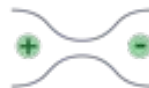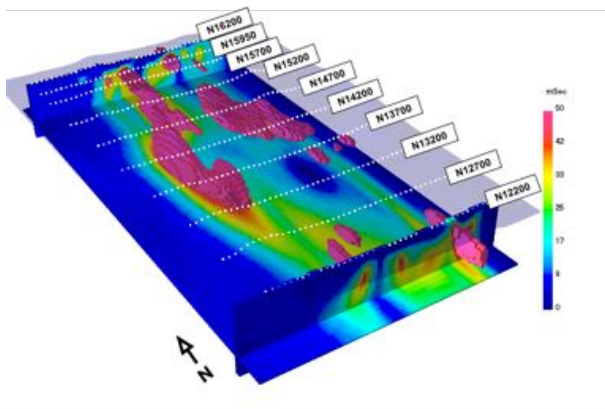# Induced Polarization

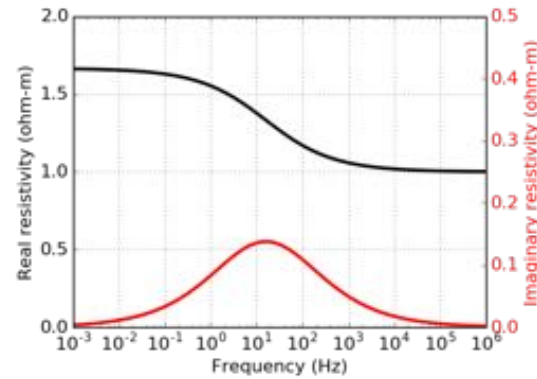# Motivation
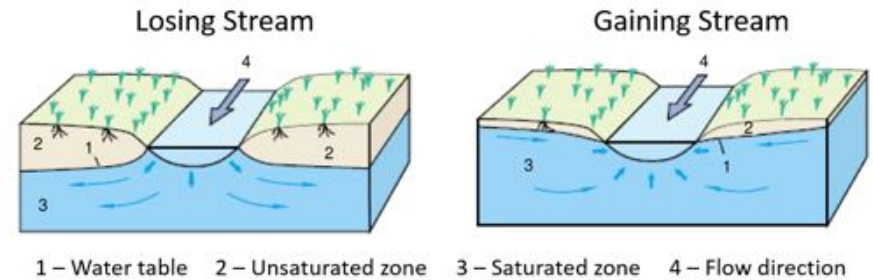
Minerals

Complex resistivity

Permafrost

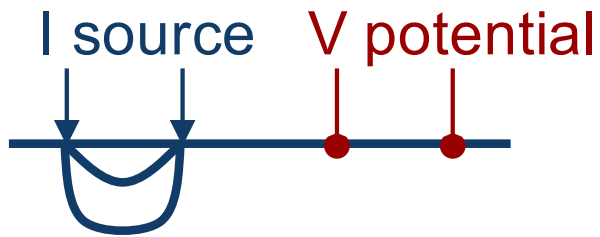Geotechnical

Groundwater

Outline

- Sources of IP

- Conceptual model of IP
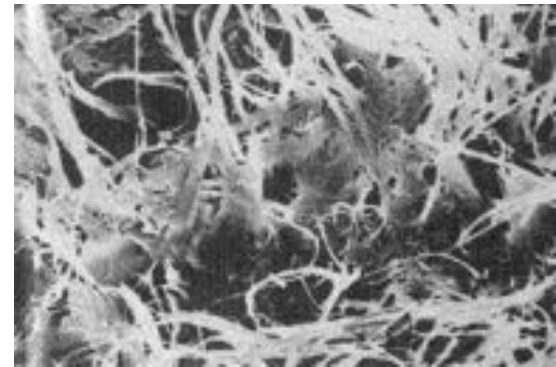
- Chargeability

- IP data

- Pseudosections

- Two stage DC-IP inversion

- Case history: Mt. Isa

Induced Polarization

- Injected currents cause materials to become polarized
- Microscopic causes → macroscopic effect
- Phenomenon is called induced polarization

I source   V potential

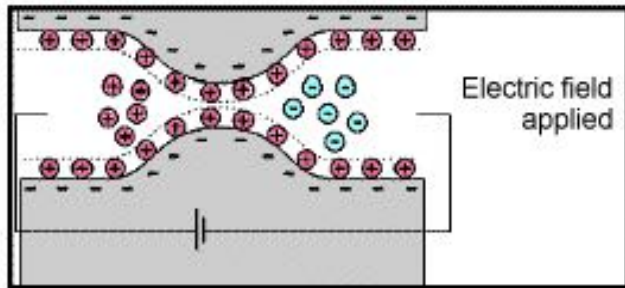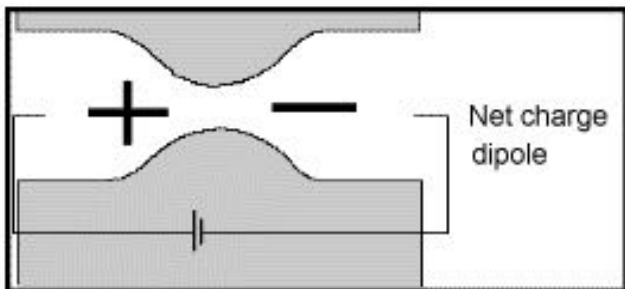|	Not chargeable	Chargeable
Source (Amps)		
Potential (Volts)		
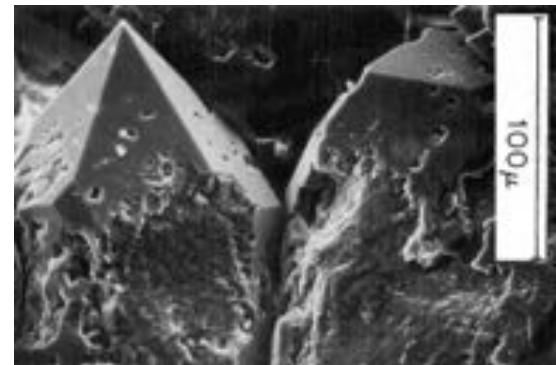
Conceptual Model of IP

