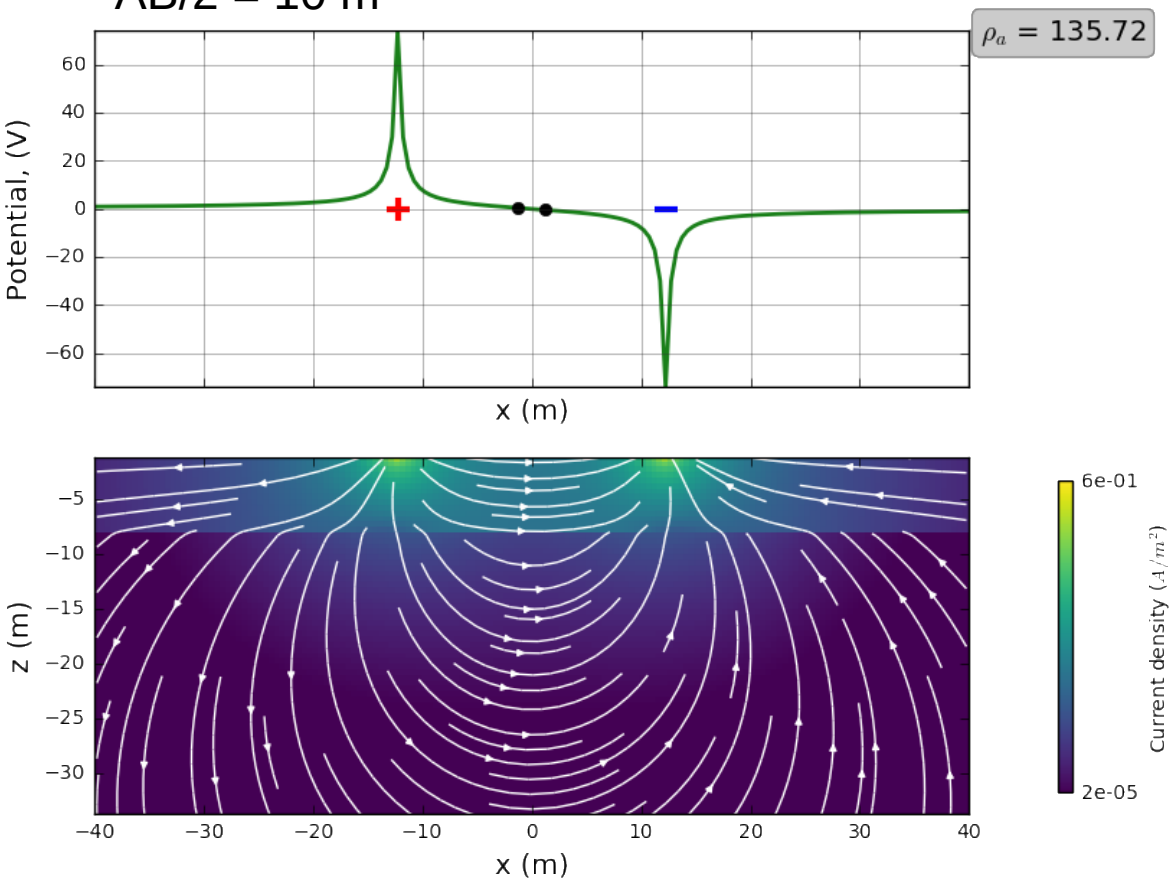


Sounding Measurements

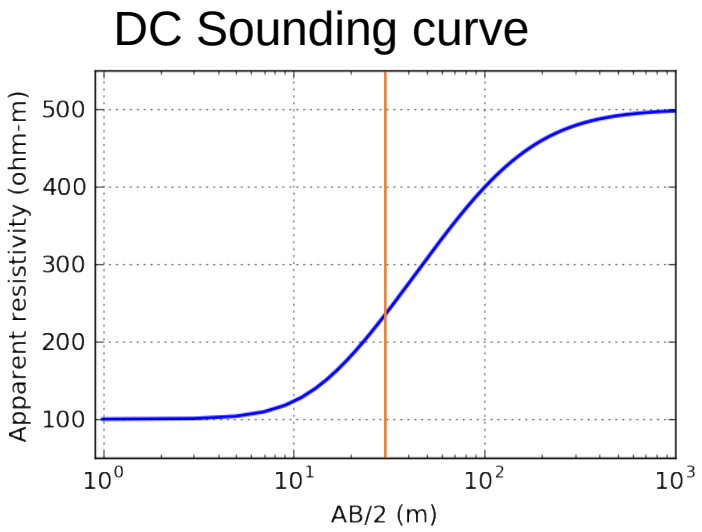
DC Sounding curve

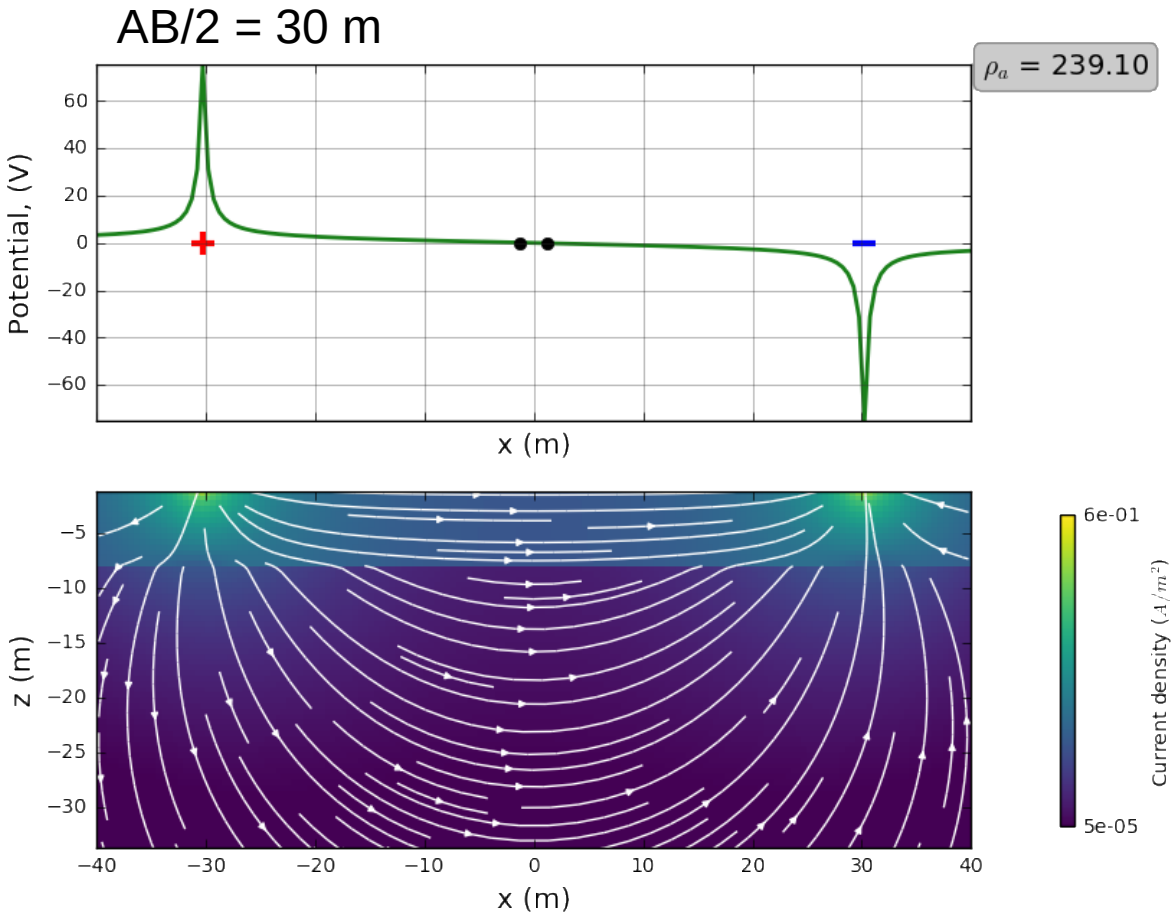


AB/2 = 10 m



Sounding Measurements

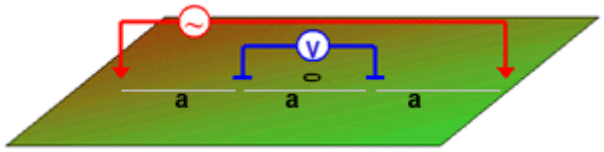




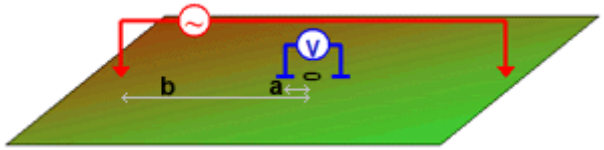
Sounding Measurements and Arrays

Geometry

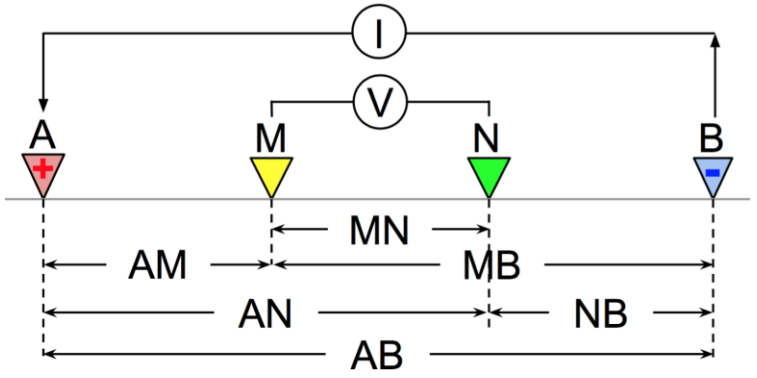
Wenner



