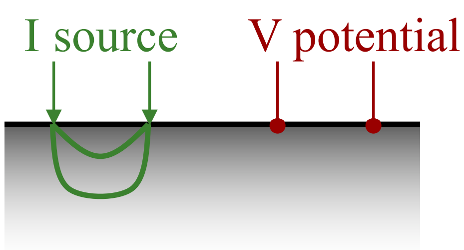
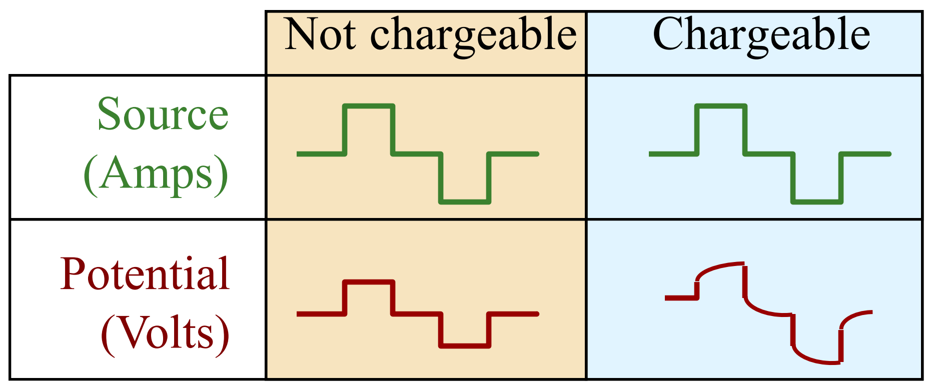
Induced Polarization (IP)

- Basic principles
- Data Acquistion
- Pseudosection
- Inversion
- Case Histories

Induced Polarization

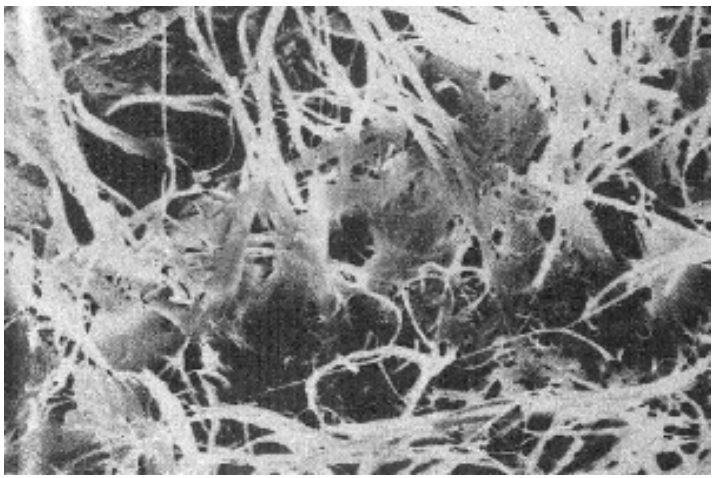
- Current injected into ground and the voltage continues to increase.
- Recognized in 1950’s: it was termed Over-voltage.
- Understand the effect in terms of charge accumulation.
- The phenomenon is called induced polarization.

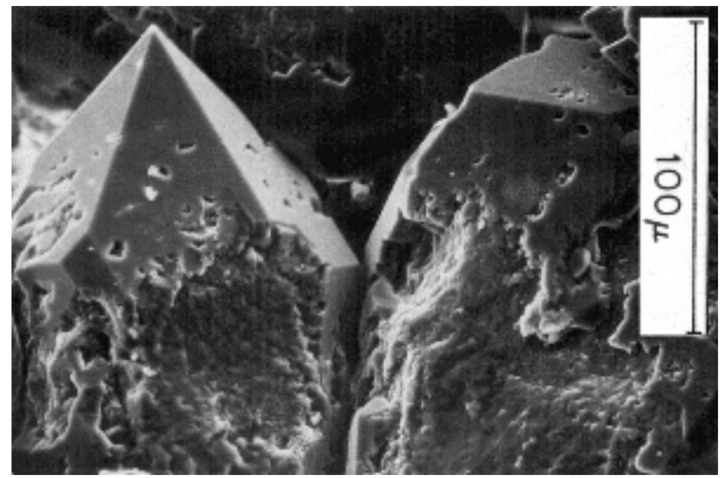




Chargeability is a microscopic phenomenon

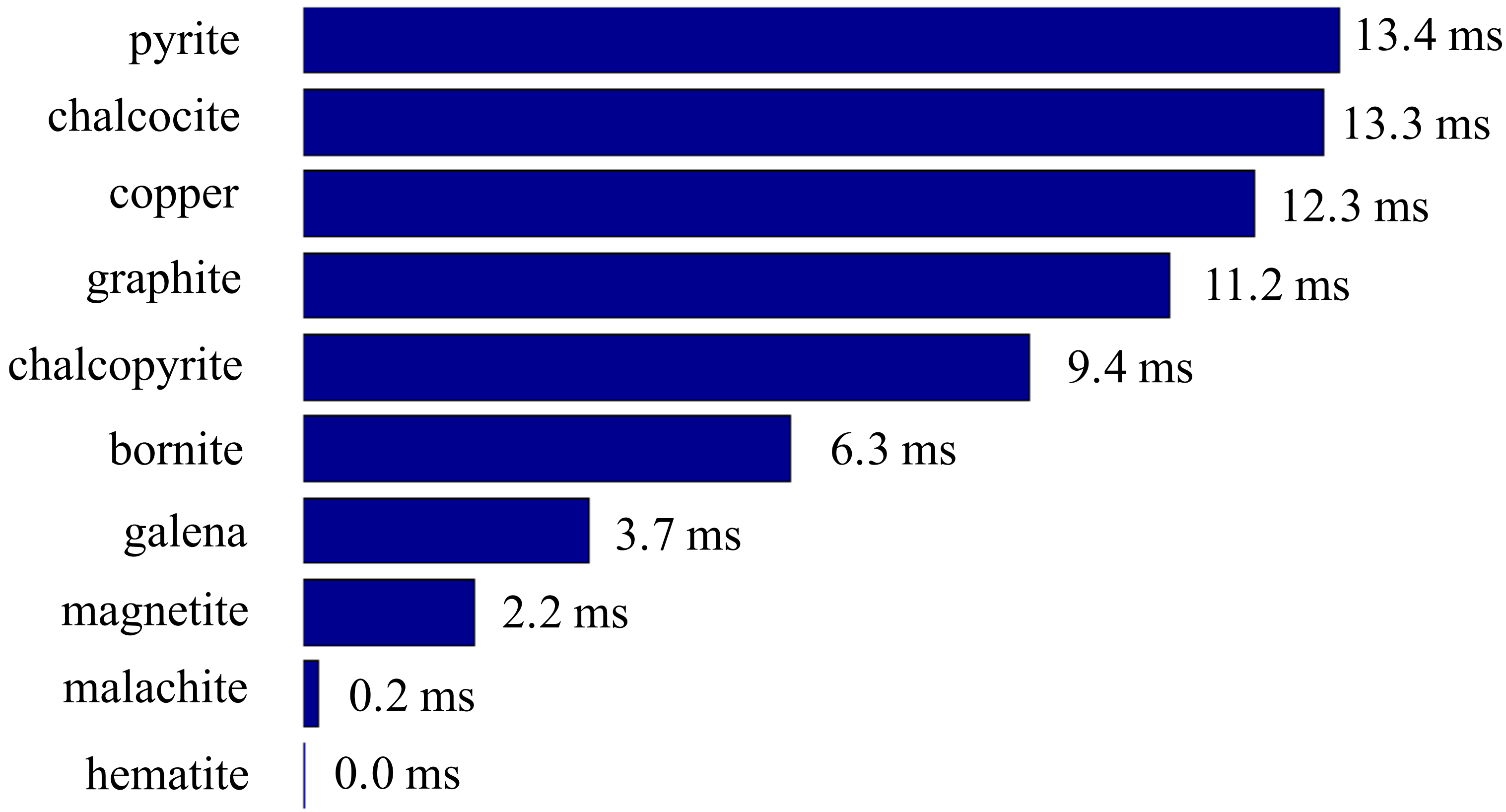
Thoroughly understanding what is happening at the microscopic level is scientifically challenging. In practice we work with the concept of "chargeability"





Chargeability

Minerals at 1% Concentration in Samples



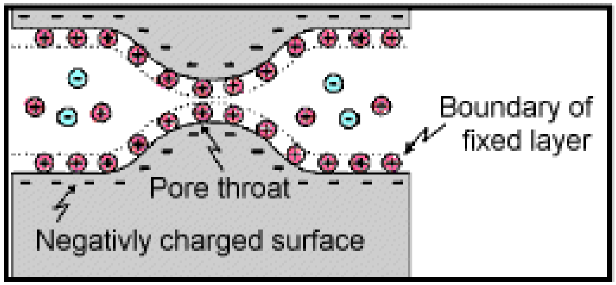
Chargeability: rocks and minerals

Material type	Chargeability (msec.)
20% sulfides	2000 - 3000
8-20% sulfides	1000 - 2000
2-8% sulfides	500 - 1000
volcanic tuffs	300 - 800
sandstone, siltstone	100 - 500
dense volcanic rocks	100 - 500
shale	50 - 100
granite, granodiorite	10 - 50
limestone, dolomite	10 - 20

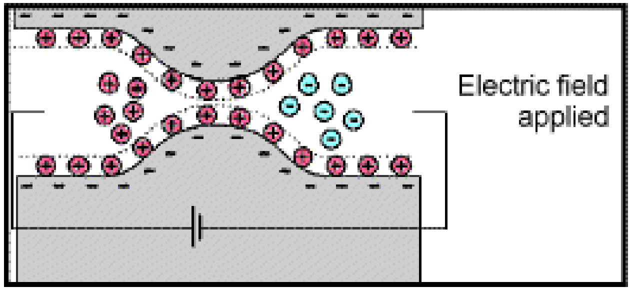
Material type	Chargeability (msec.)
ground water	0
alluvium	1 - 4
gravels	3 - 9
precambrian volcanics	8 - 20
precambrian gneisses	6 - 30
schists	5 - 20
sandstones	3 - 12

Earth materials are "chargeable"

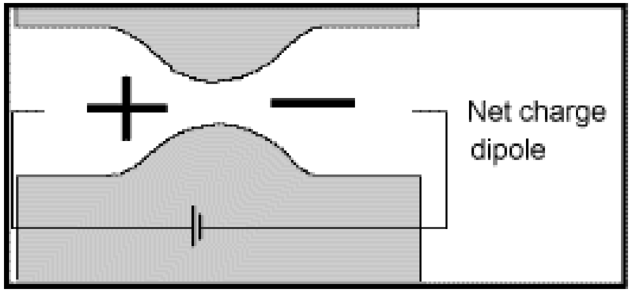
Initial situation
Neutrality



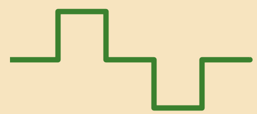
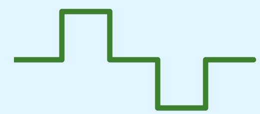
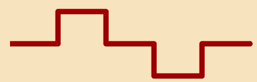
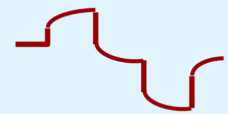
Apply an electric field
Build up of charges