Membrane polarization

Initially - neutral
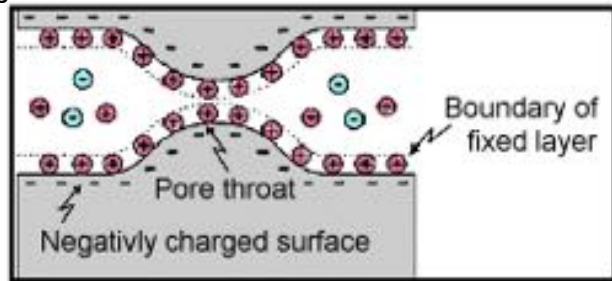
Apply electric field, build up charges

Charge polarization, Electric dipole

Electrode polarization
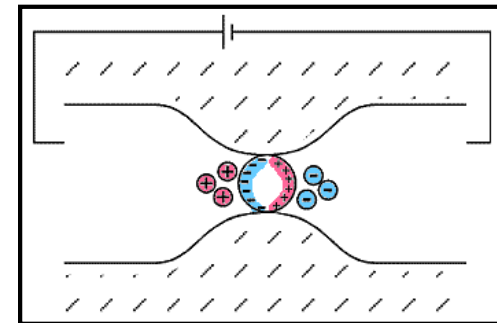
Chargeability

Minerals at 1% Concentration in Samples

Mineral	Chargeability
pyrite	13.4 ms
chalcocite	13.3 ms
copper	12.3 ms
graphite	11.2 ms
chalcopyrite	9.4 ms
bornite	6.3 ms
galena	3.7 ms
magnetite	2.2 ms
malachite	0.2 ms
hematite	0.0 ms

Chargeability

Minerals at 1% Concentration in Samples

Mineral	Chargeability
pyrite	13.4 ms
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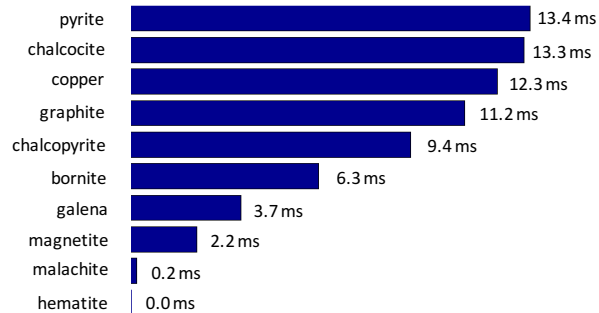
Material type	Chargeability (msec.)
20% sulfides	2000 - 3000
8-20% sulfides	1000 - 2000
2-8% sulfides	500 - 1000
volcanic tuffs	300 - 800
sandstone, siltstone	100 - 500
dense volcanic rocks	100 - 500
shale	50 - 100
granite, granodiorite	10 - 50
limestone, dolomite	10 - 20

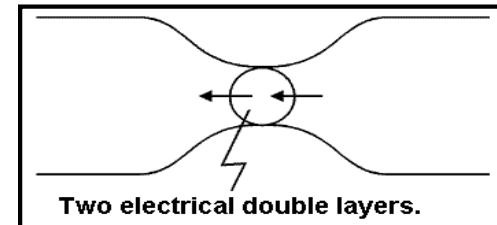| Material type	Chargeability (msec.)
ground water	0
alluvium	1 - 4
gravels	3 - 9
precambrian volcanics	8 - 20
precambrian gneisses	6 - 30
schists	5 - 20
sandstones	3 - 12