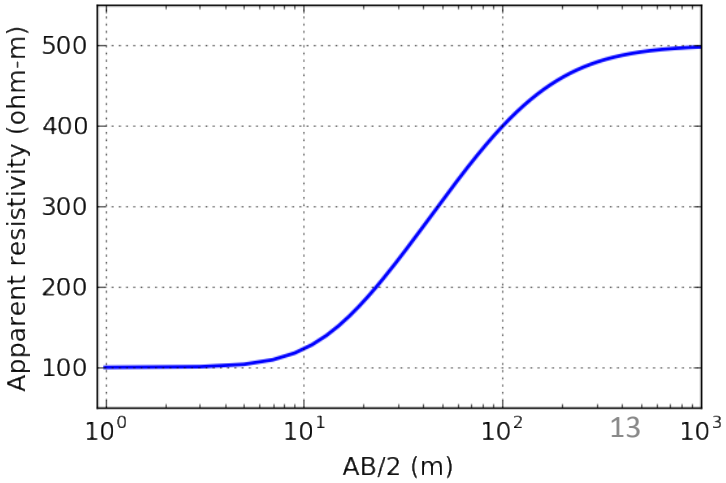
Schlumberger



4 electrode Array

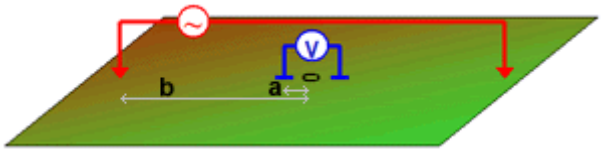


Sounding

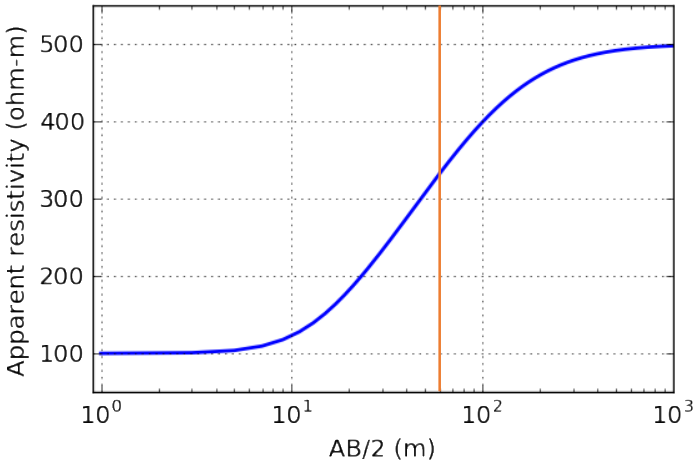


Sounding: Summary

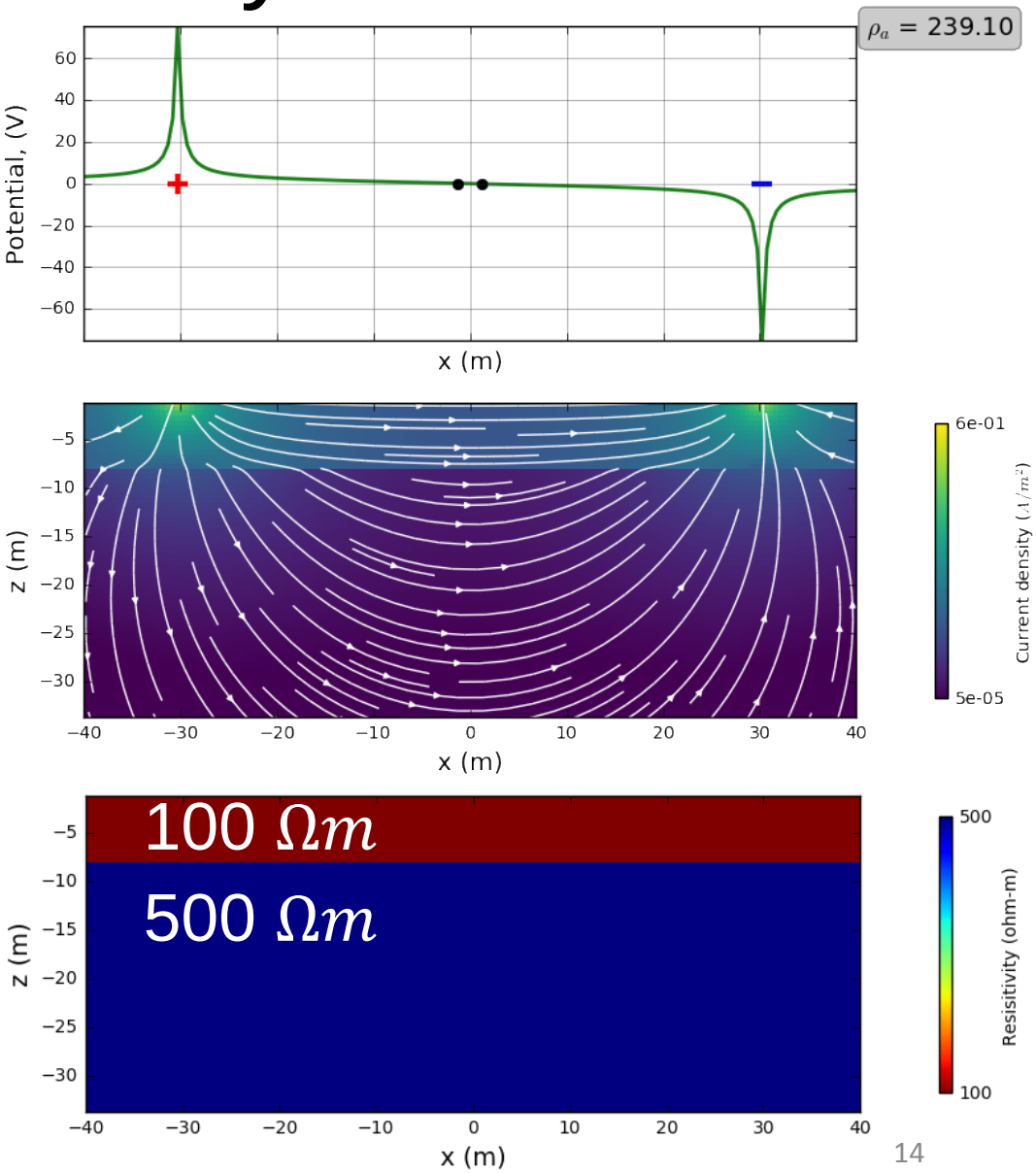
Schlumberger array



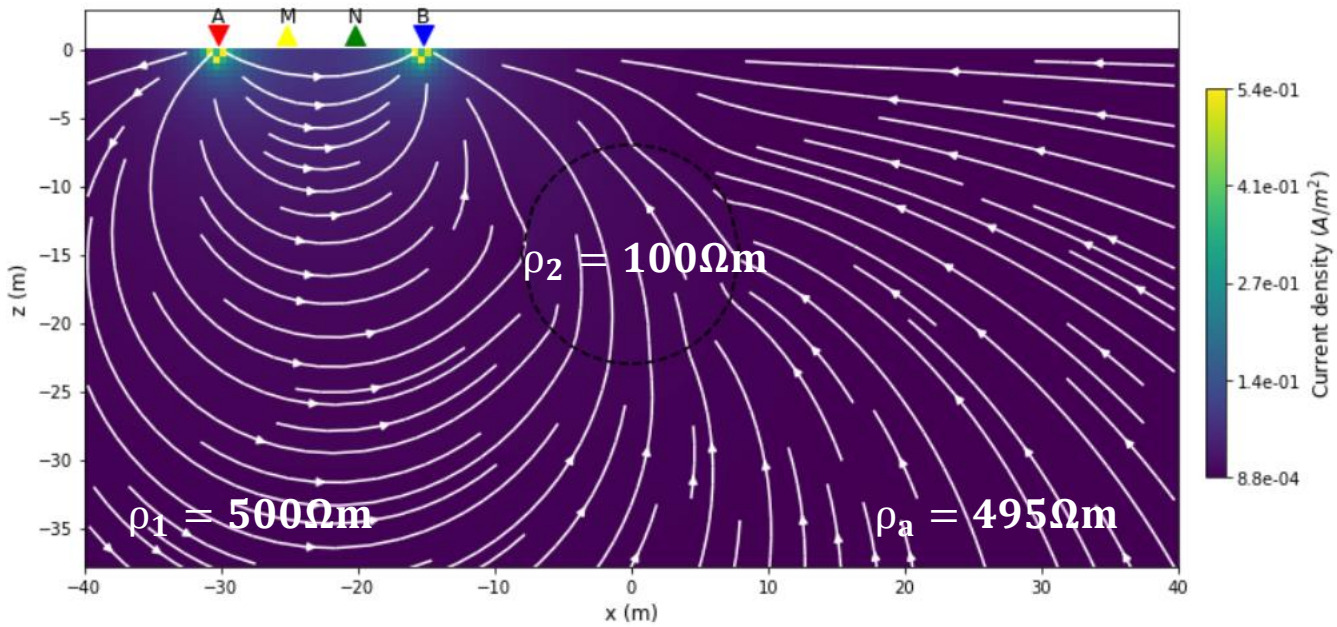
DC **Sounding** curve



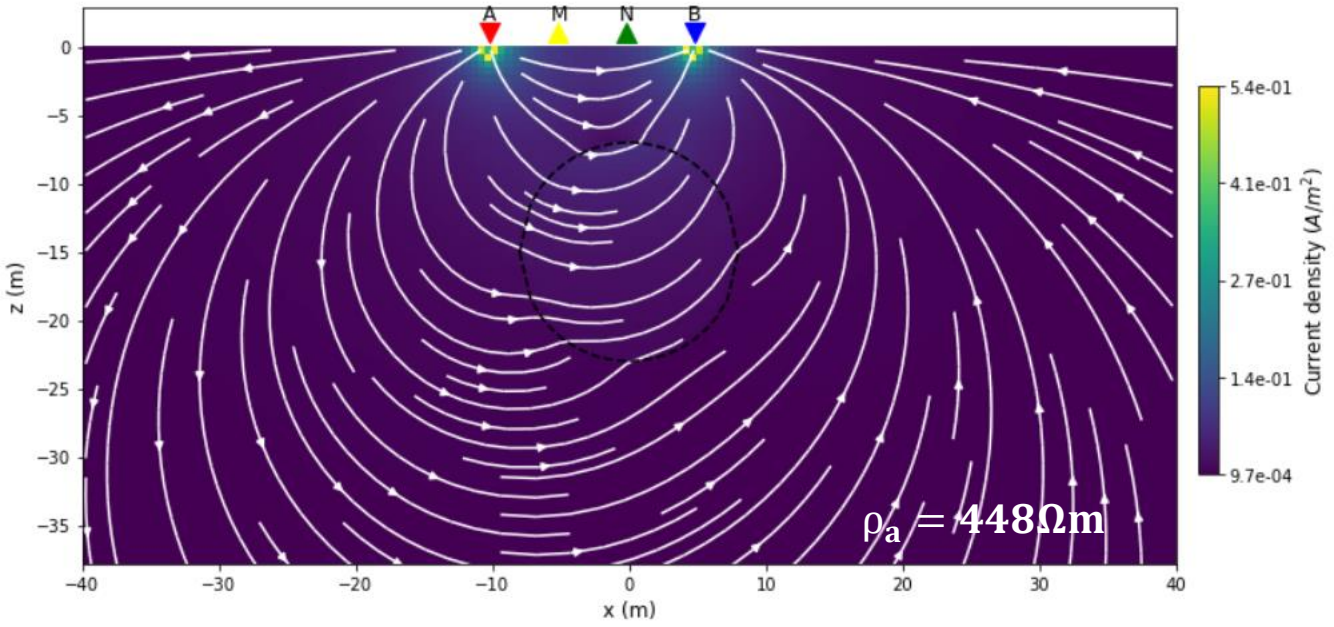
Scale length of array must be large to see deep