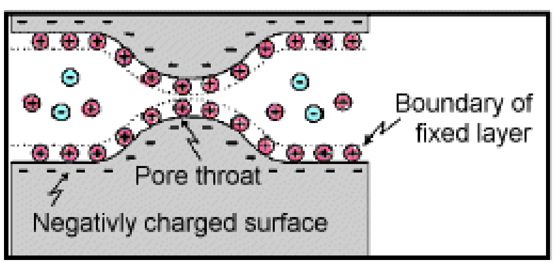


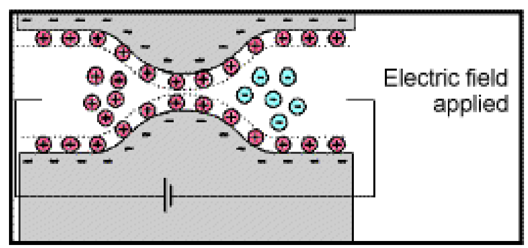
Net effect
Charge Polarization
Electric dipole

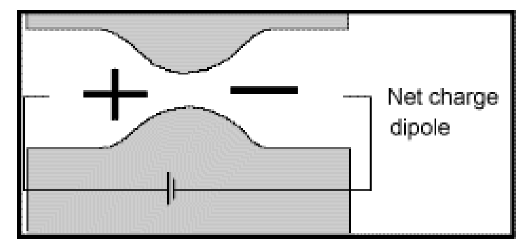


Induced Polarization: Over-voltage

	Not chargeable	Chargeable
Source (Amps)		
Potential (Volts)		





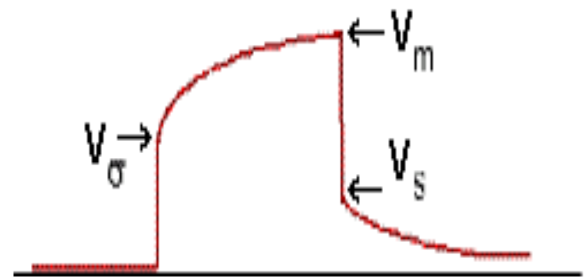


Chargeability Data: Time domain IP

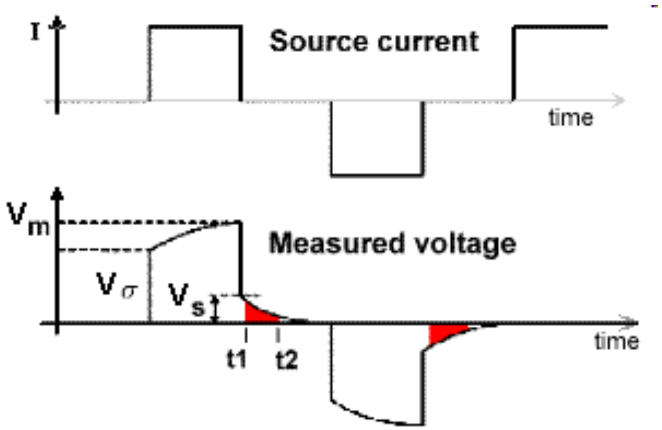
Intrinsic chargeability

0<n<1 (dimensionless)

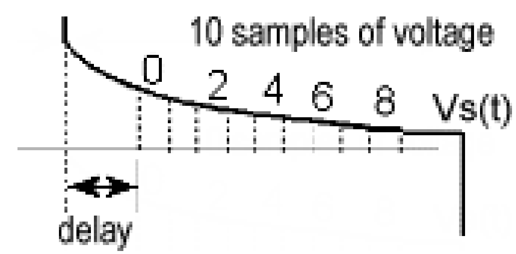
$$\eta = \frac{V_s}{V_m}$$



Integrate over the decay



Sample a channel



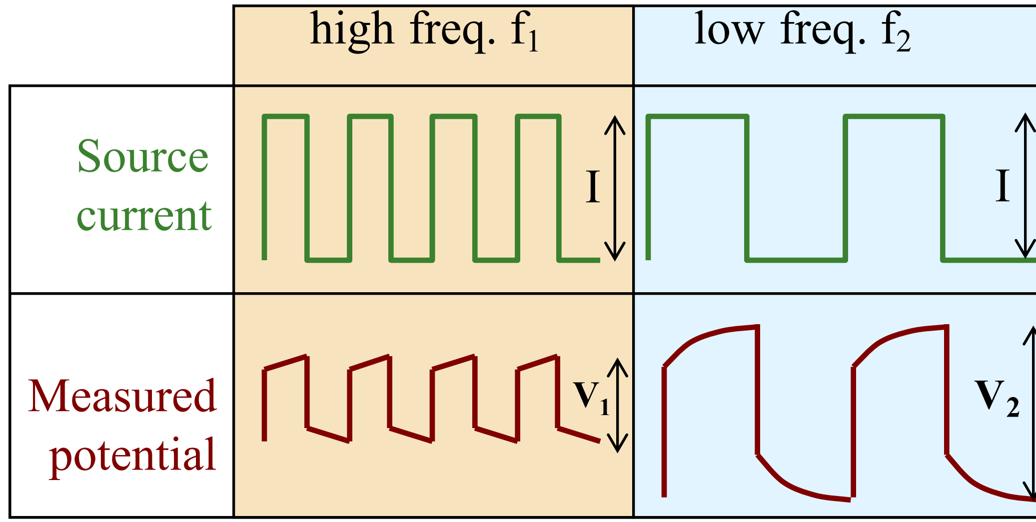
$$d_{IP} = \frac{1}{V_m}\int_{t_1}^{t_2} V_s(t)dt$$ (msec)

$$d_{IP} = \frac{V_s(t)}{V_m}$$ mV/V

IP data: frequency domain

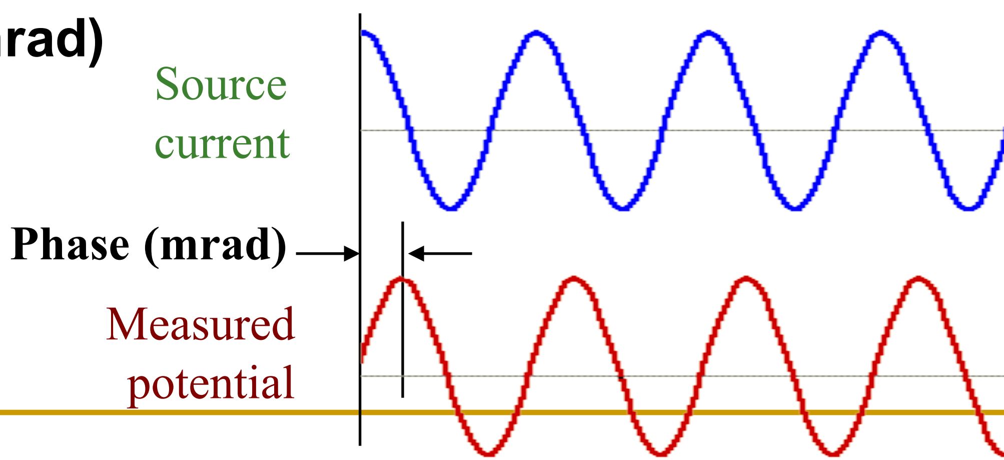
- **Percent frequency effect:**

$$d_{IP} = PFE = 100\left(\frac{\rho_{a2} - \rho_{a1}}{\rho_{a1}}\right)$$



- **Phase:**

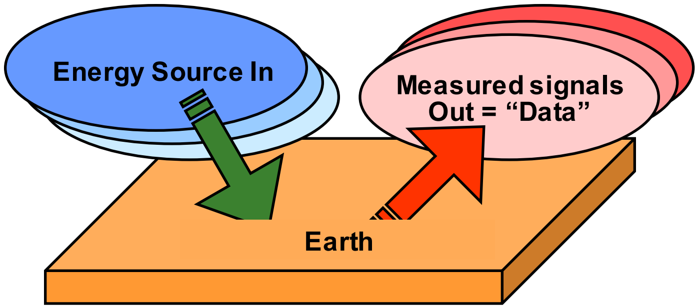
$d_{IP} =$ **phase (mrad)**

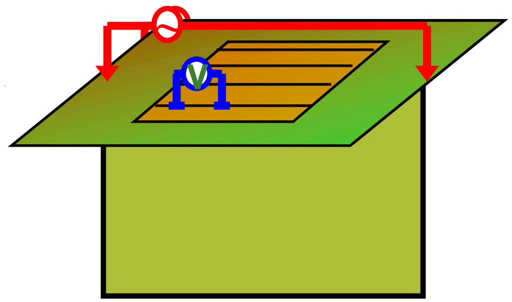


Data acquisition

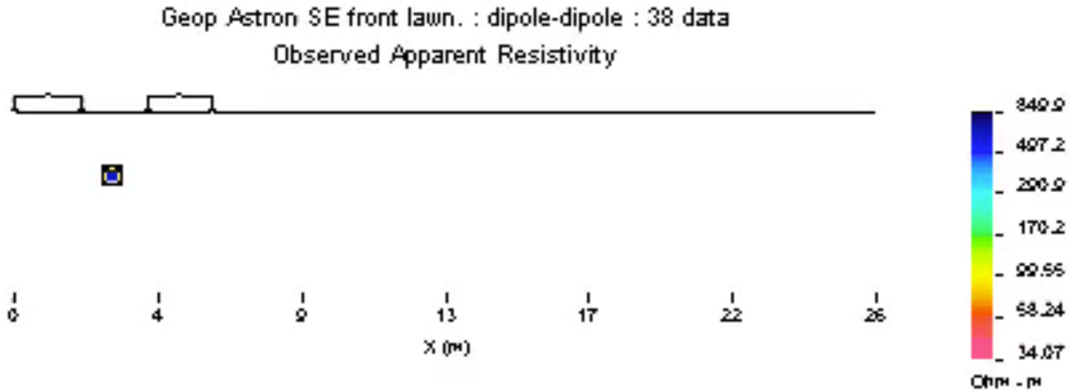
- Data are acquired along with DC resistivity data (just sample a different part of the waveform)
- Data are plotted as pseudosections (exactly the same as DC resistivity)
- For IP the data plotted in the pseudosections will have units (mV/V, msec, mrad, PFE).