Chargeability

Initially - neutral

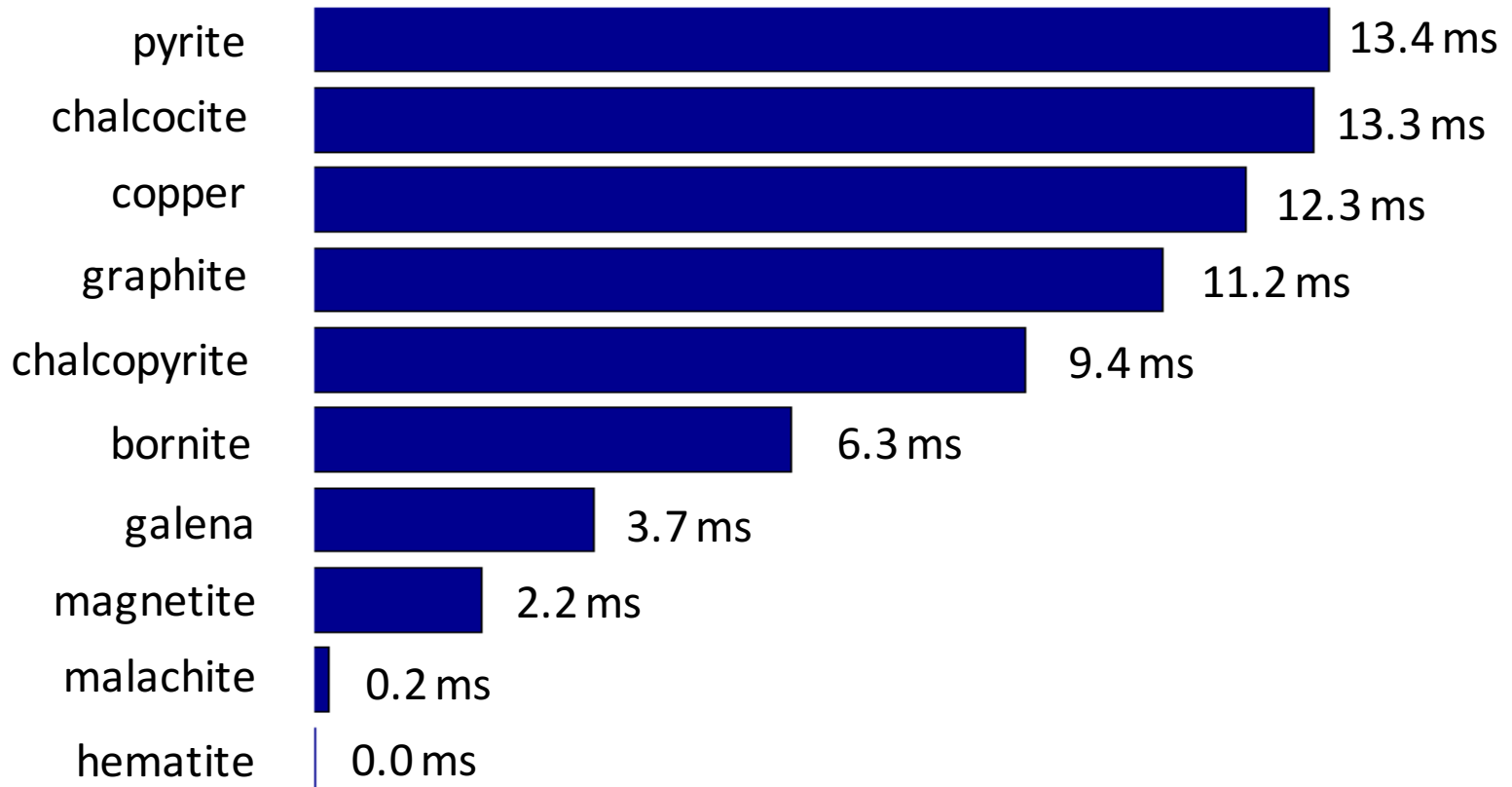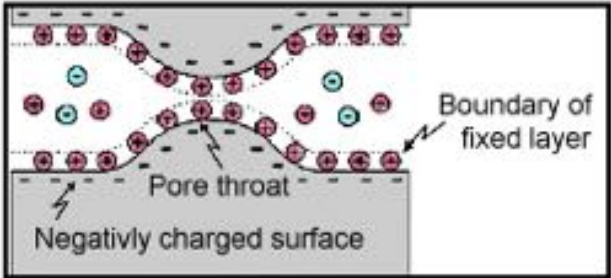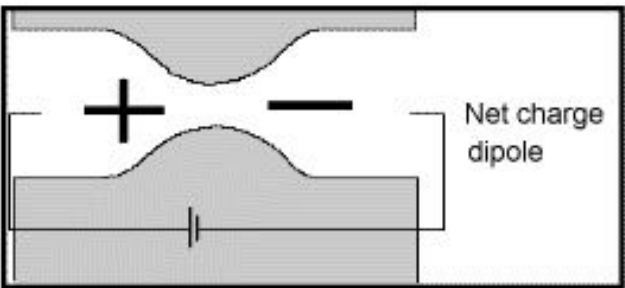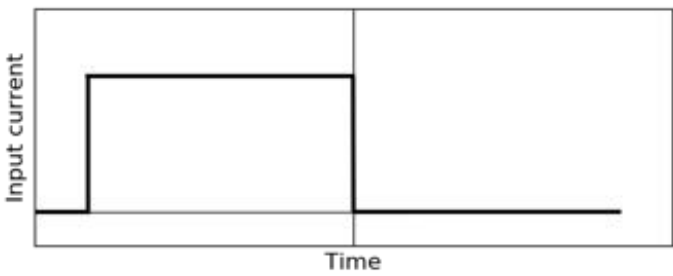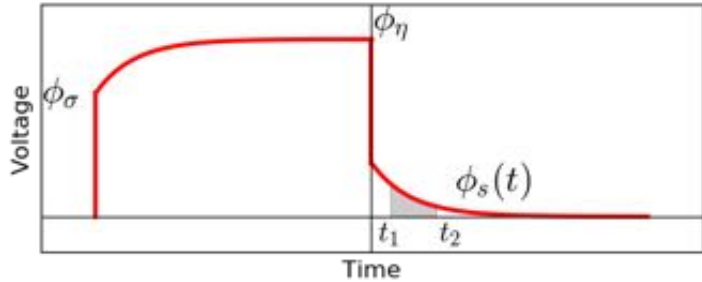Apply electric field, build up charges
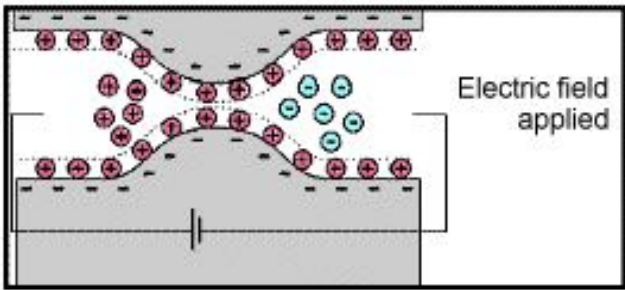
Charge polarization, Electric dipole
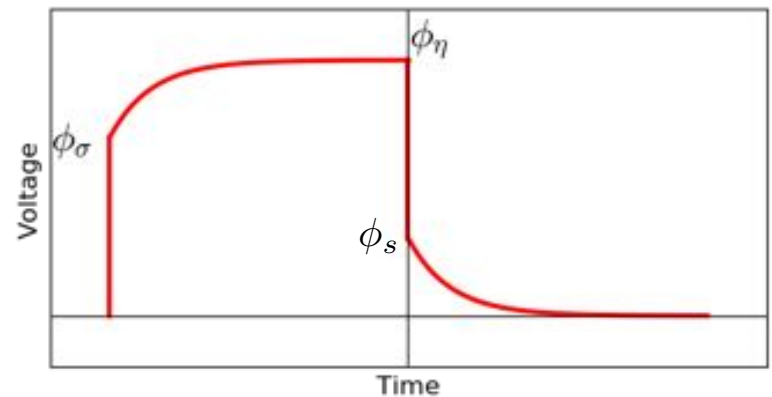
Input current