Profiling: Buried Conductor



- Most currents near electrodes
- Sphere has negligible impact on apparent resistivity



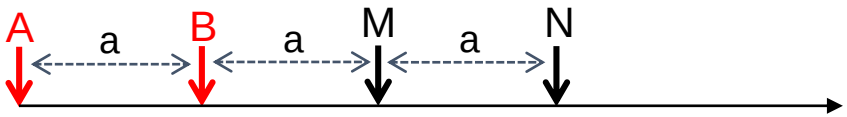
- Current affected by sphere
- Apparent resistivity shows buried conductor

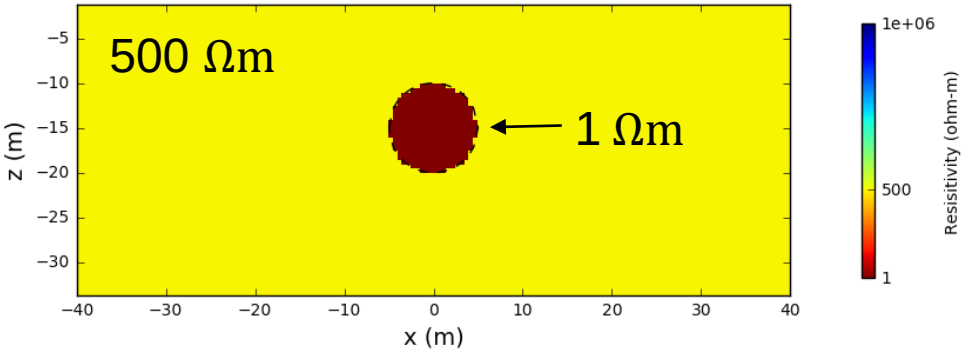
Profiling: Apparent Resistivity

Fixed geometry: Move laterally

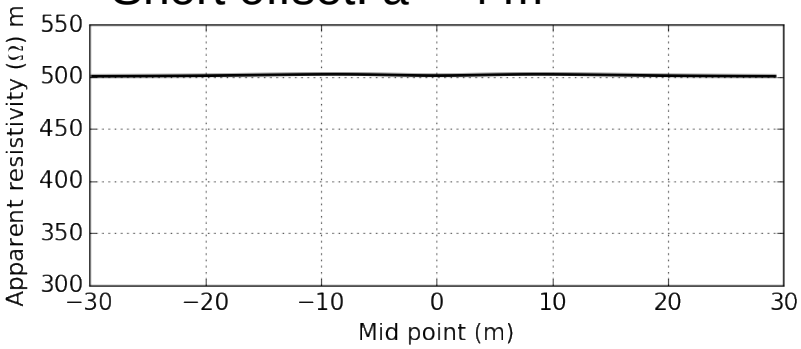
Short offset, a=4m

Long offset, a=20m

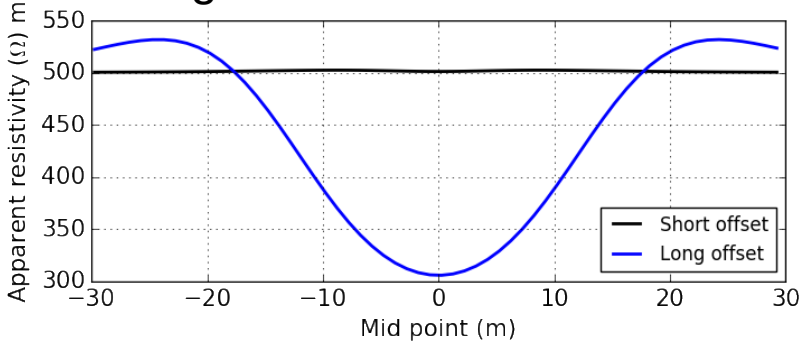




Short offset: a = 4 m



Long offset: a = 20 m

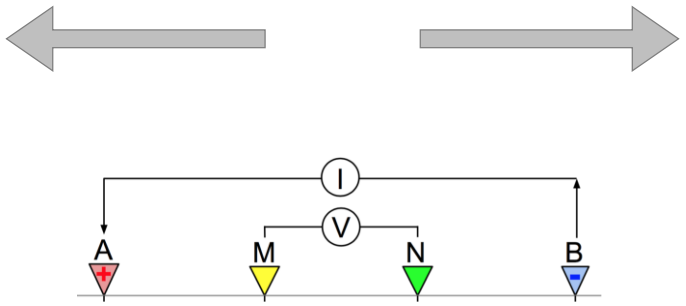


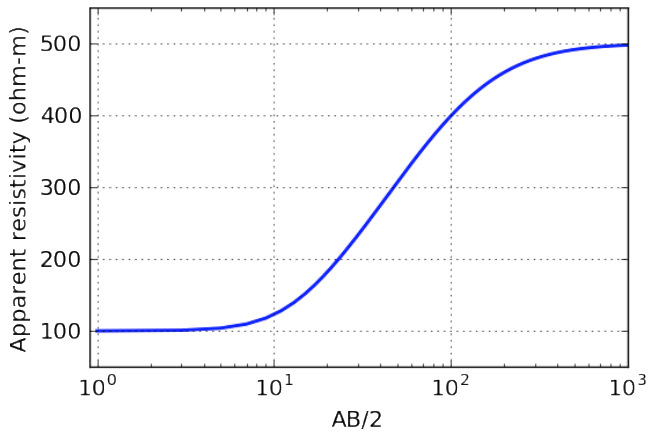
Depth of investigation depends upon offset or array length

Summary: Soundings and Profiles

Sounding

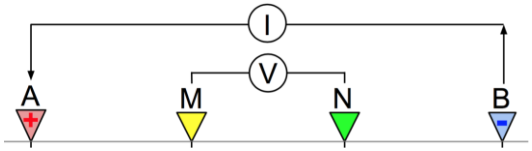
Expand

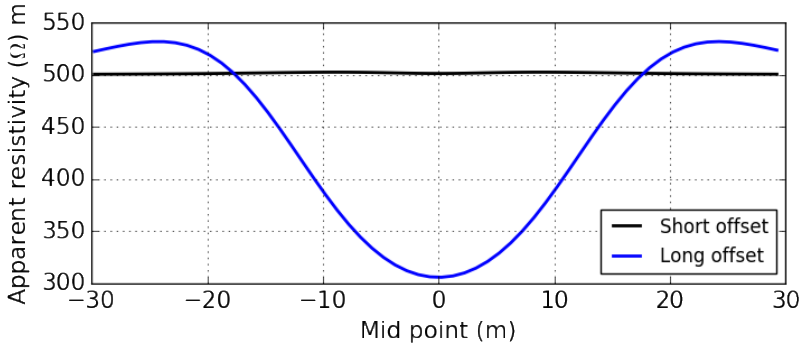




Profiling

Translate





Sounding vs. Profiling

Profiling: Current and potential electrodes moved along a line (e.g. Real Section, Wenner and Schlumberger)

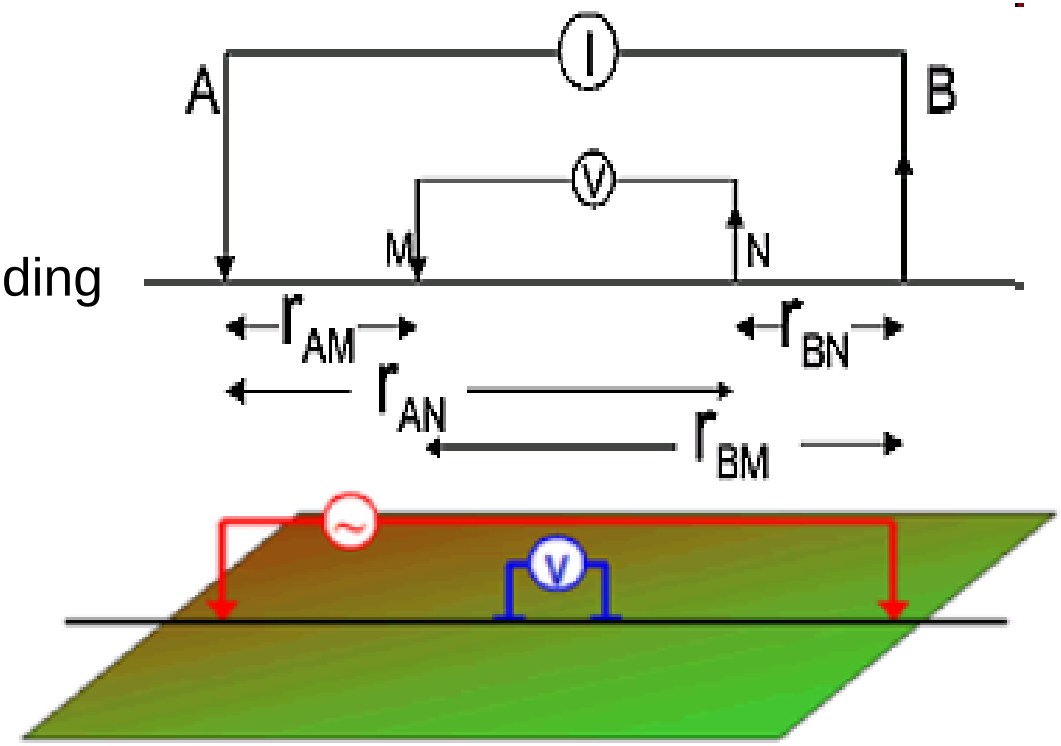
→ Lateral changes in resistivity

Sounding: Current and potential electrodes expanded symmetrically about a central point (e.g. Wenner and Schlumberger)