DC resistivity and IP data

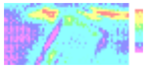




Each data point is an ***apparent*** resistivity: $\rho_a = \dfrac{2\pi \Delta V}{IG}$

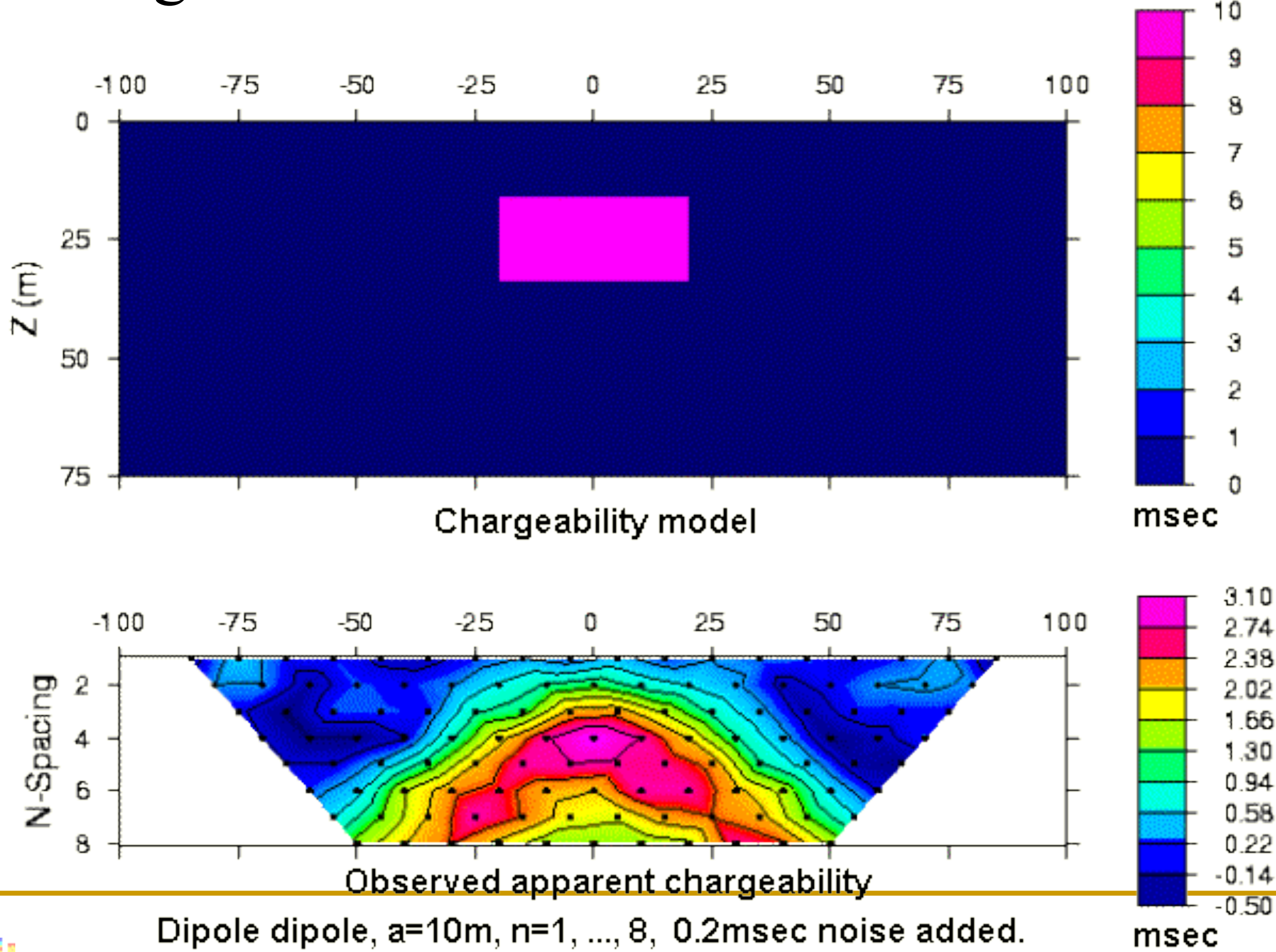


(Click for animation)



Example IP pseudosection

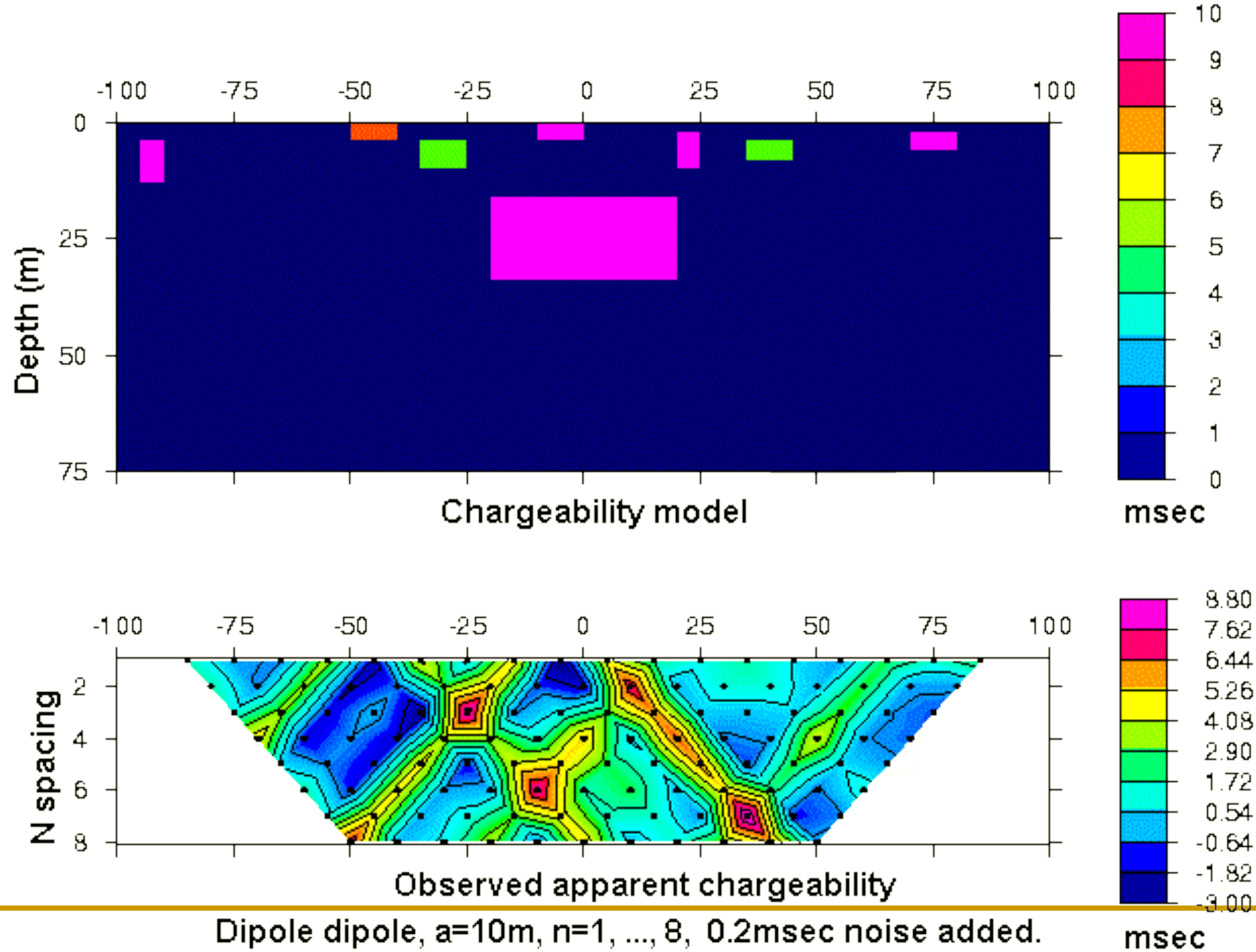
2) A chargeable block.

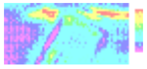


Dipole dipole, a=10m, n=1, ..., 8, 0.2msec noise added.

Example IP pseudosection

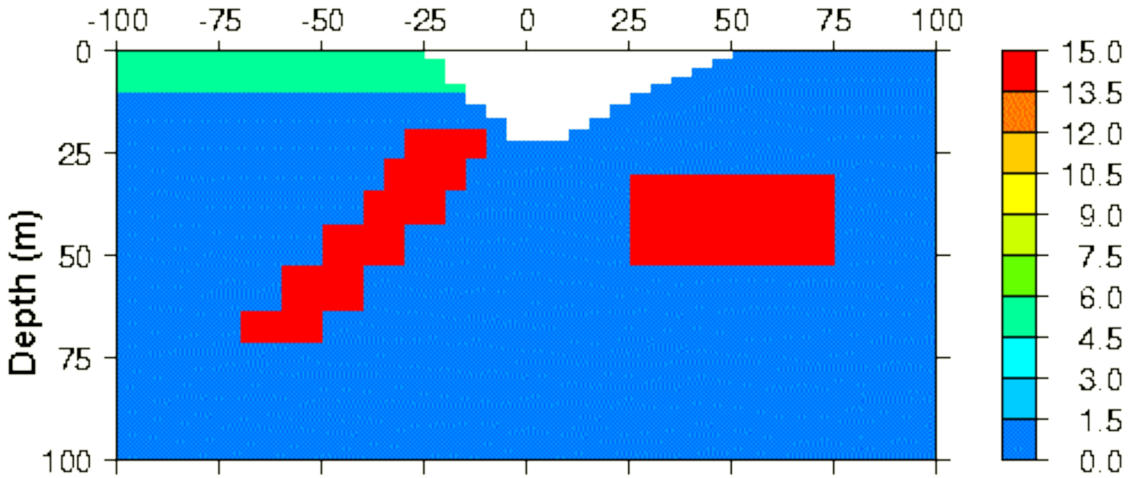
2) A chargeable block and geologic noise.



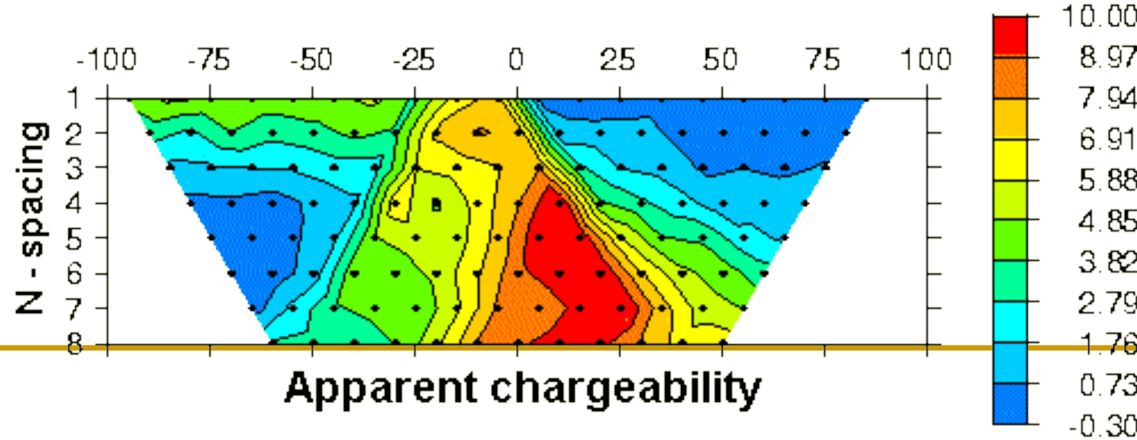


Example IP pseudosection

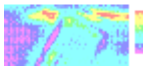
3) The "UBC-GIF model"