Measured voltage

IP data

- Seigel (1959):
  - Introduced chargeability: η
  - Effect reduces conductivity

$$\sigma_\eta = \sigma(1 - \eta) \qquad \eta \in [0, 1)$$

- Theoretical chargeability data

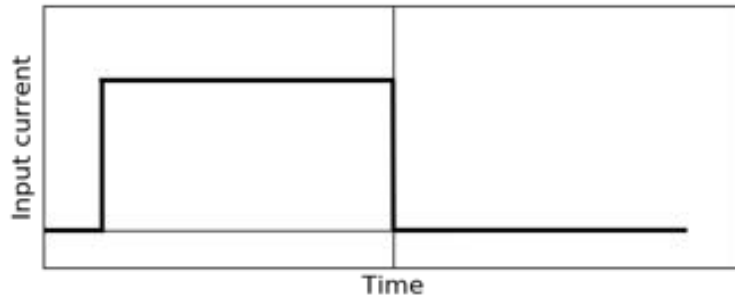$$d^{IP} = \frac{\phi_s}{\phi_\eta} = \frac{\phi_\eta - \phi_\sigma}{\phi_\eta}$$
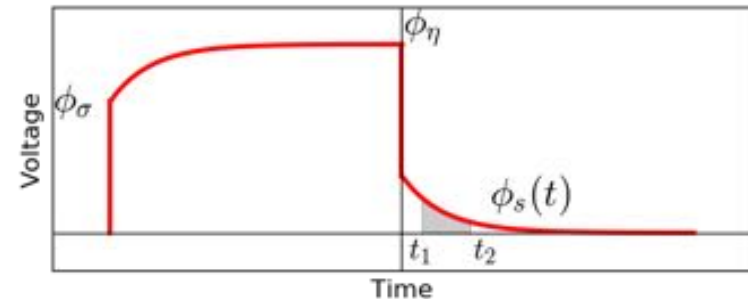

- Not directly measureable

IP data: time domain

- IP decay

Input current

Measured voltage

- IP datum

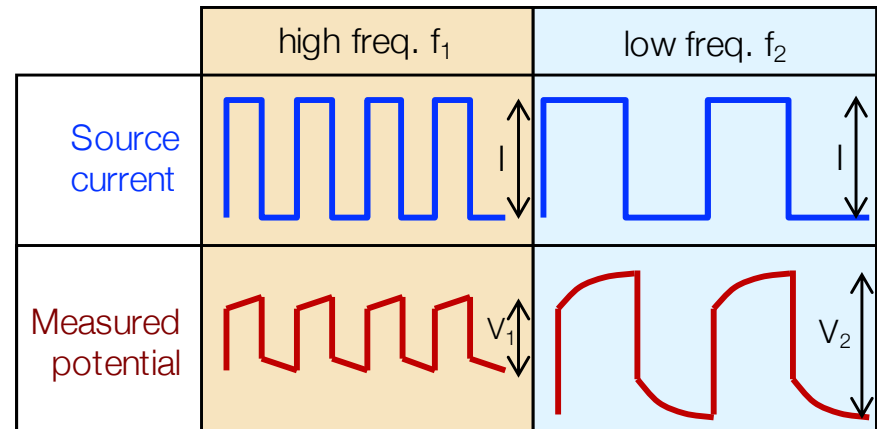|	
Dimensionless:	$\eta = \phi_s / \phi_\eta$
Value at individual time channel:	$\phi_s(t)$
Area under decay curve:	$M = \dfrac{1}{\phi_\eta} \displaystyle\int_{t_1}^{t_2} \phi_s(t)\,dt$

IP data: frequency domain
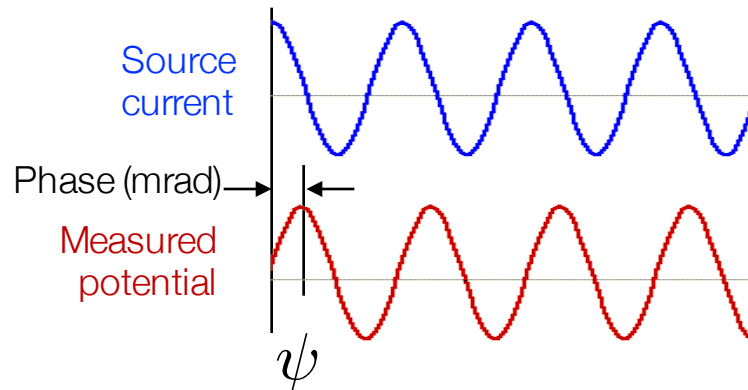
- Percent frequency effect:

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

ρ_{a1}: apparent resistivity at f_1

ρ_{a2}: apparent resistivity at f_2

	high freq. f_1	low freq. f_2
Source current		
Measured potential		

- Phase ψ

Source current

Phase (mrad)

Measured potential

ψ

IP data

- IP signals due to a perturbation (small change) in conductivity

$$\sigma_\eta = \sigma(1 - \eta) \qquad\qquad \eta \in [0, 1)$$

- An IP datum can be written as

$$d_i^{IP} = \sum_{j=1}^{M} J_{ij} \eta_j \qquad i = 1, \dots, N$$

$$J_{ij} = \frac{\partial log\phi^i}{\partial log\sigma_j} \qquad \text{sensitivities for the DC resistivity problem}$$
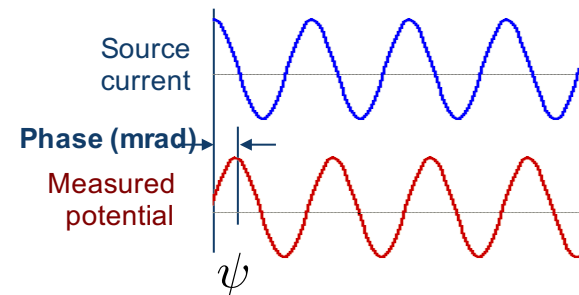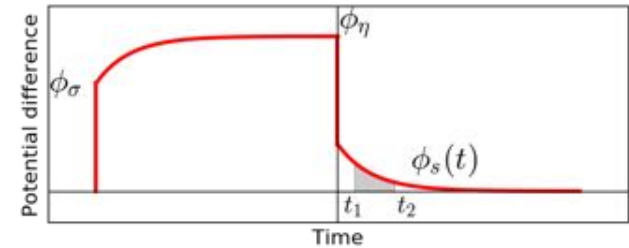
- In matrix form