→ Vertical changes in resistivity

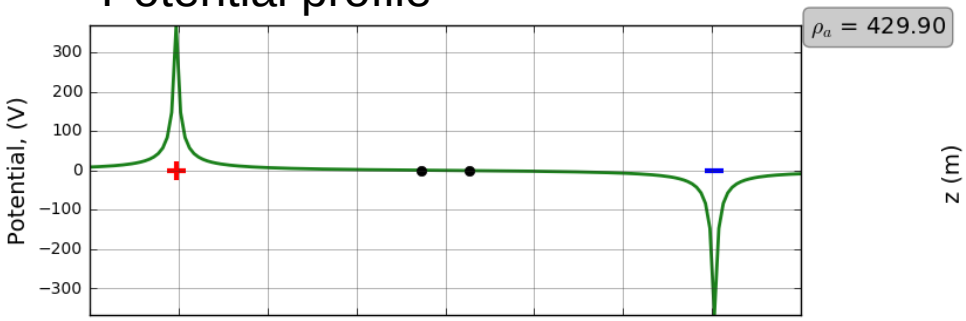
General Configuration: Uses a combination of profiling and sounding

→ Vertical and lateral changes in resistivity

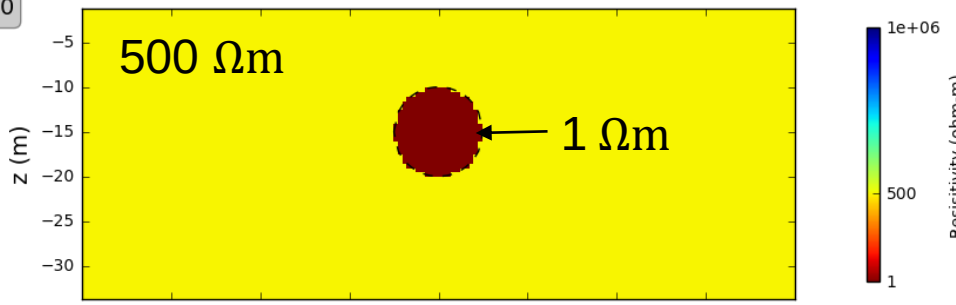


Gradient Array: Buried Conductor

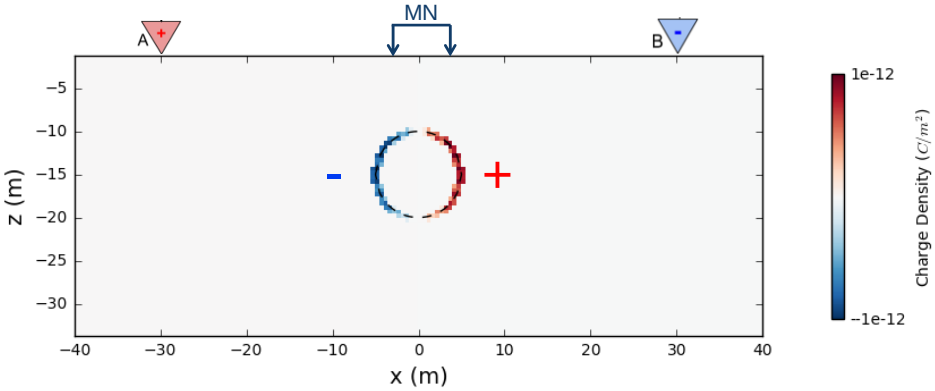
Potential profile



Resistivity model

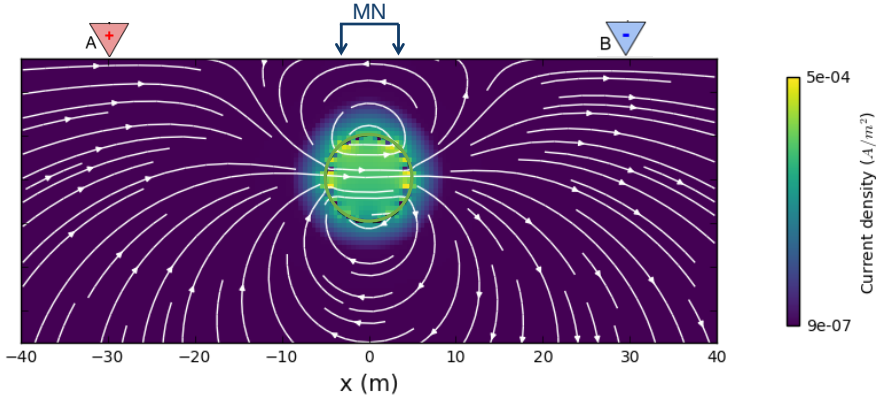


ρ_a = 430



Secondary charges: Q_s

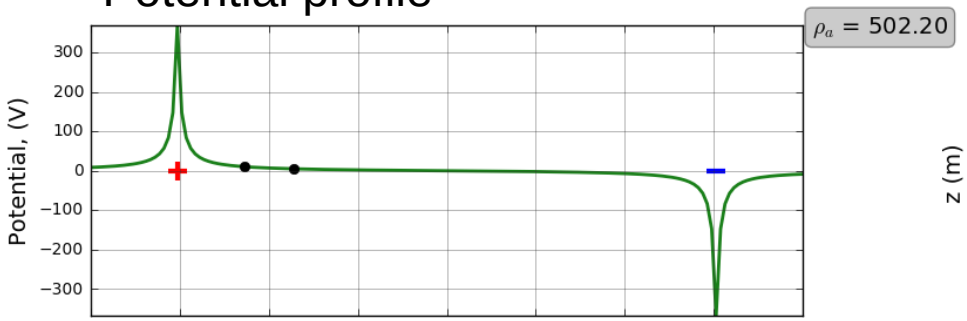
ρ_a = 430



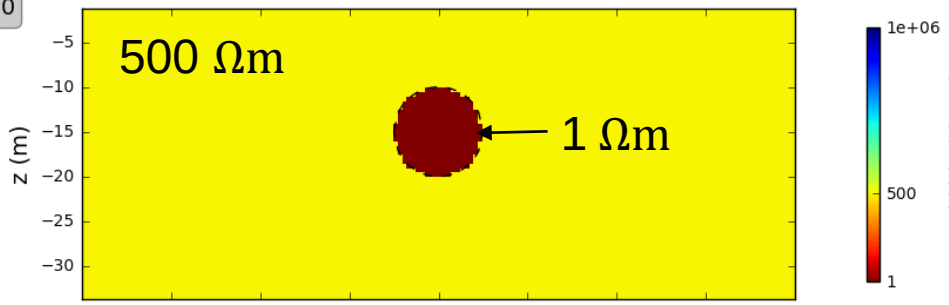
Secondary currents: J_s

Gradient Array: Buried Conductor

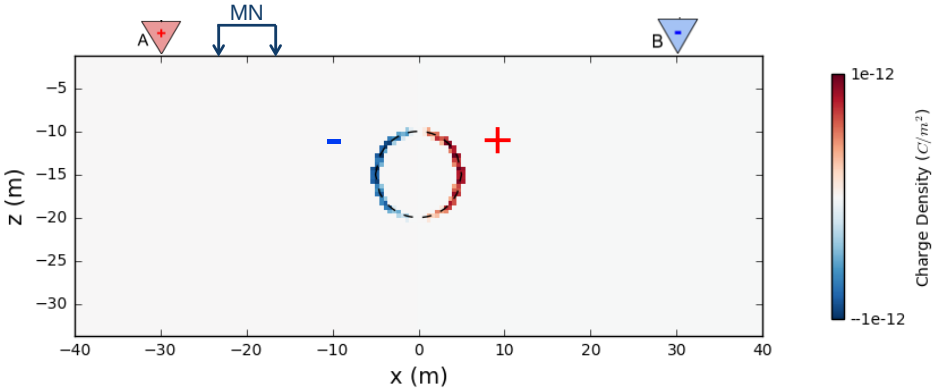
Potential profile



Resistivity model

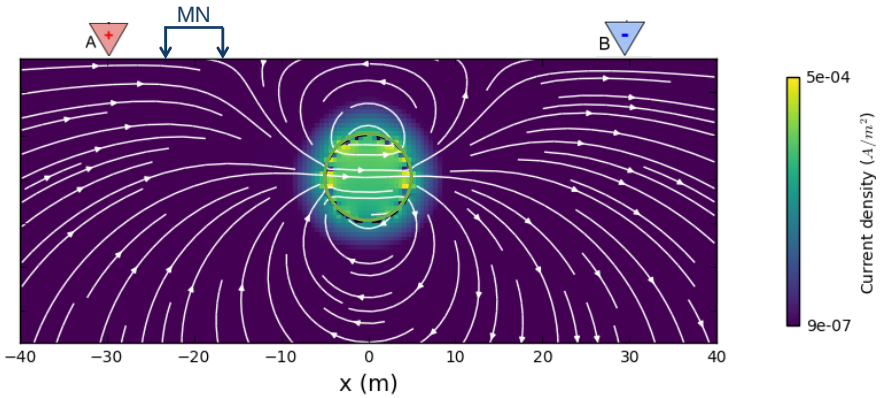


ρ_a = 502



Secondary charges: Q_s

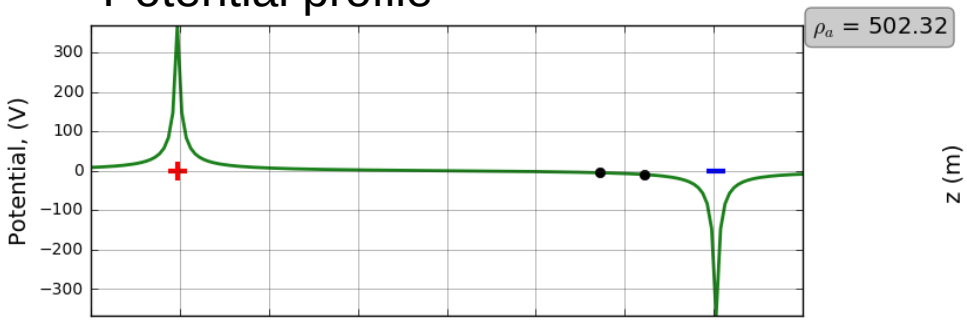
ρ_a = 502