Chargeability model



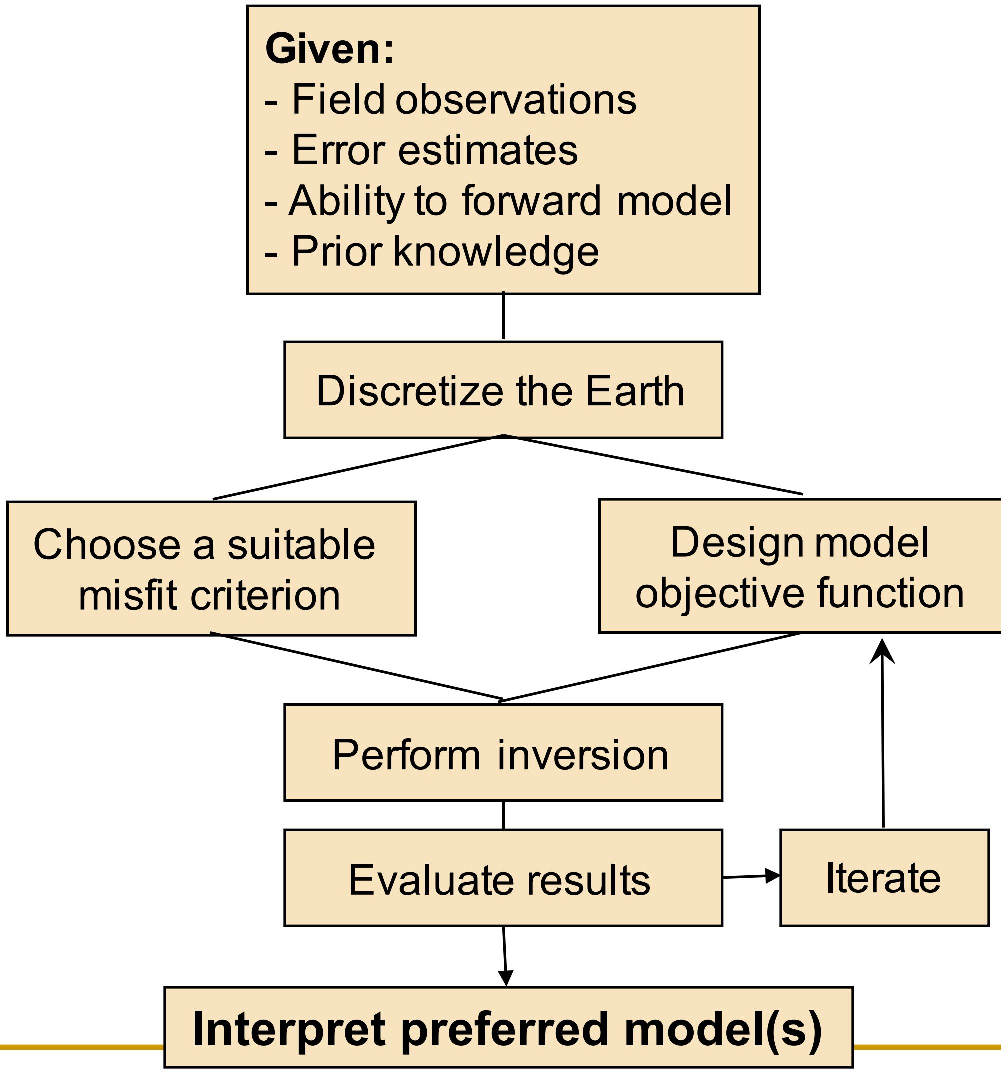
Apparent chargeability



Pseudosections … conclusions

- Except for very simple structures, geologic interpretations can not be clearly made directly from pseudosections.
- Interpretation is even more difficult in 3D

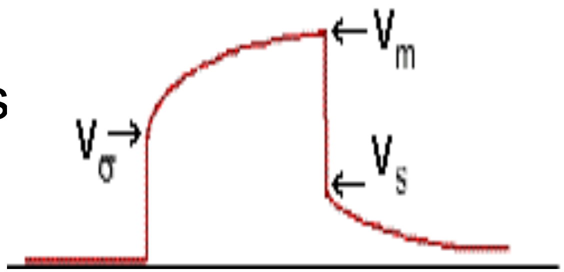
Summary: what is needed to invert a data set?



$$\phi_m = \alpha_s \int (m - m_0)^2 \, dx + \alpha_x \int \left(\frac{d}{dx}(m - m_0) \right)^2 dx + \alpha_z \int \left(\frac{d}{dz}(m - m_0) \right)^2 dz$$

Summary of IP data types:

- Time domain:
  - Theoretical chargeability (dimensionles
  - Integrated decay time (msec).

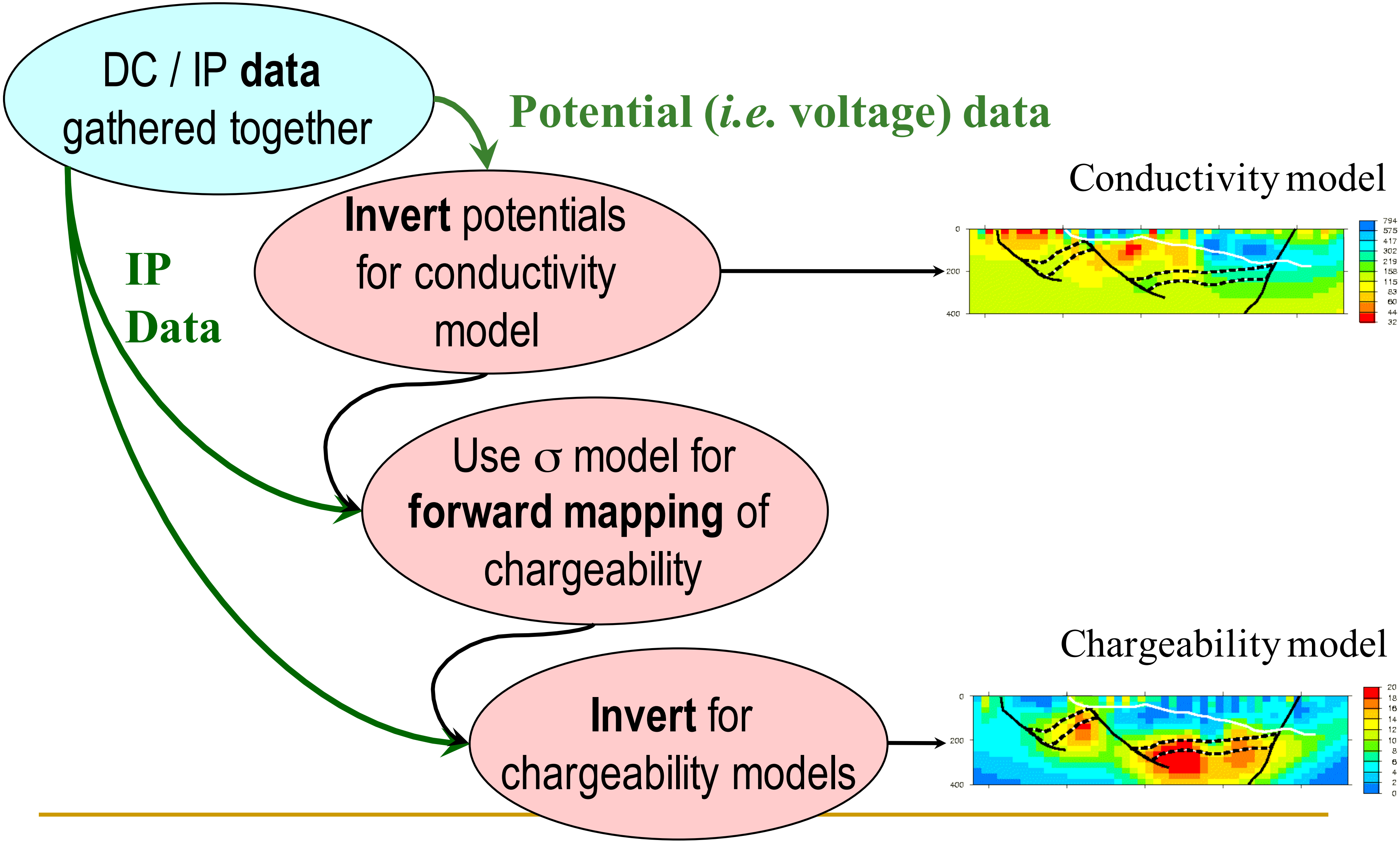


- Frequency domain:
  - PFE (dimensionless)
  - Phase (mrad)

- For all data types, $\mathbf{J}\eta = \boldsymbol{d}$.

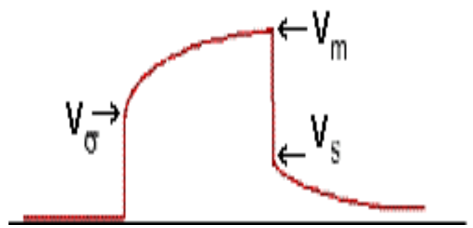
- where **J** is a sensitivity matrix that requires that the electrical conductivity σ is known. We find σ by inverting the DC resisitivity data.

IP Inversion



Inversion of IP data

Step 1: Invert V_m to obtain σ.



Step 2: Generate sensitivities

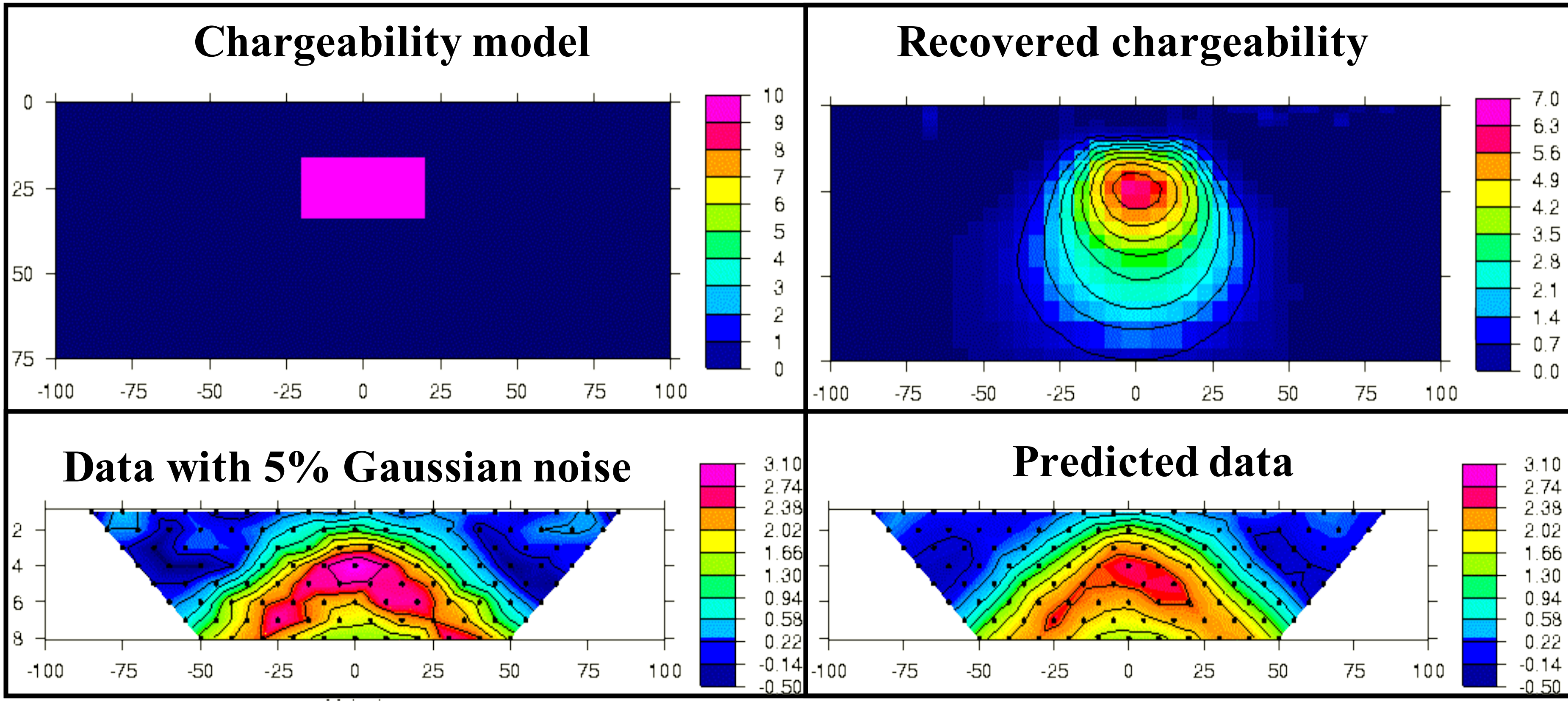
$$J_{ij} = -\frac{\partial \ln \phi^i}{\partial \ln \sigma_j}$$