$$\mathbf{d}^{IP} = \mathbf{J}\boldsymbol{\eta}$$

$\mathbf{J}$ is an N×M matrix

Summary of IP data

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

- Frequency domain:
  - PFE (dimensionless)
  - Phase (mrad)
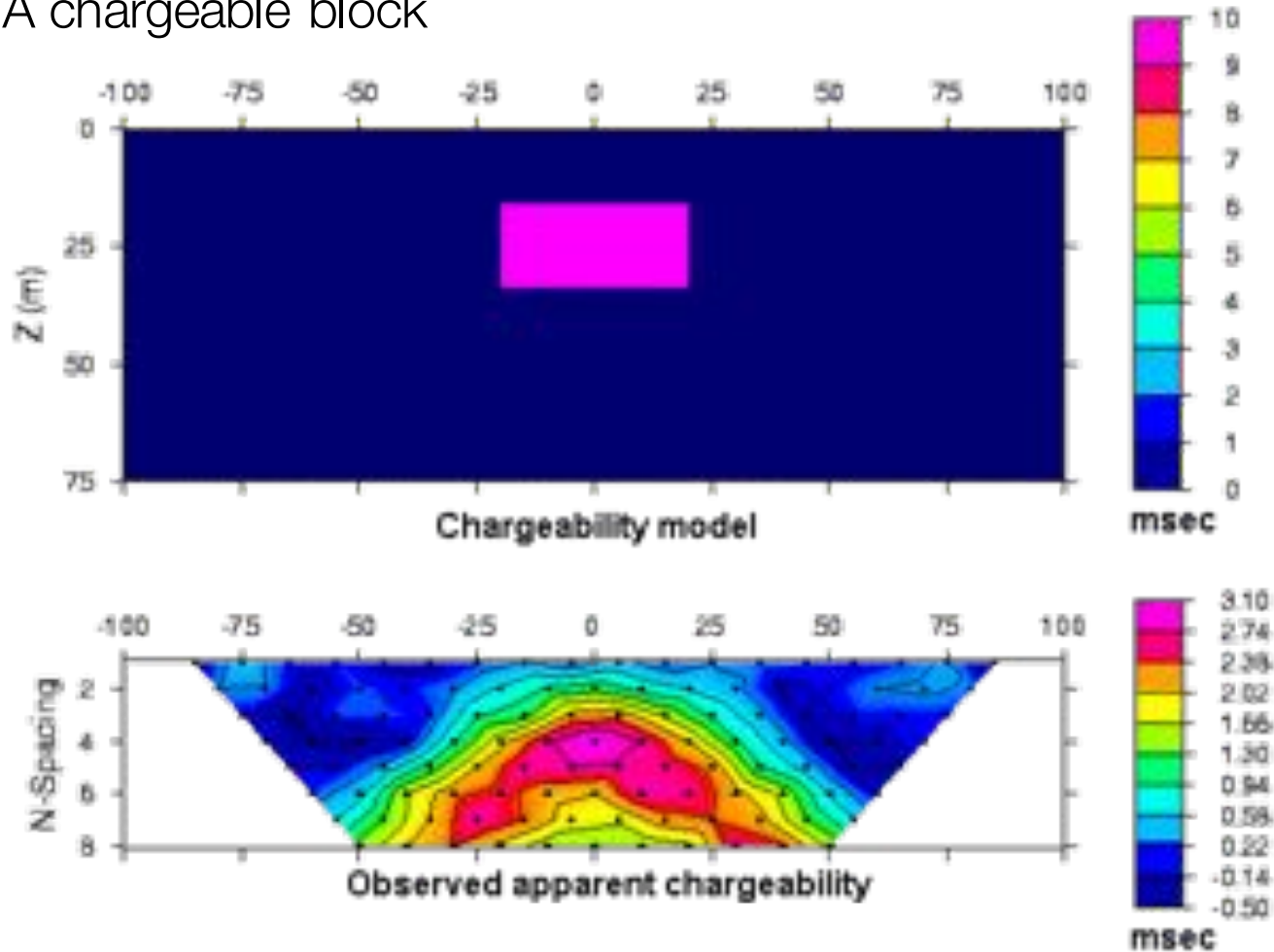
- For all data types: linear problem

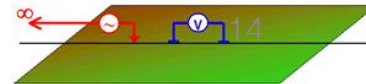$$\mathbf{d}^{IP} = \mathbf{J}\boldsymbol{\eta}$$