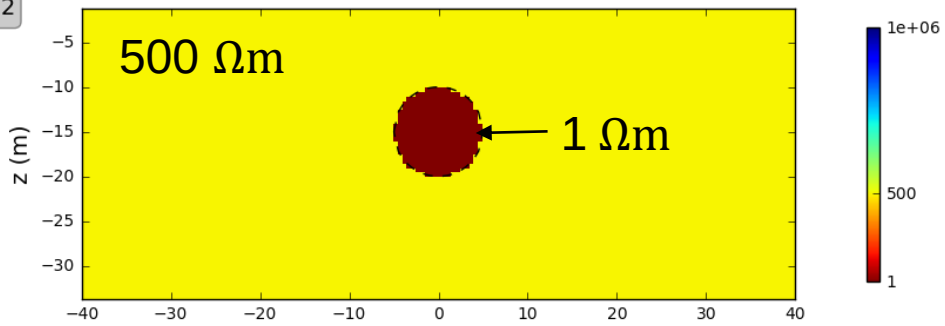
Secondary currents: J_s

Gradient Array: Buried Conductor

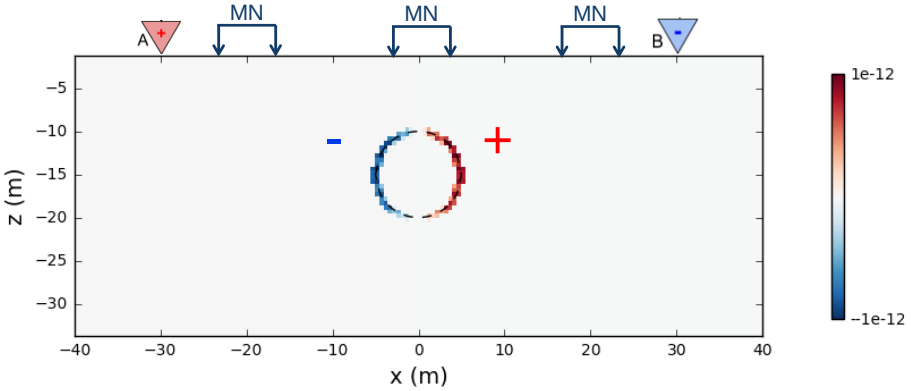
Potential profile



Resistivity model

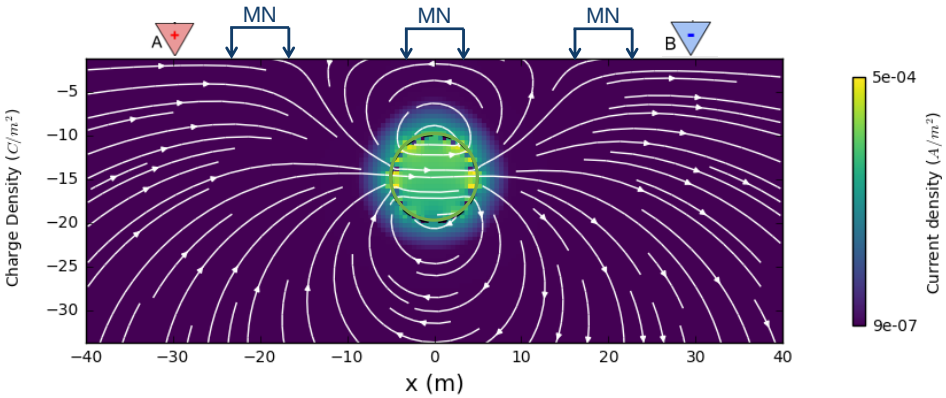


ρ_a = 502 ρ_a = 430 ρ_a = 502



Secondary charges: Q_s

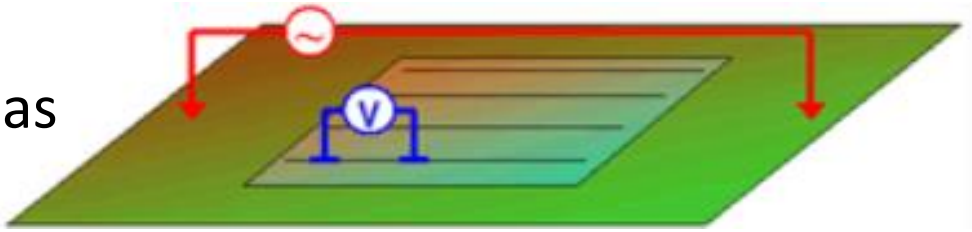
ρ_a = 502 ρ_a = 430 ρ_a = 502

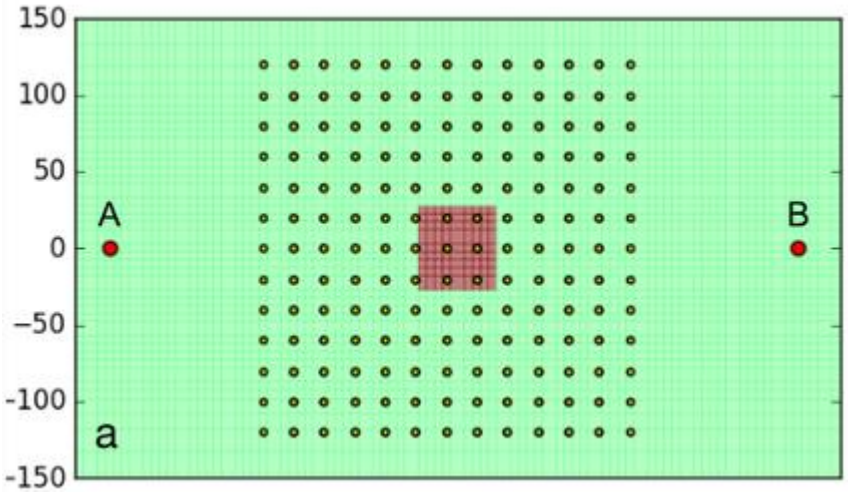


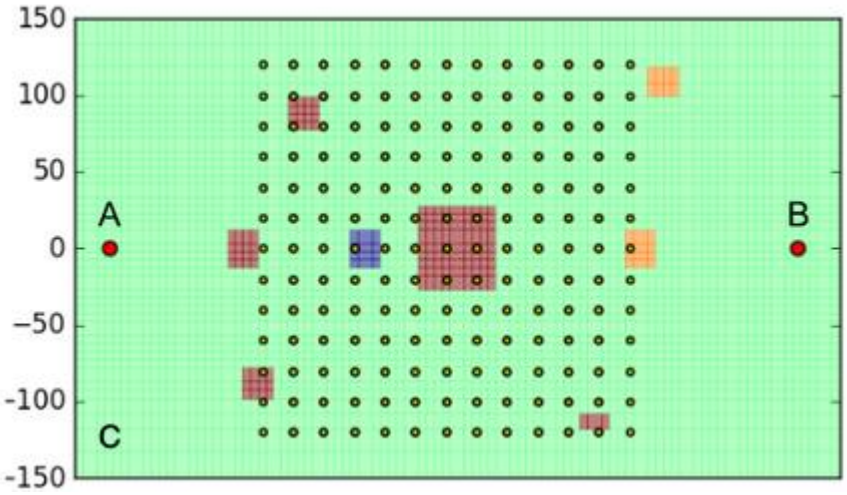
Secondary currents: J_s

Example: Gradient Array

- Consistent electrode spacing
- Detects lateral variations in resistivity
- Rapid acquisition of large areas

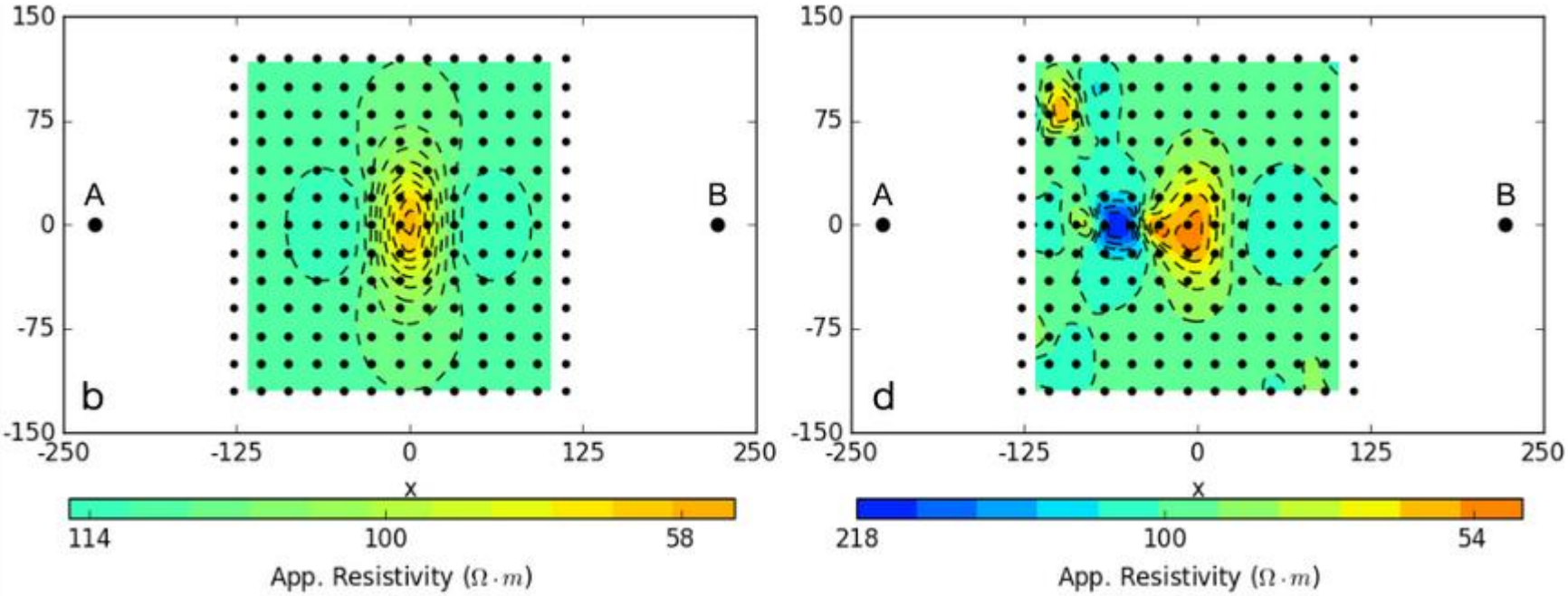






Example: Gradient Array

- Apparent resistivities show location of most blocks
- Can’t find blocks outside array
- Subsequent survey to find depths