Step 3: Invert the IP data (any form) by solving:

$$J\eta = d^{obs} \quad \text{subject to } \boldsymbol{\eta} > 0.$$

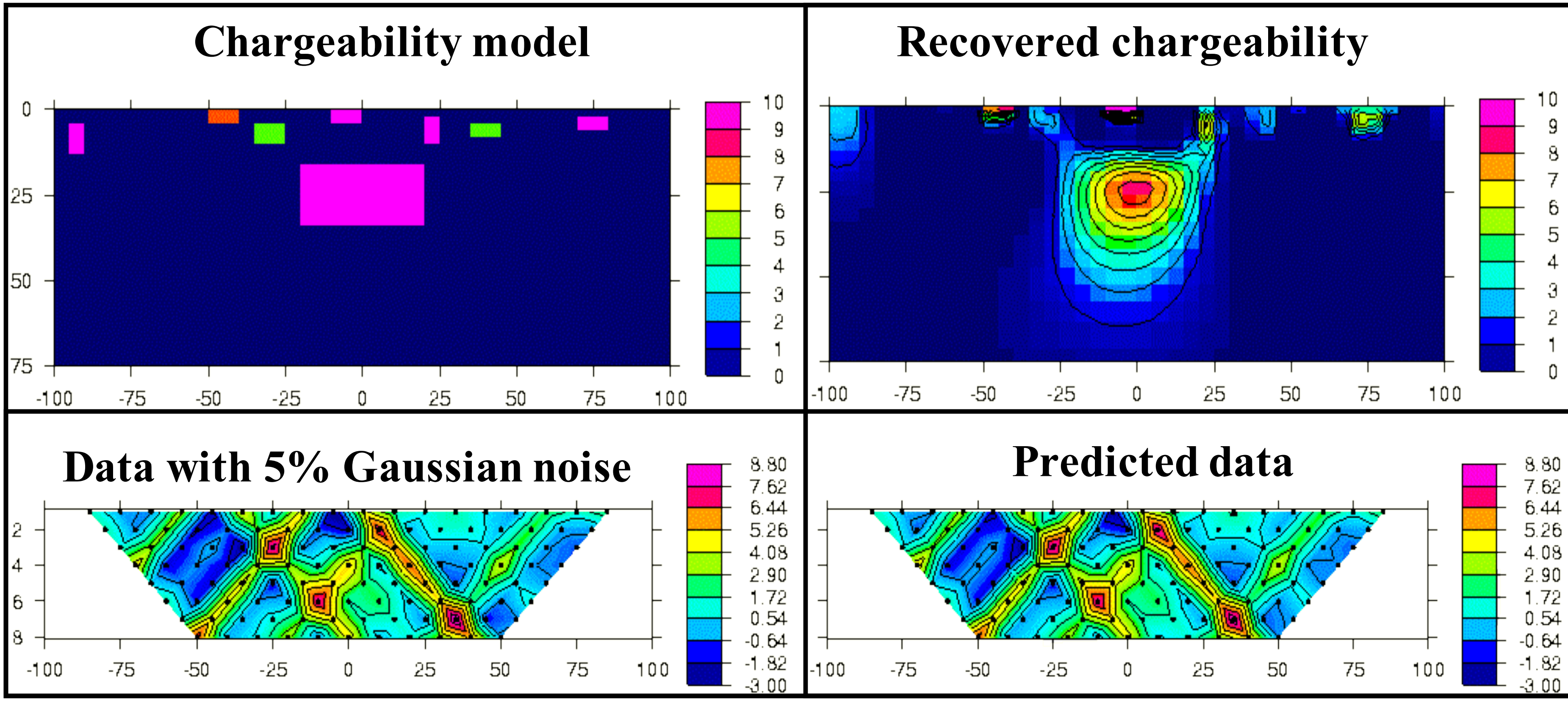
Example 1: buried prism.

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



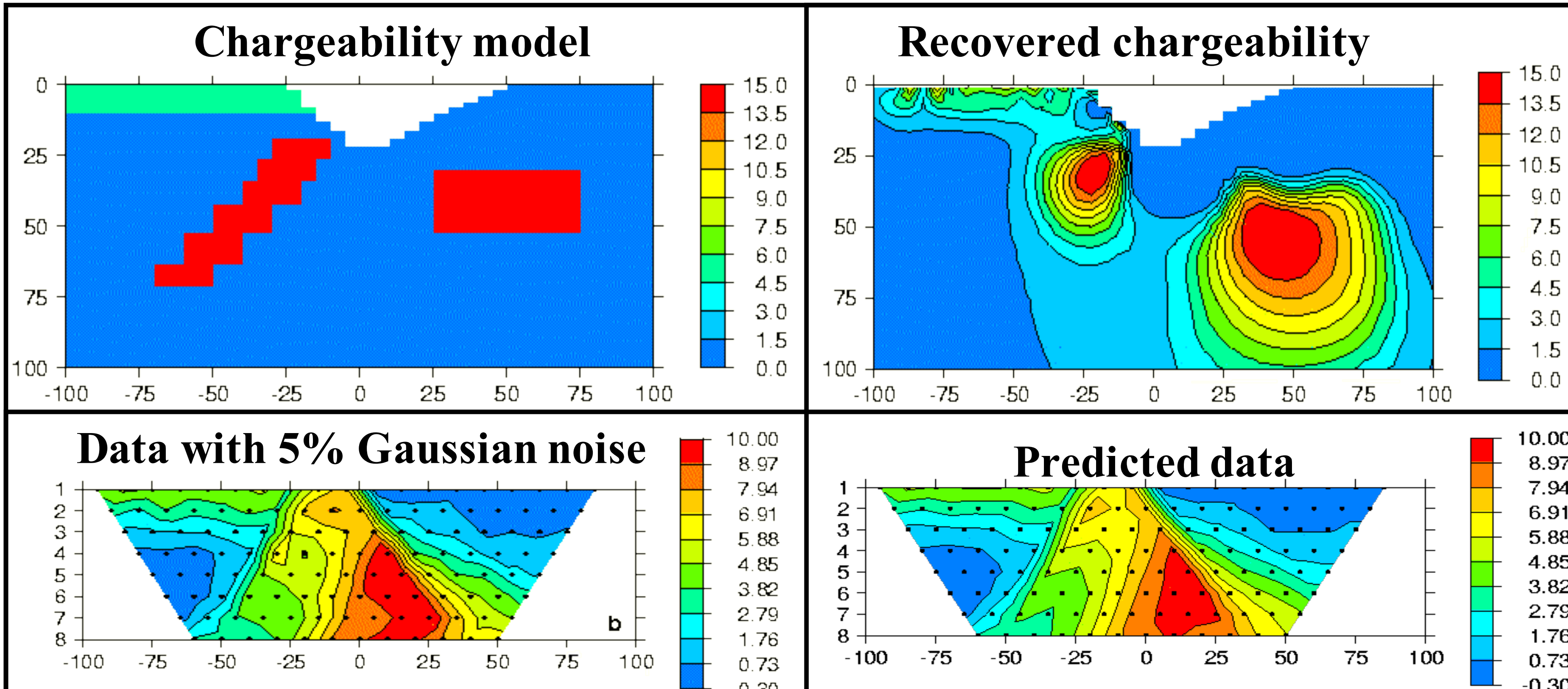
Example 2: prism with geologic noise.

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



Example 3: UBC-GIF model.

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

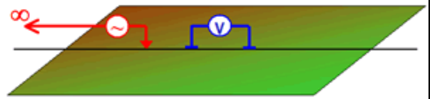


Field Case History

- Cluny deposit, Australia
- 10 lines of DCIP data acquired
- Inversion carried out in 3D

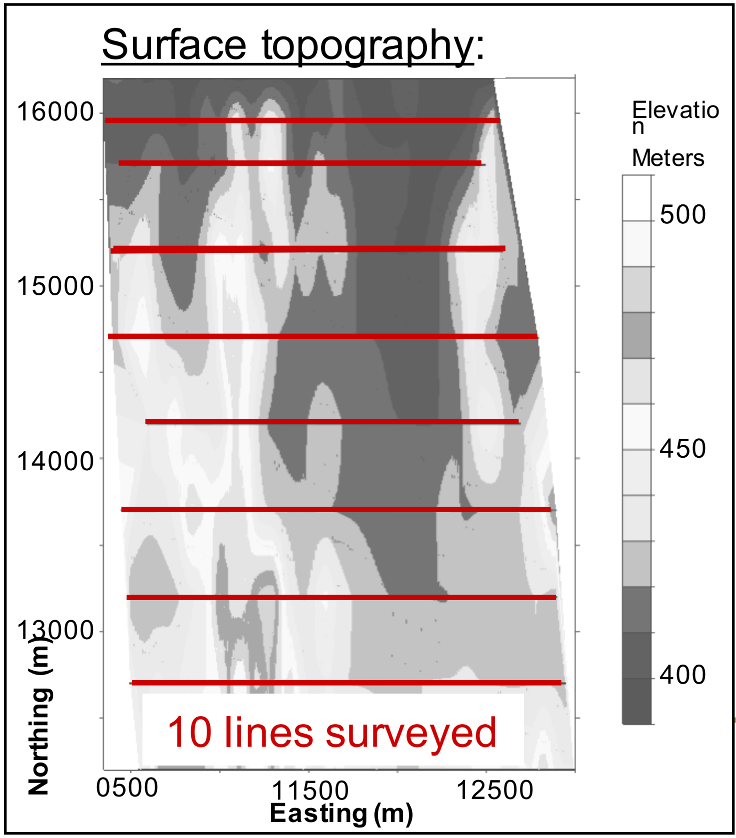
Cluny: 3D resistivity

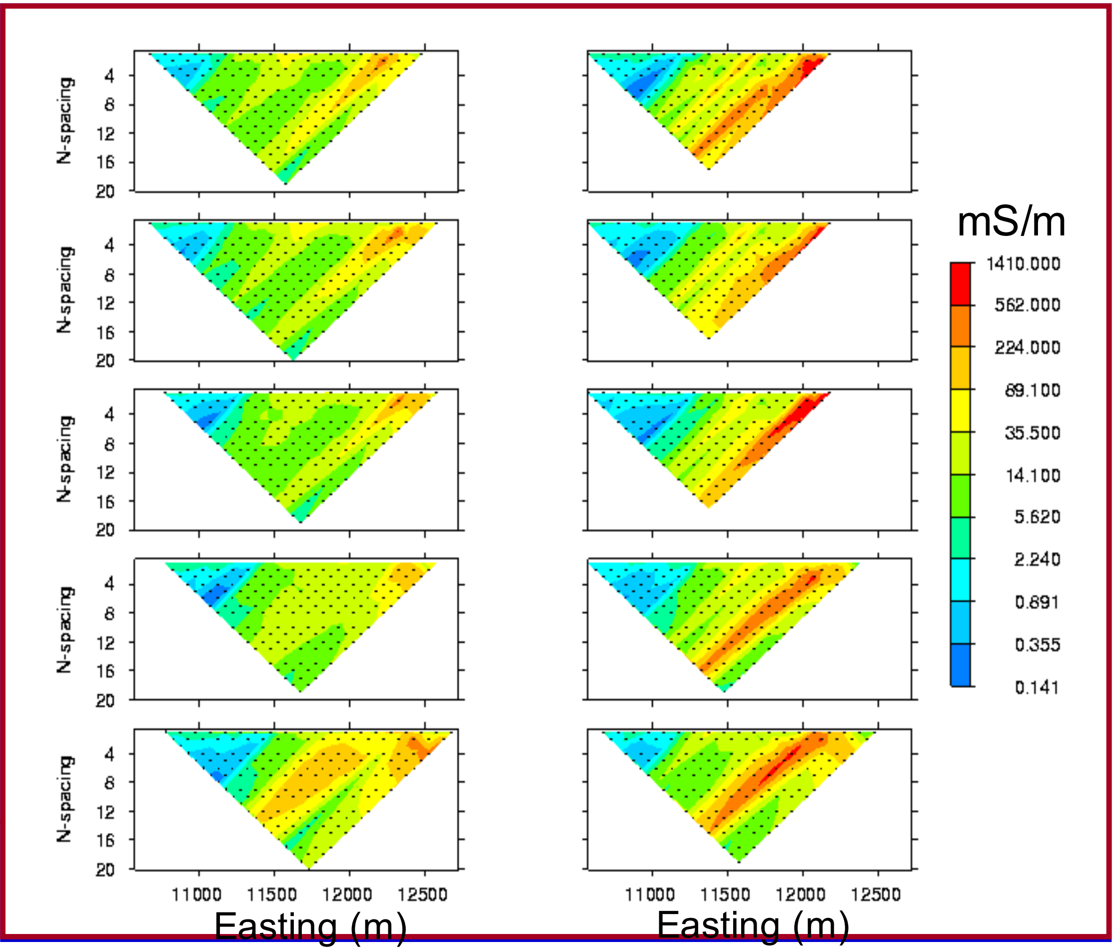
- Eight survey lines
- Two survey configurations.