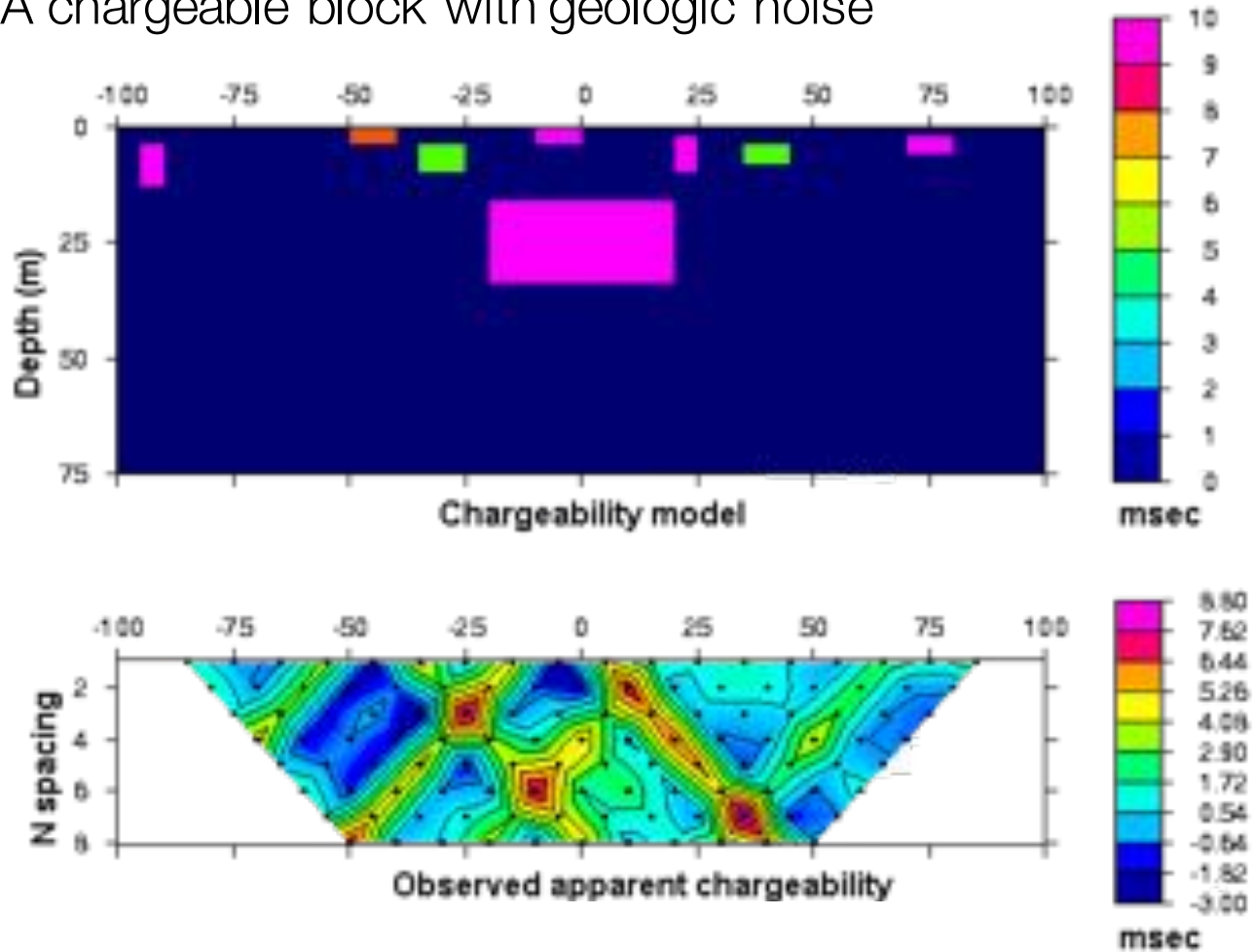$\mathbf{J}$ is an N×M matrix

IP pseudosections

1) A chargeable block

Chargeability model

Observed apparent chargeability

Pole-Dipole

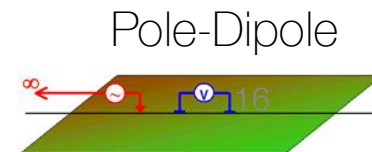- Pole-dipole; n=1,8; a=10m; N=316

IP pseudosections

2) A chargeable block with geologic noise

Chargeability model

Observed apparent chargeability

Pole-Dipole

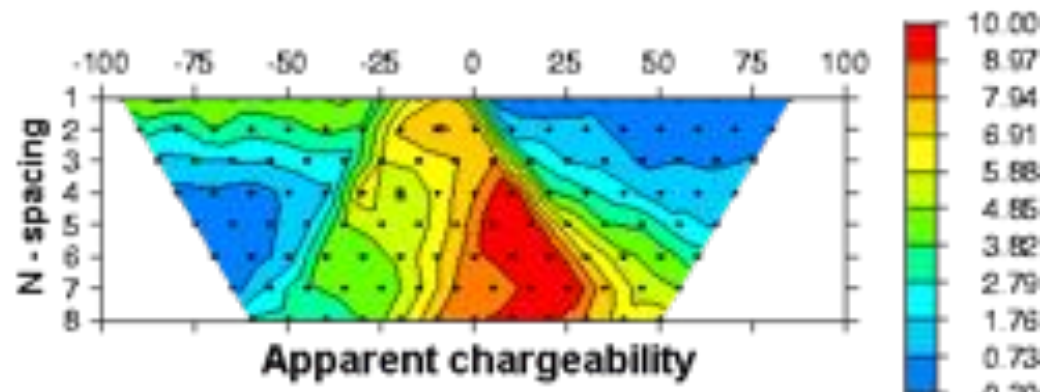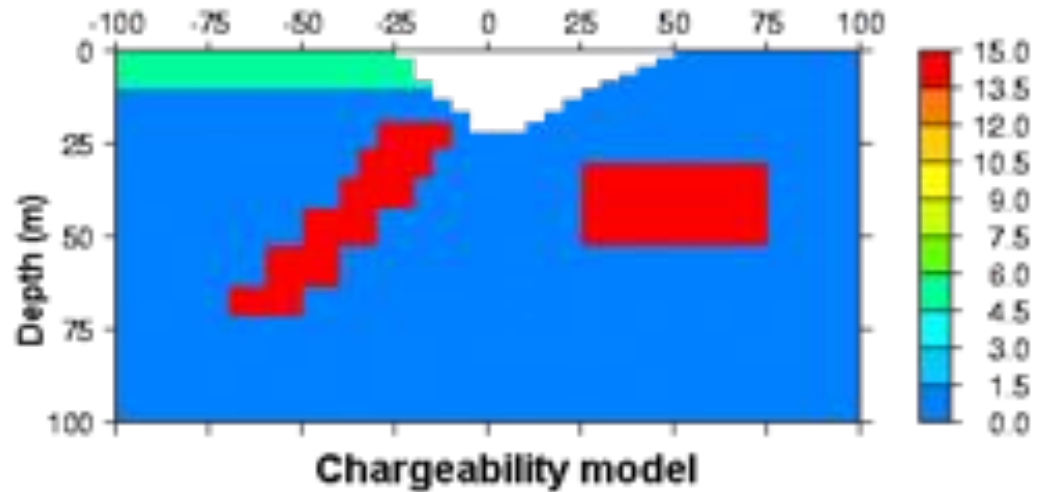- Pole-dipole; n=1,8; a=10m; N=316
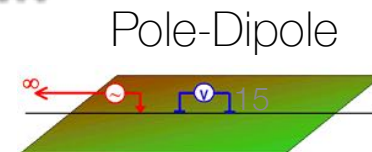
IP pseudosections

3) The "UBC-GIF model"