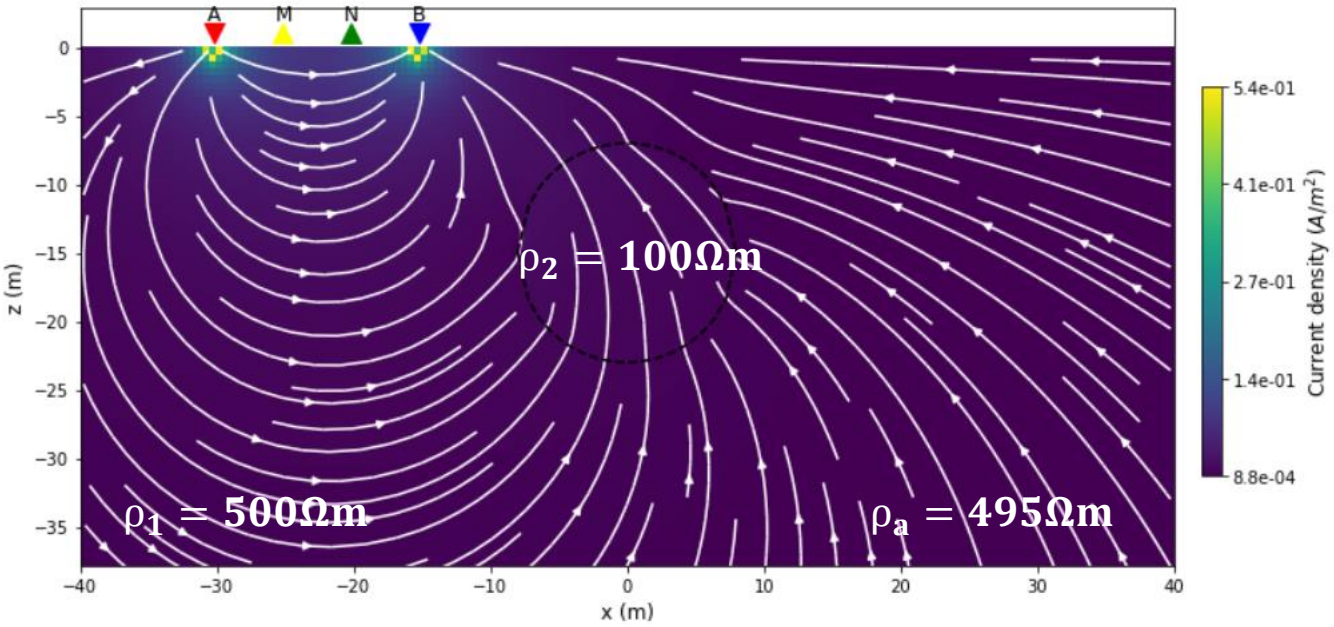


Surveys Recap

- Different configurations and spacings for different applications
- Wider electrode spacing → Image deeper
- Sounding → Vertical variations
  Profiling → Horizontal variations
- Significant current must run through target for it to affect measurements

Survey: Recap Questions

- If we do a profile survey over a buried conductor, why might we not see it?

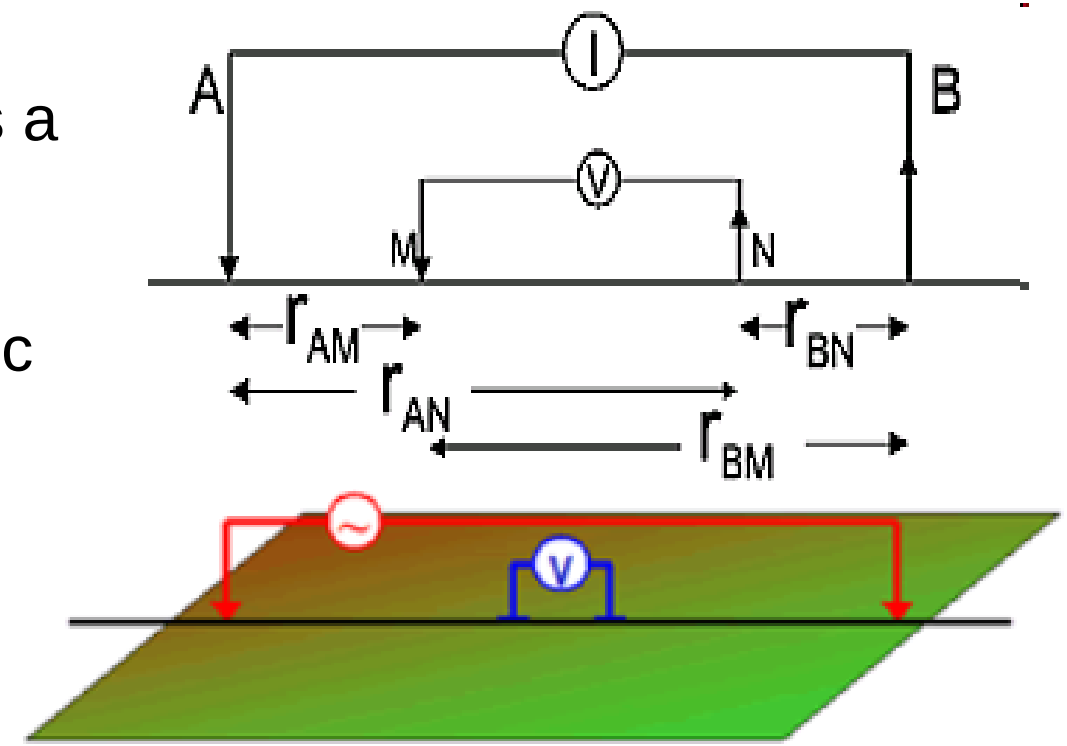


- What would happen if the sphere were below a conductive overburden?

Data

Raw Data

- Potential electrodes act as a circuit with a resistor
- Records the drop in electric potential (ΔV) between points M and N
- Units: Volts or milliVolts
- Less diagnostic if electrode spacing changes for each reading

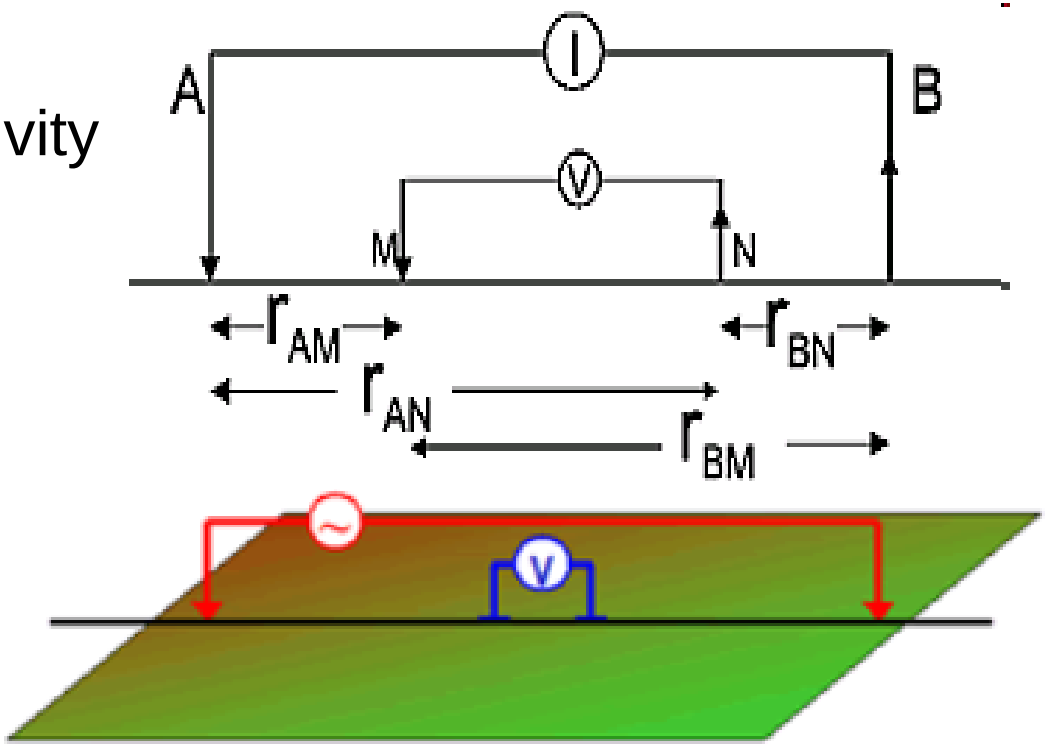


Apparent Resistivity Data

- Apparent resistivity: Resistivity if we assume a halfspace:

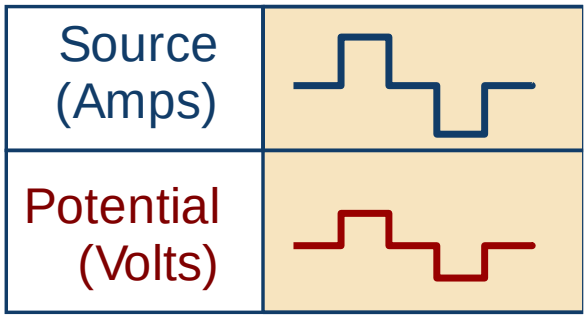
$$\rho_a = \frac{\Delta V}{IG} \quad \text{where}$$

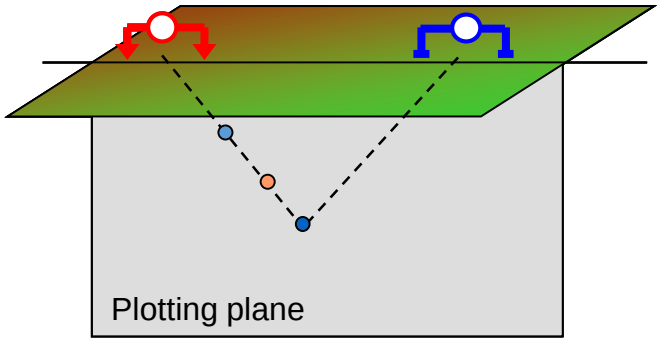
$$G = \frac{1}{2\pi}\left\{\frac{1}{r_{AM}} - \frac{1}{r_{BM}} - \frac{1}{r_{AN}} + \frac{1}{r_{BN}}\right\}$$