Data set #2:

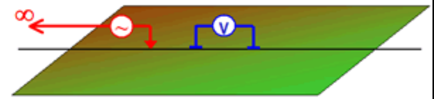
Apparent resistivity, pole - dipole.





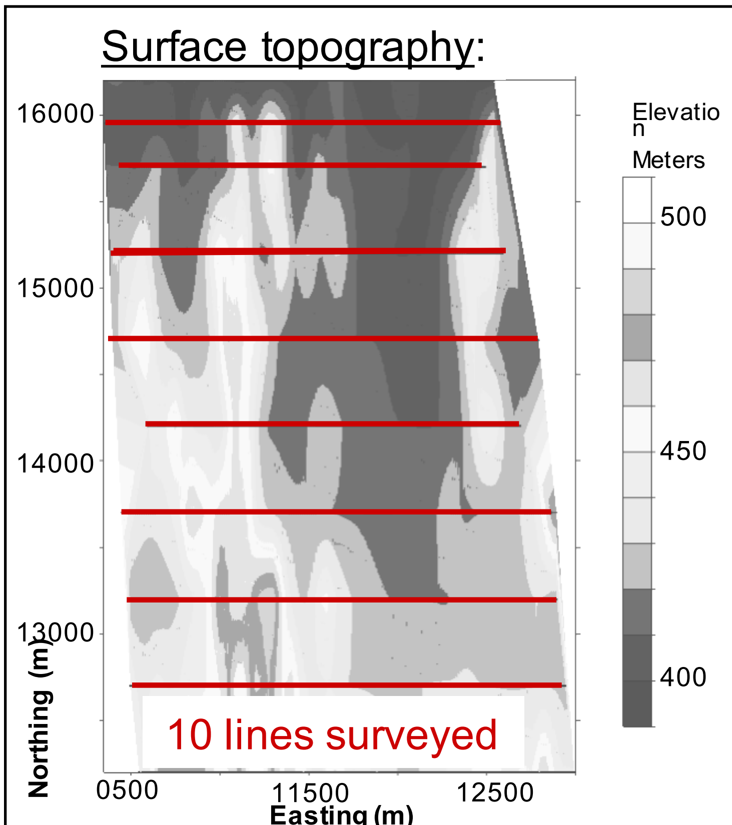
Cluny: 3D resistivity

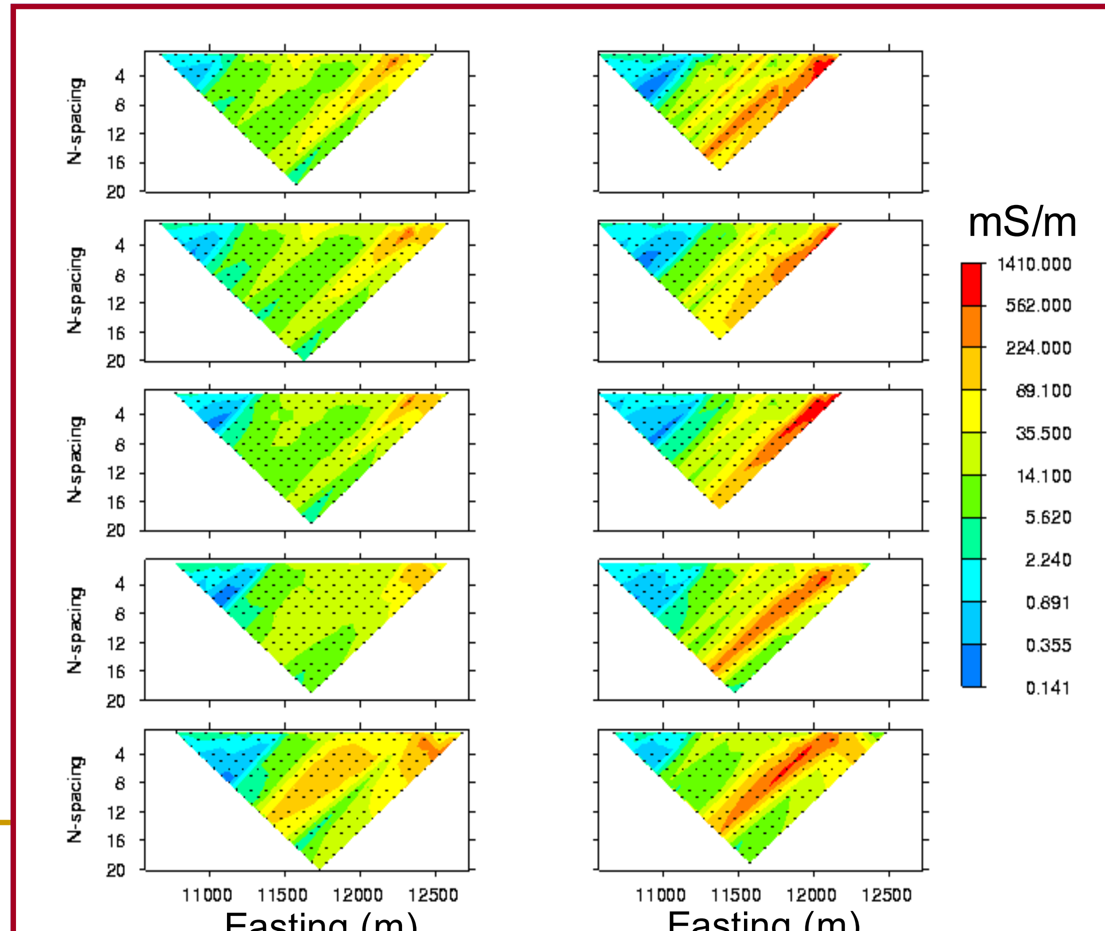
- Eight survey lines
- Two survey configurations.



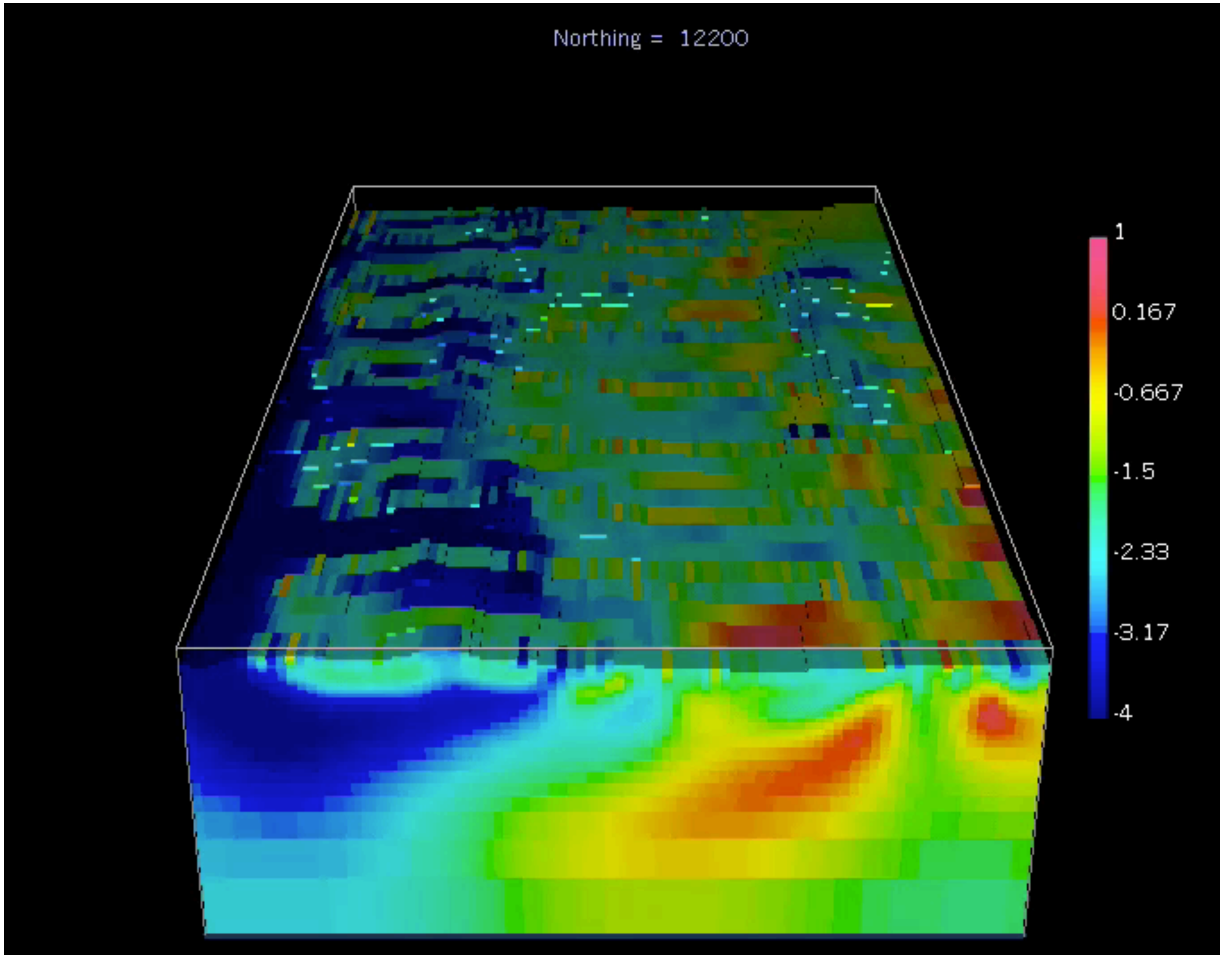
Data set #2:

Apparent resistivity, pole - dipole.