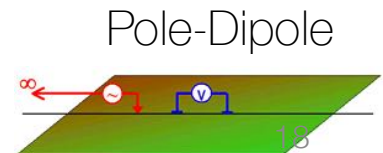Chargeability model

Apparent chargeability

Pole-Dipole

IP Inversion

DC / IP data collected

Potential (i.e. voltage) data

IP Data

Invert potentials for conductivity, σ

Conductivity model

Use σ model for sensitivity

Invert for chargeability

Chargeability model

Example 1: buried prism

Chargeability model

Recovered chargeability

Data with 5% Gaussian noise

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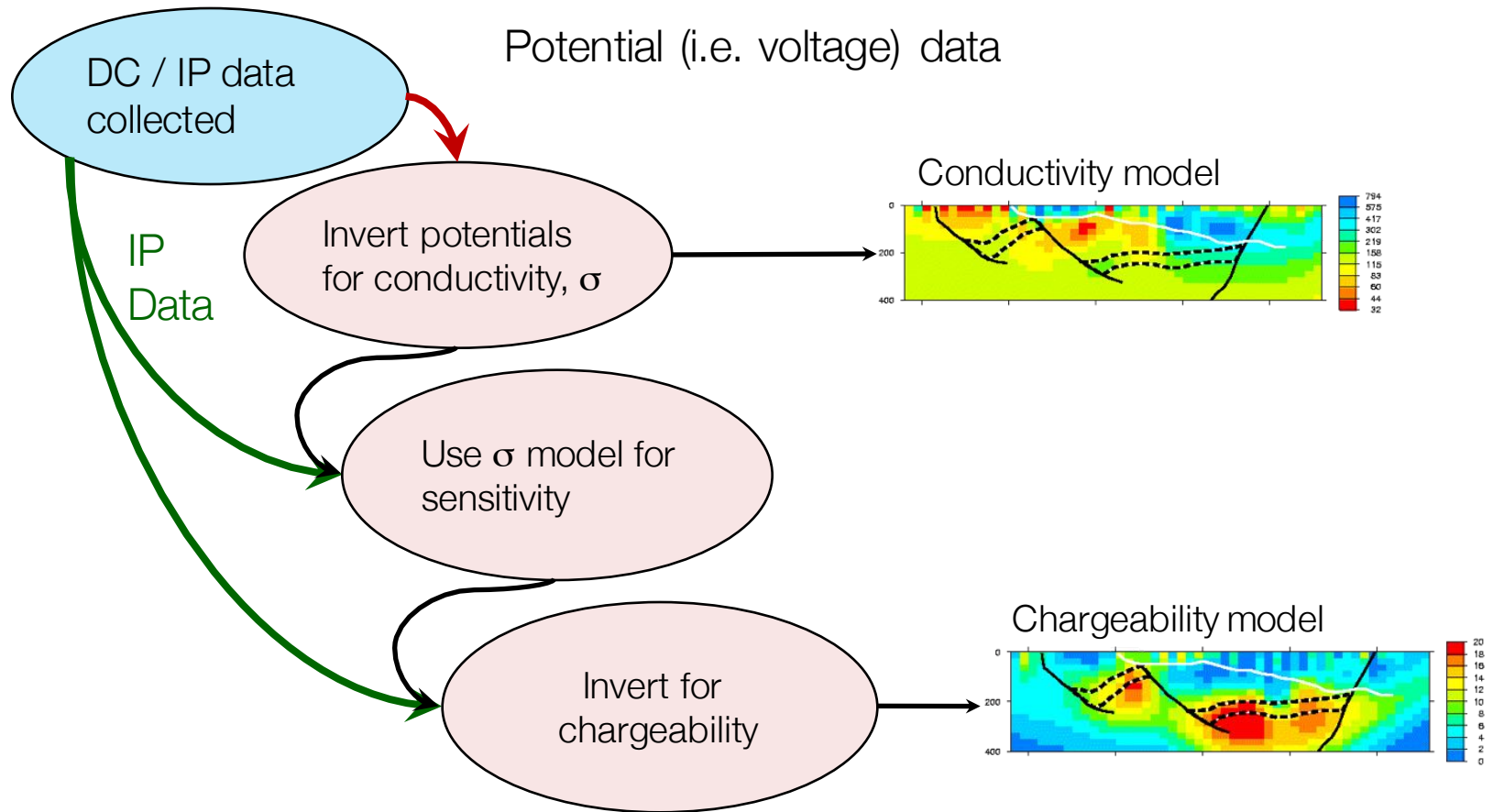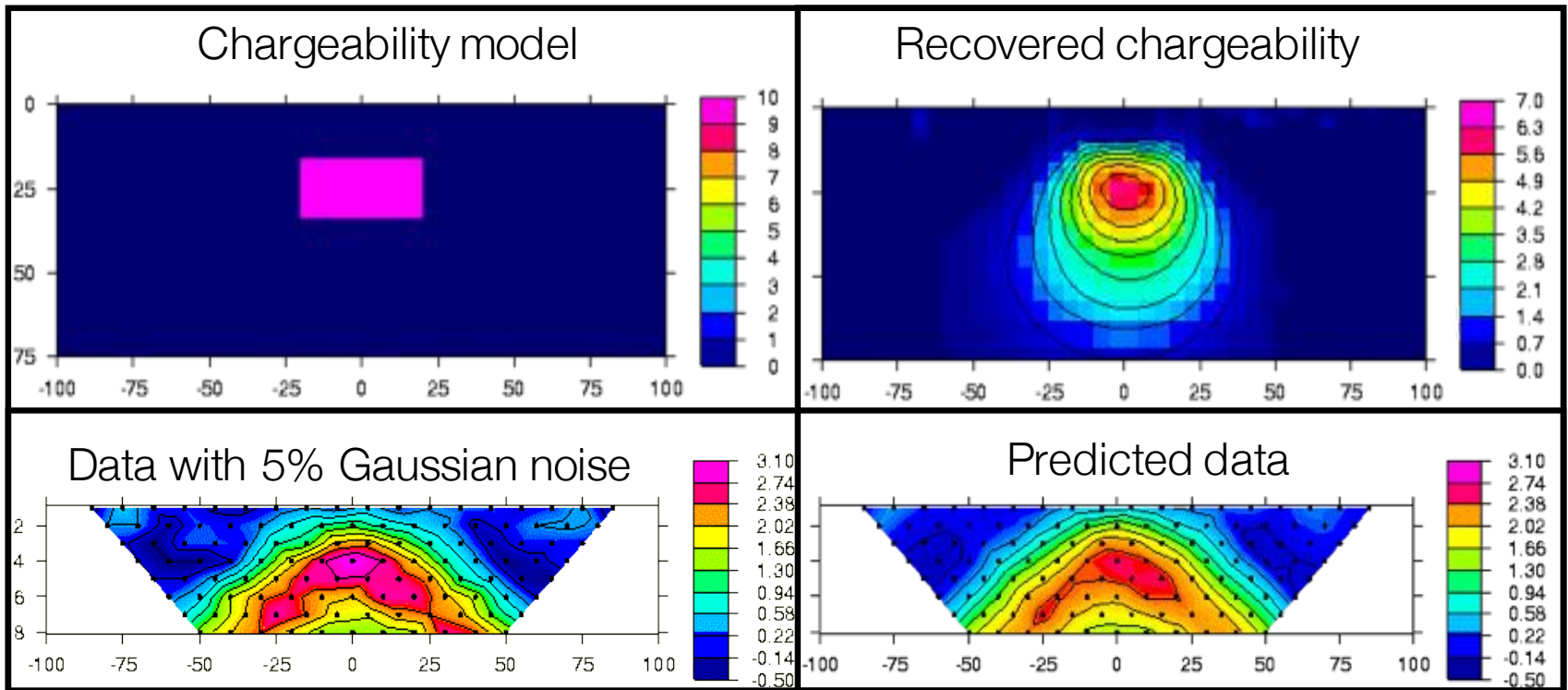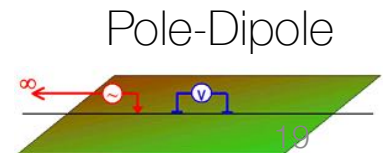
- Pole-dipole;   n=1,8; a=10m; N=316; $(\alpha_s, \alpha_x, \alpha_z)=(.001, 1.0, 1.0)$