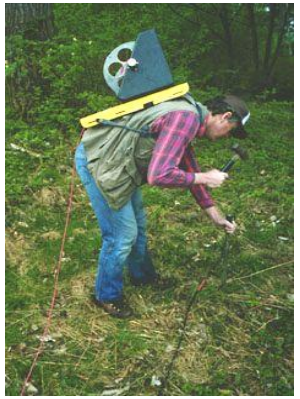


- Finds regions of high/low resistivity relative to background
- Easier to interpret than raw potentials
- Units: Ωm

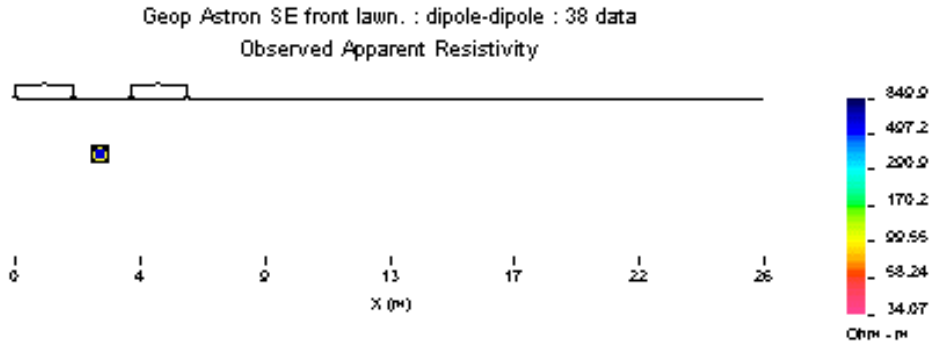
Data as Pseudo-section





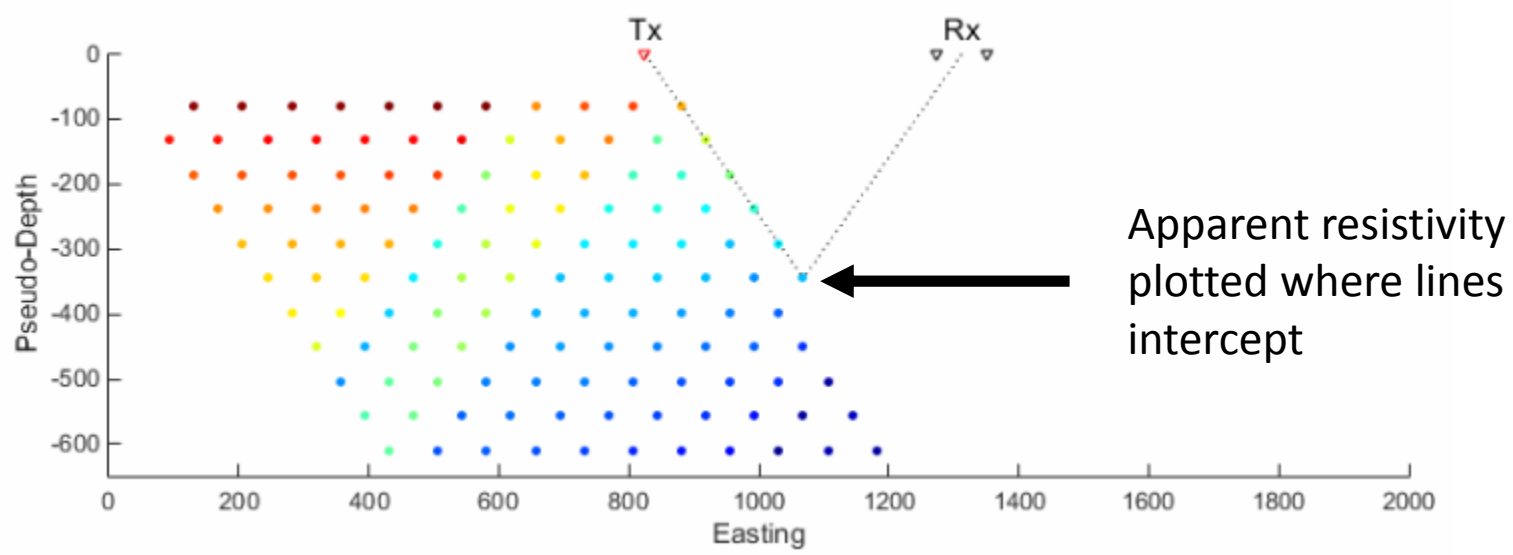


Each data point is an apparent resistivity: $\rho_a = \frac{2\pi\Delta V}{IG}$



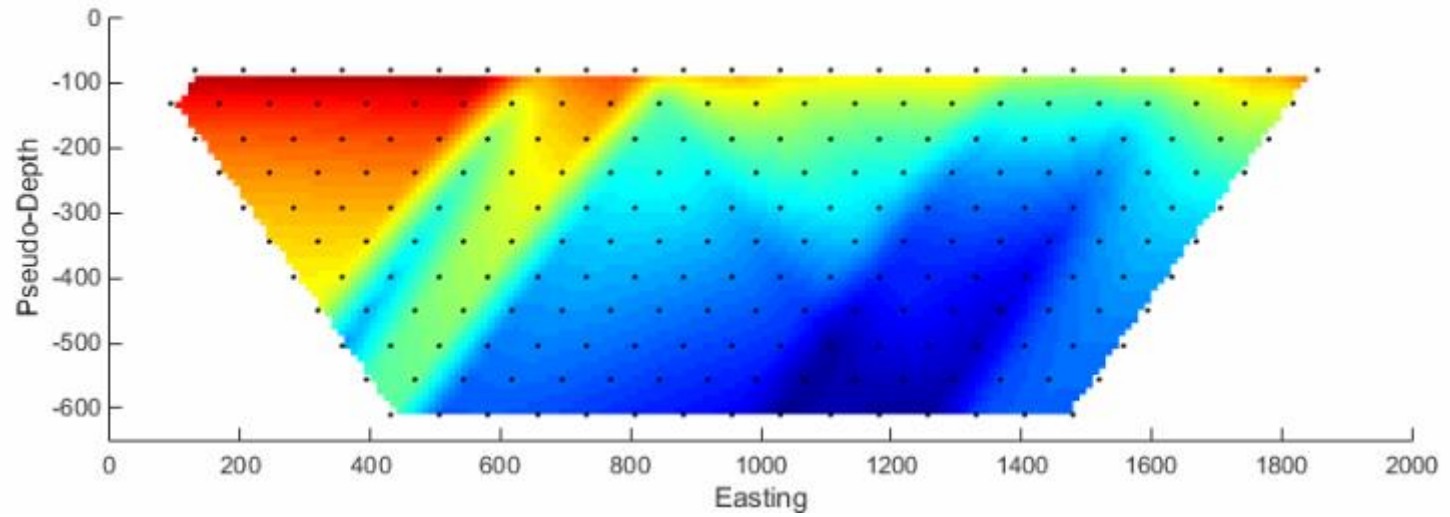
Pseudo-Sections

- Current electrodes (Tx) and potential electrodes (Rx)
- Pseudo-depth: estimated depth for which Tx-Rx configuration is sensitive
- Larger electrode spacing
  → Generally sensitive to deeper structures
  → Larger “pseudo-depth”



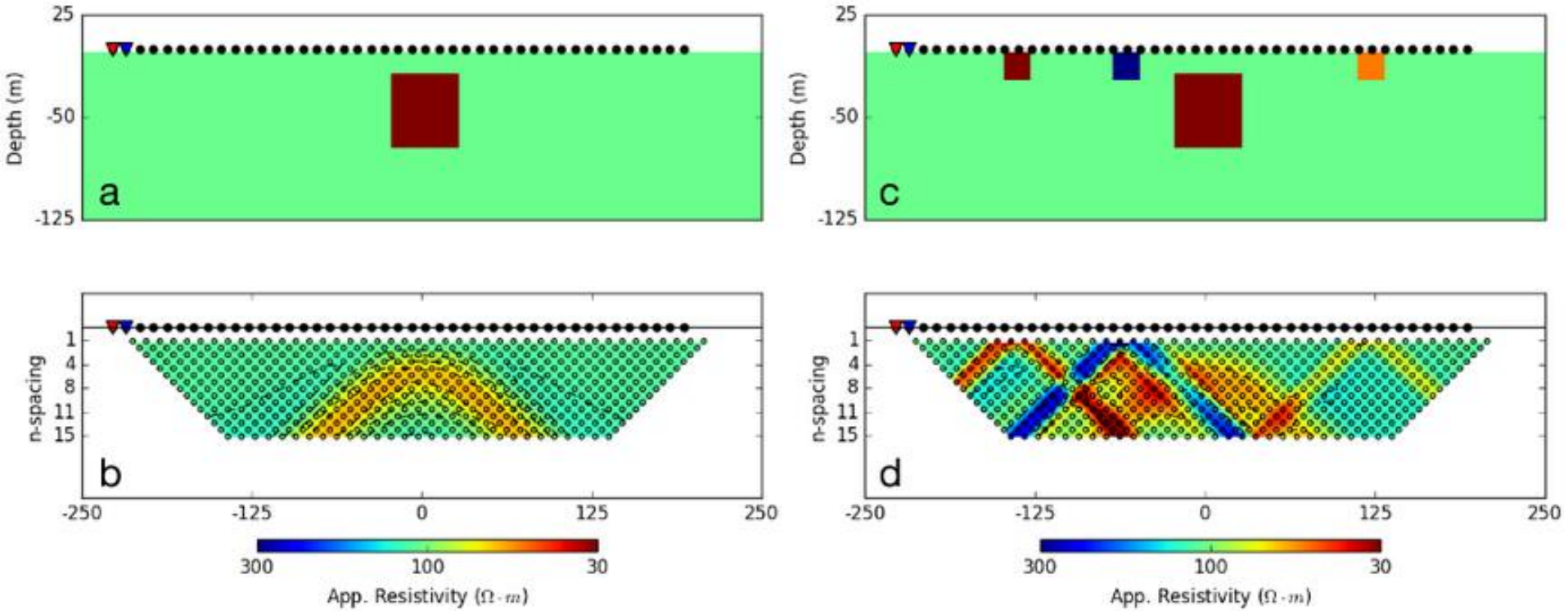
Pseudo-Sections

- Visualize apparent resistivities when sounding and profiling
- Apparent resistivity (color scale) plotted as a function of electrode position
- Easy to interpret for simple geologies