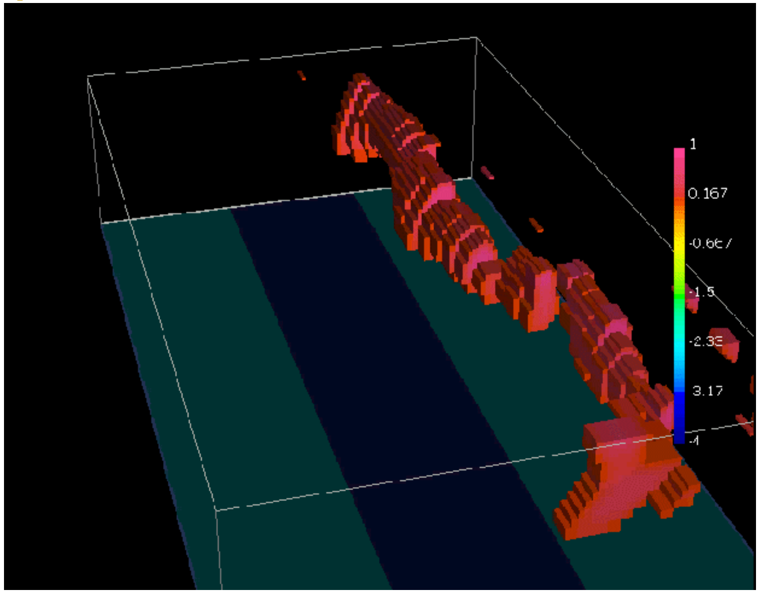


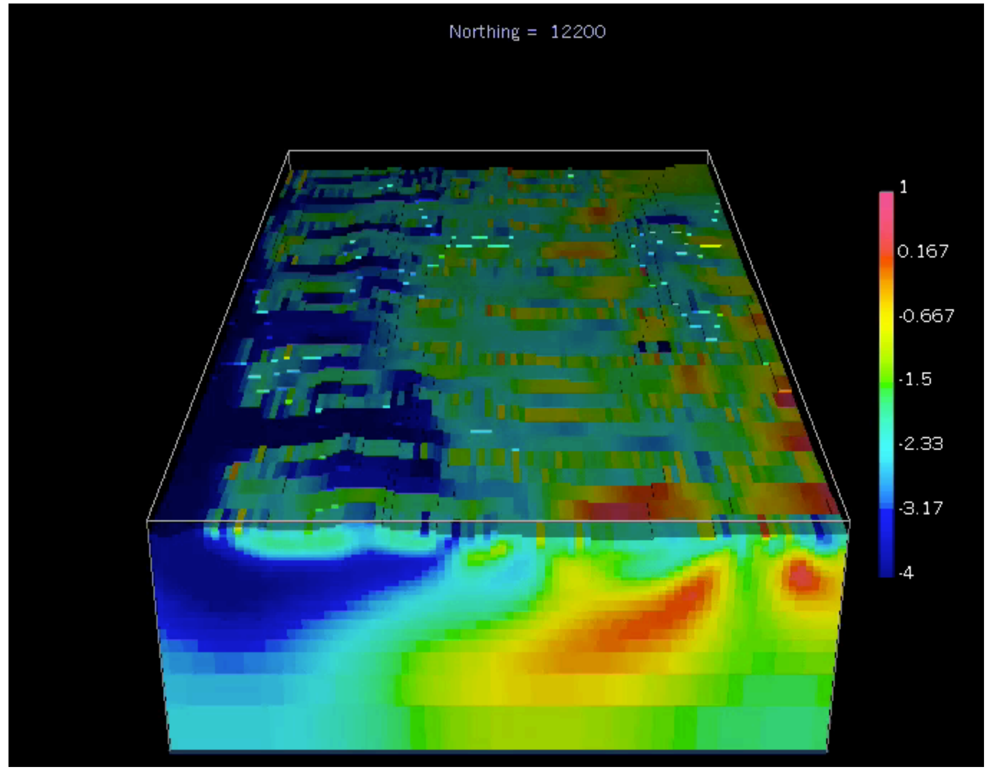


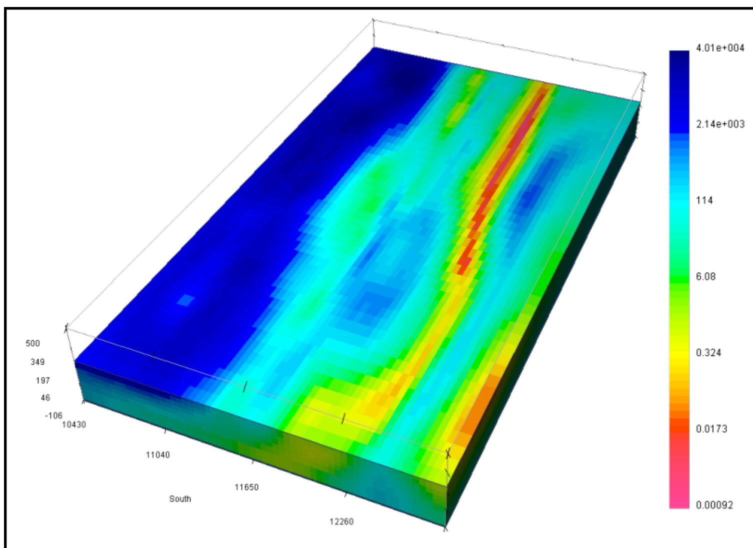
Conductivity model from 3D inversion of DC

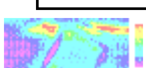


Conductivity model from 3D inversion of DC



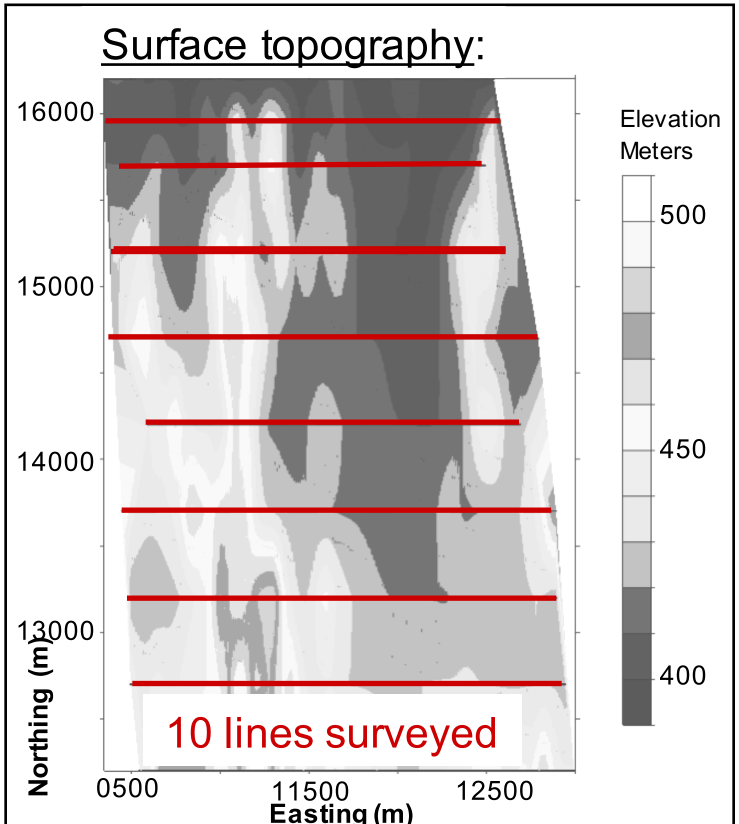


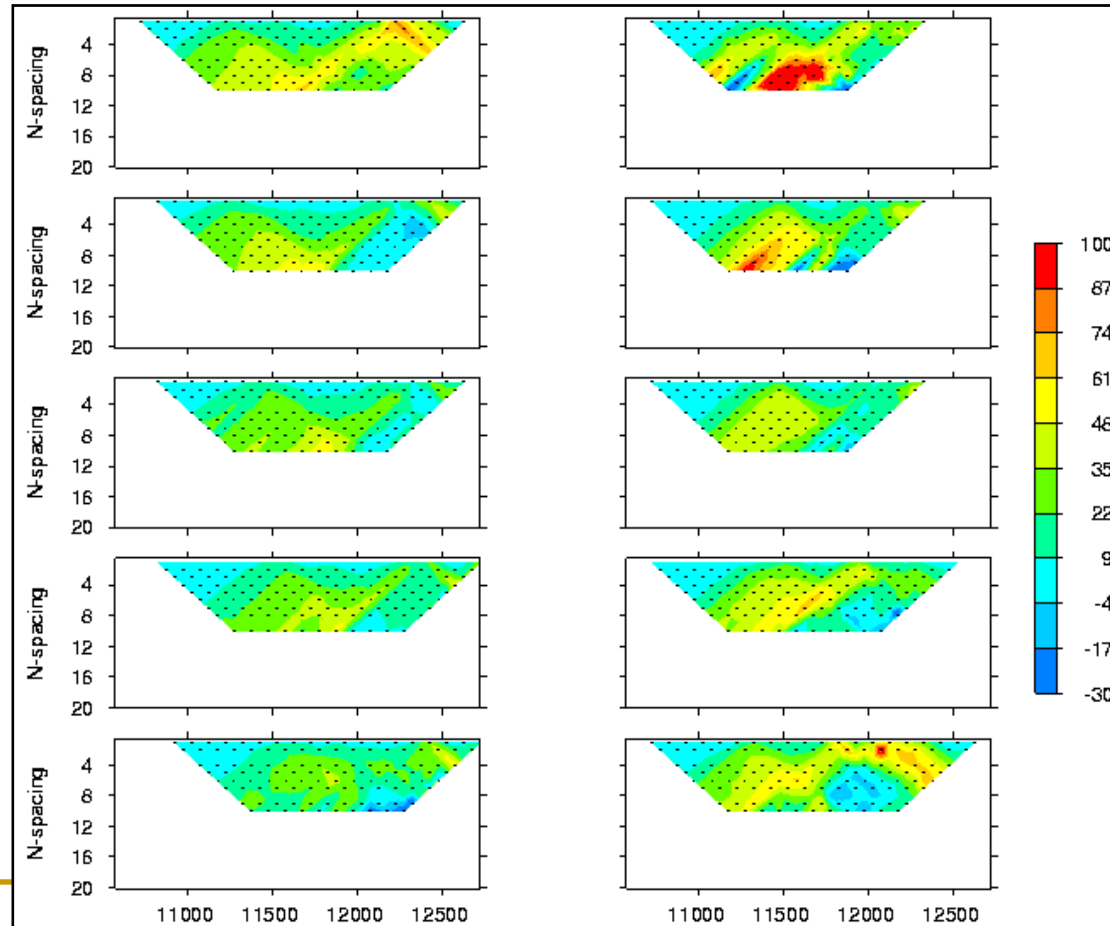




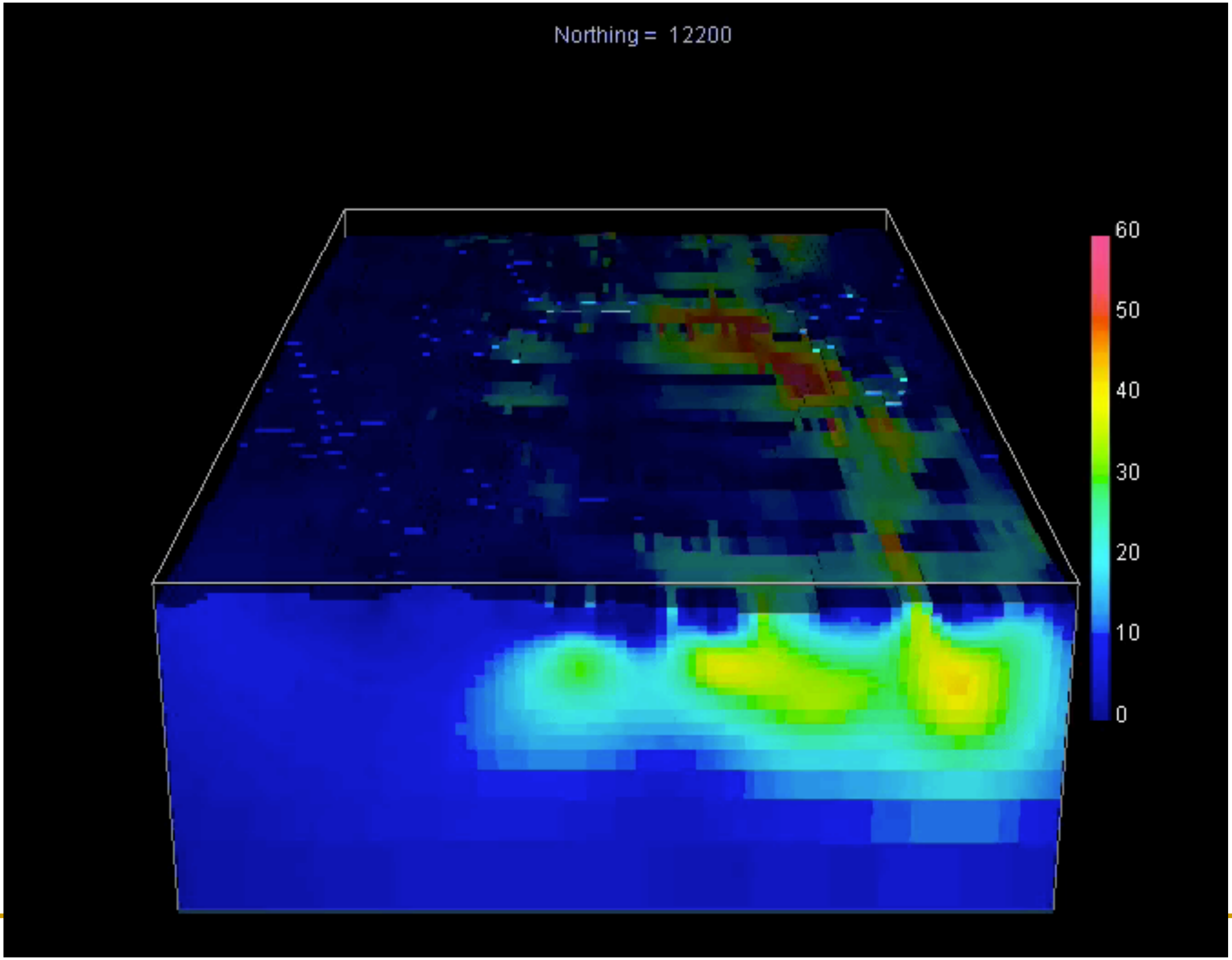
3D Induced polarization (IP)

Apparent chargeability, dipole - pole.



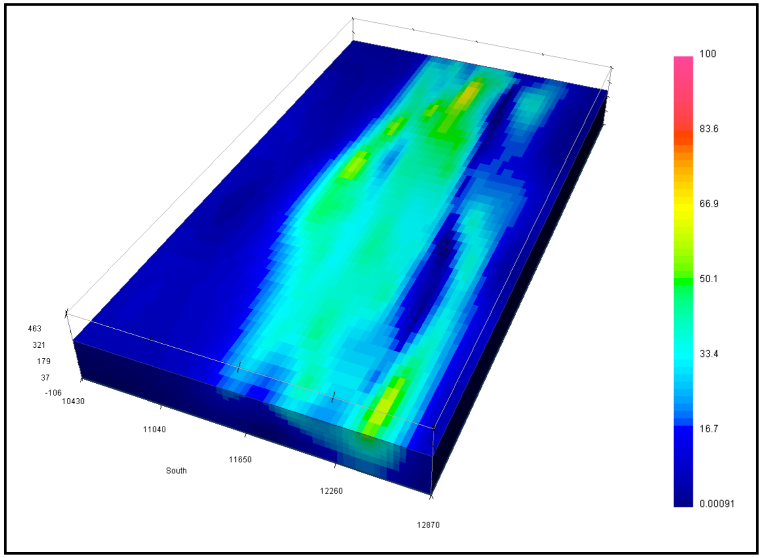


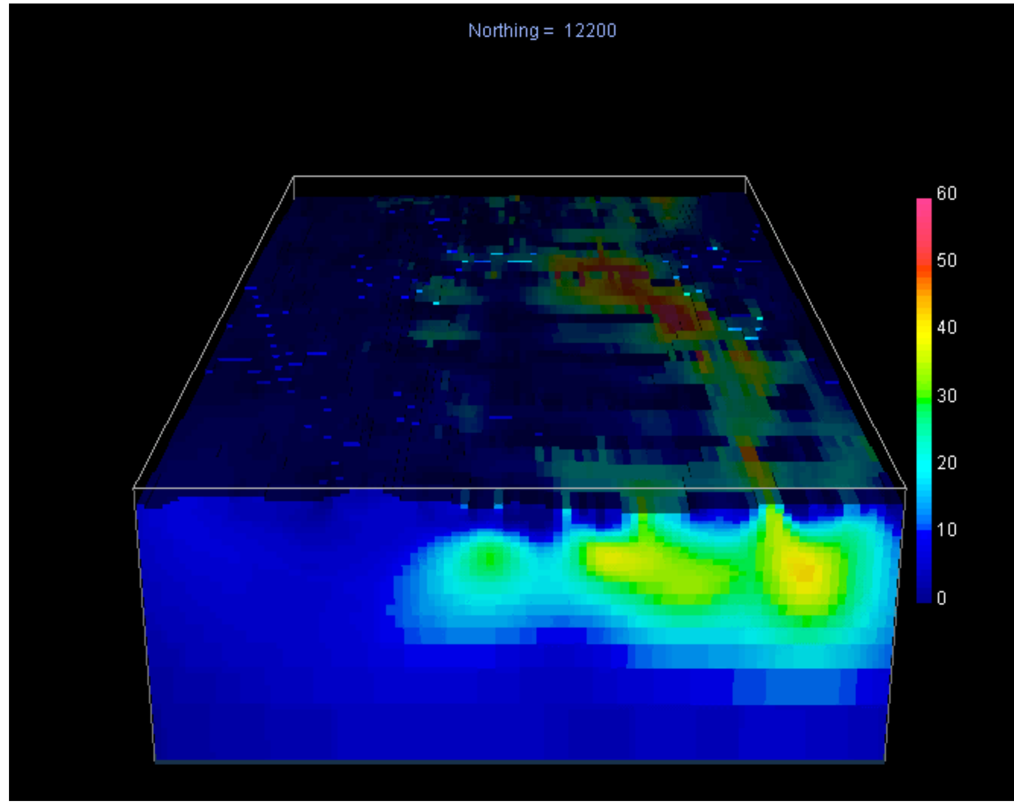
Chargeability model from 3D inversion of IP



Click image to see the AVI movie

Chargeability model from 3D inversion of IP

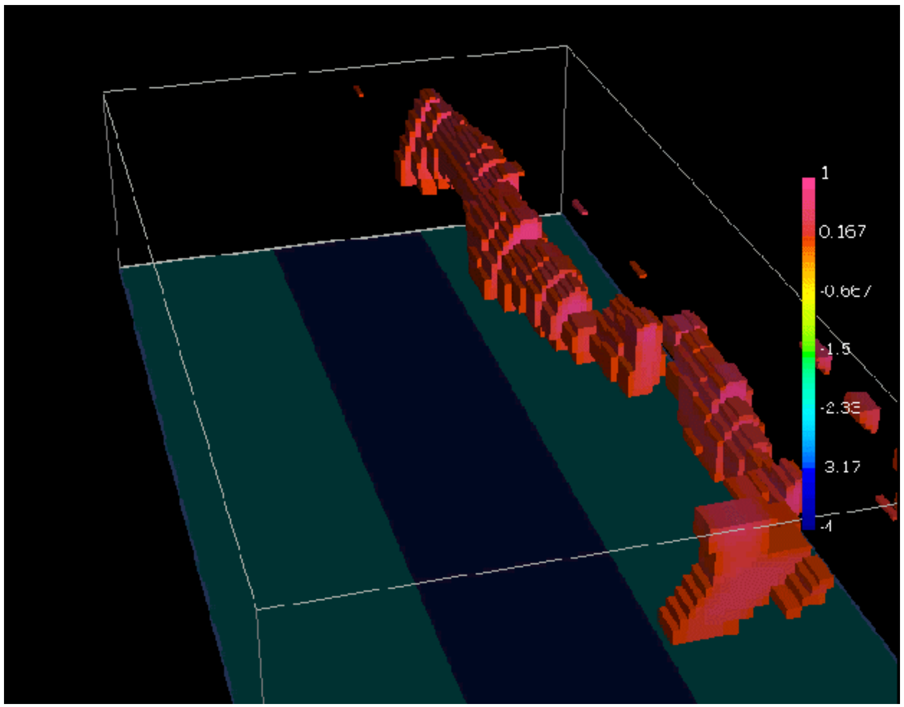




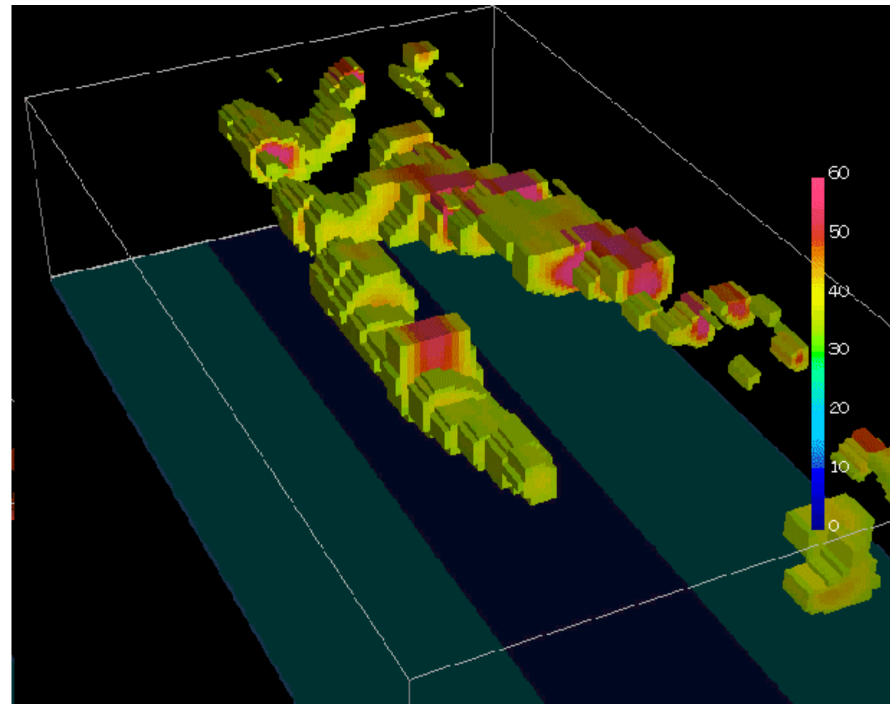
Click image to see the AVI movie

3D conductivity and chargeability models

Volume rendered resistivity model



Volume rendered chargeability model



Coming Up

- TBL DC resistivity and IP
- Quiz