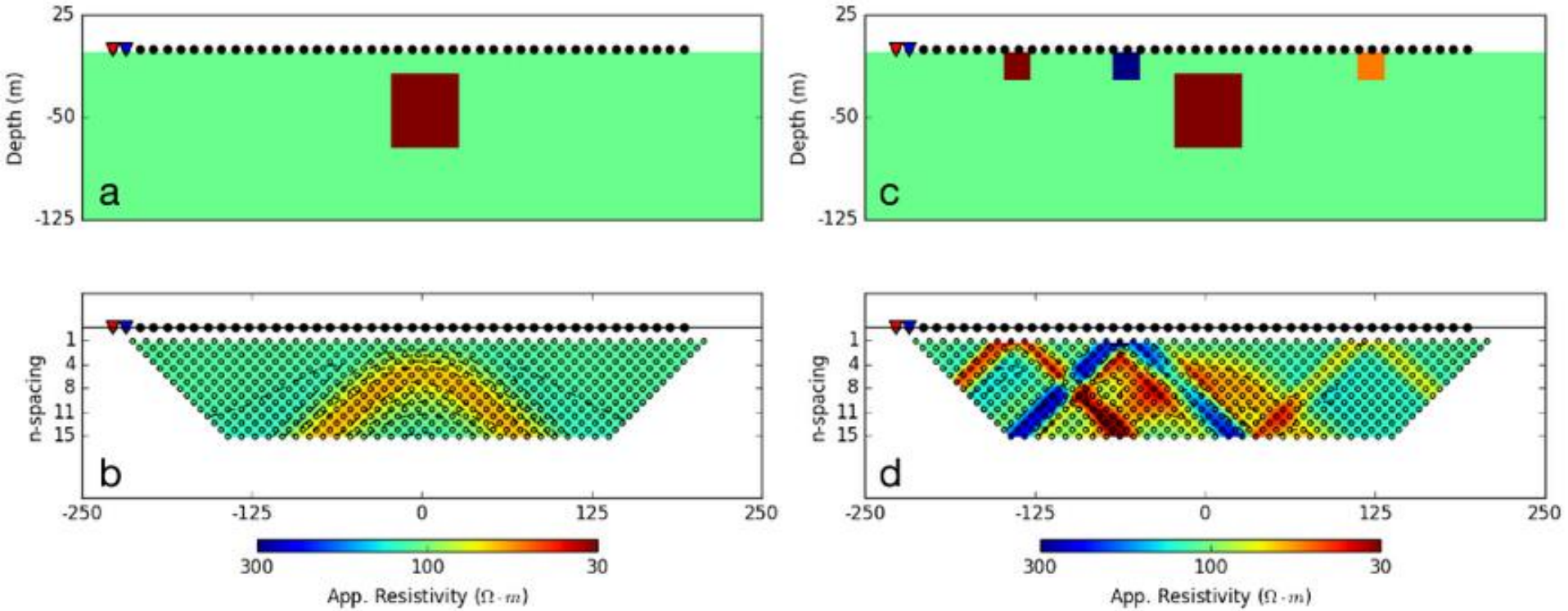
Example: Blocks in Halfspace

- Compact bodies → arc signature for dipole-dipole survey
- Depth of arc signature → depth of target
- Thickness of arc → size of target



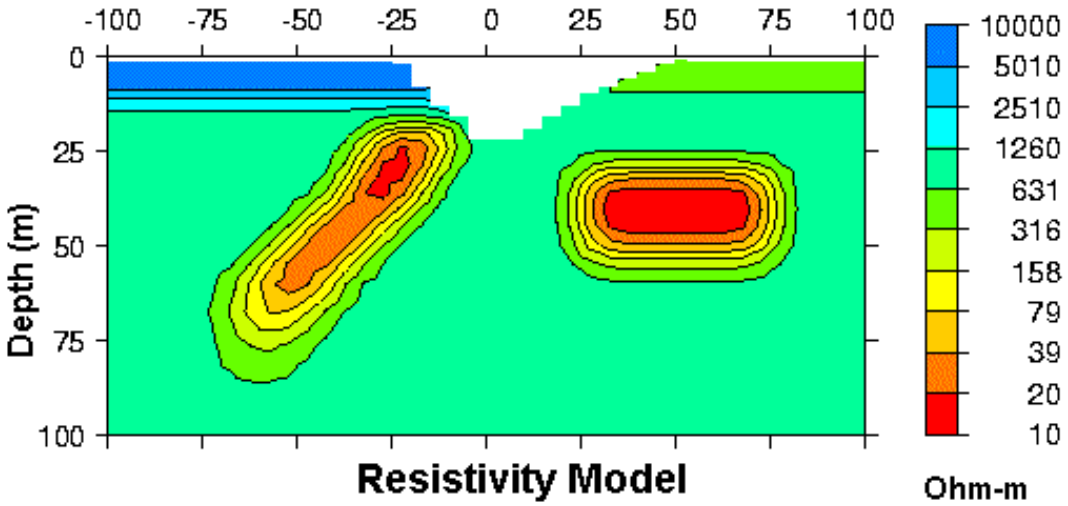
Example: Blocks in Halfspace

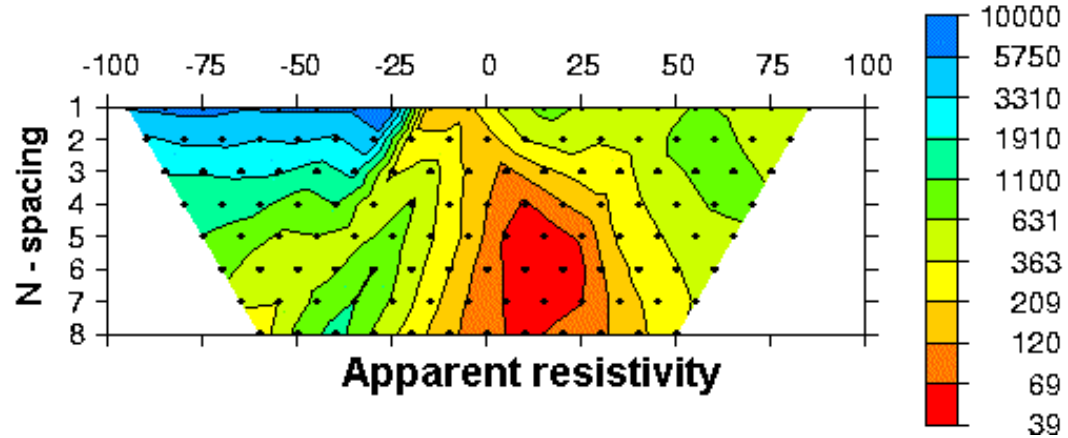
- One block (left) → easy to interpret
- Shallow blocks (right) → mask large buried conductor
  → hard to interpret



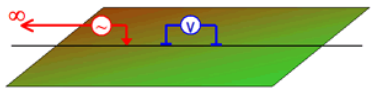
Example:

3) The “UBC-GIF model”





Pole-Dipole



Data Recap

- Raw data in Volts or milliVolts

- Easier to interpret raw data as apparent resistivity

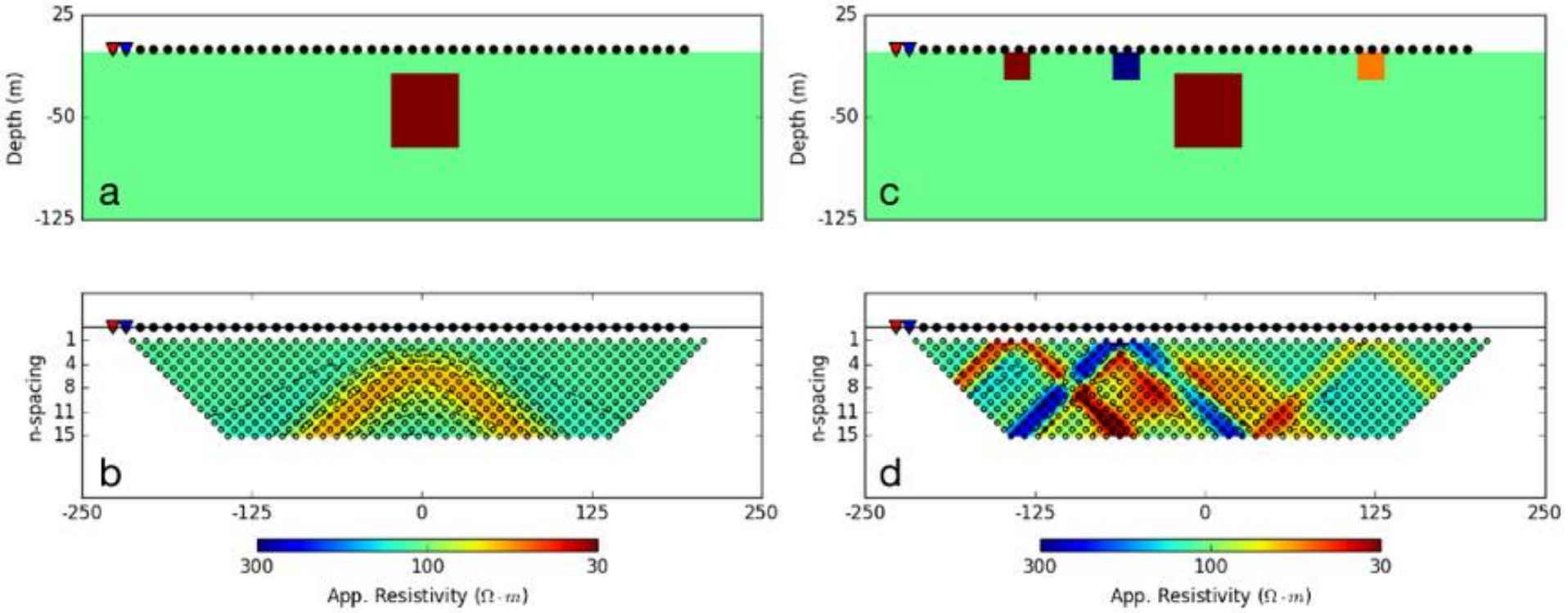
- Vertical variations → Sounding curve
  Horiztonal variations → Profile
  Vertical and horizontal variations → Pseudo-section

- Pseudo-sections:
  - Good for simple geology
  - Deep structures masked by surface structures

Recap: Questions

- Why use apparent resistivity instead of raw voltage?

- Can horizontal position of buried conductors/resistors be inferred directly from pseudo-section?



Unit Activities

- **Labs: (DC)**
  - Monday, October 28th
  - Tuesday, October 29th

- **Quiz:**
  - Friday, November 1st