Pole-Dipole

Example 2: prism with geologic noise

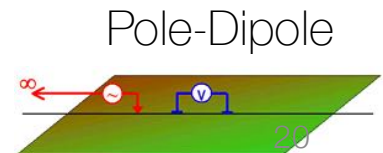Chargeability model

Recovered chargeability

Data with 5% Gaussian noise

Predicted data

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

Pole-Dipole

Example 3: UBC-GIF model

Chargeability model

Recovered chargeability

Data with 5% Gaussian noise

Predicted data
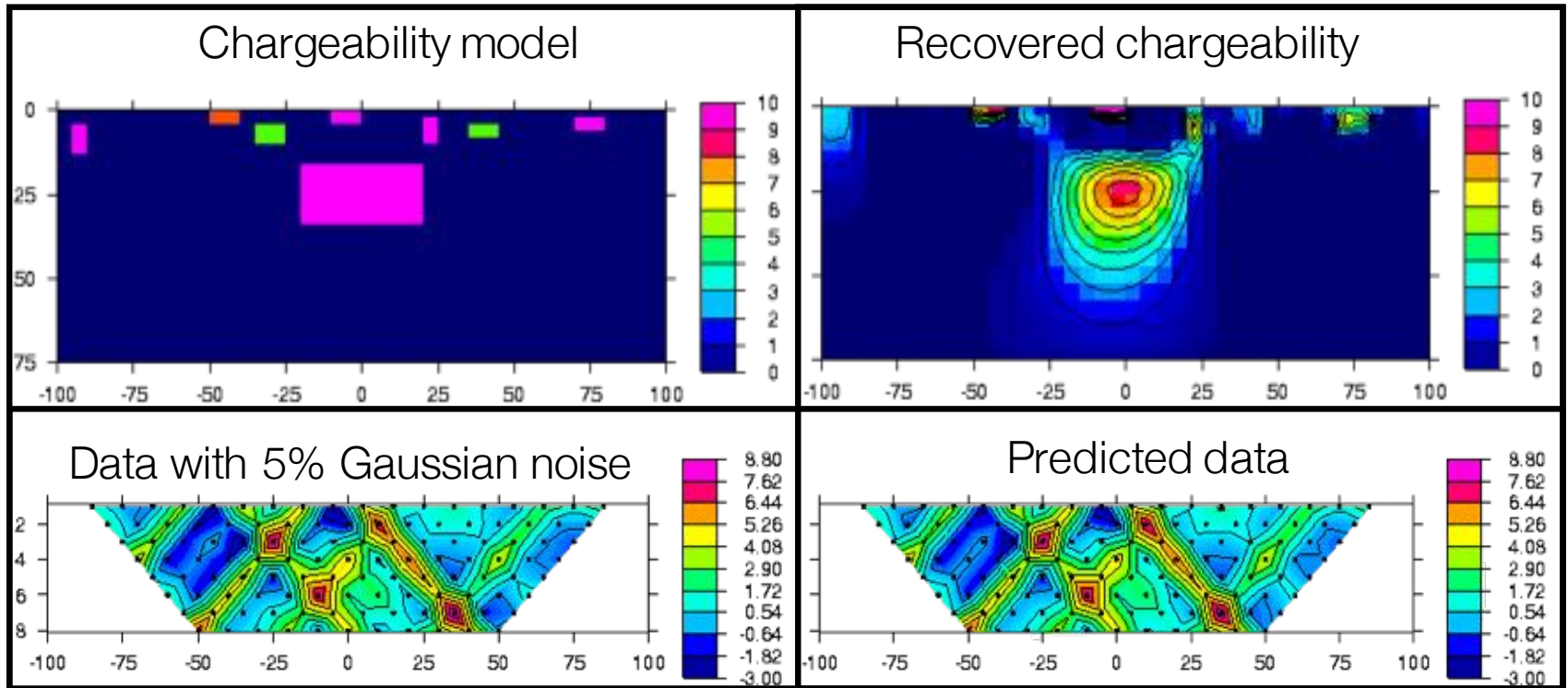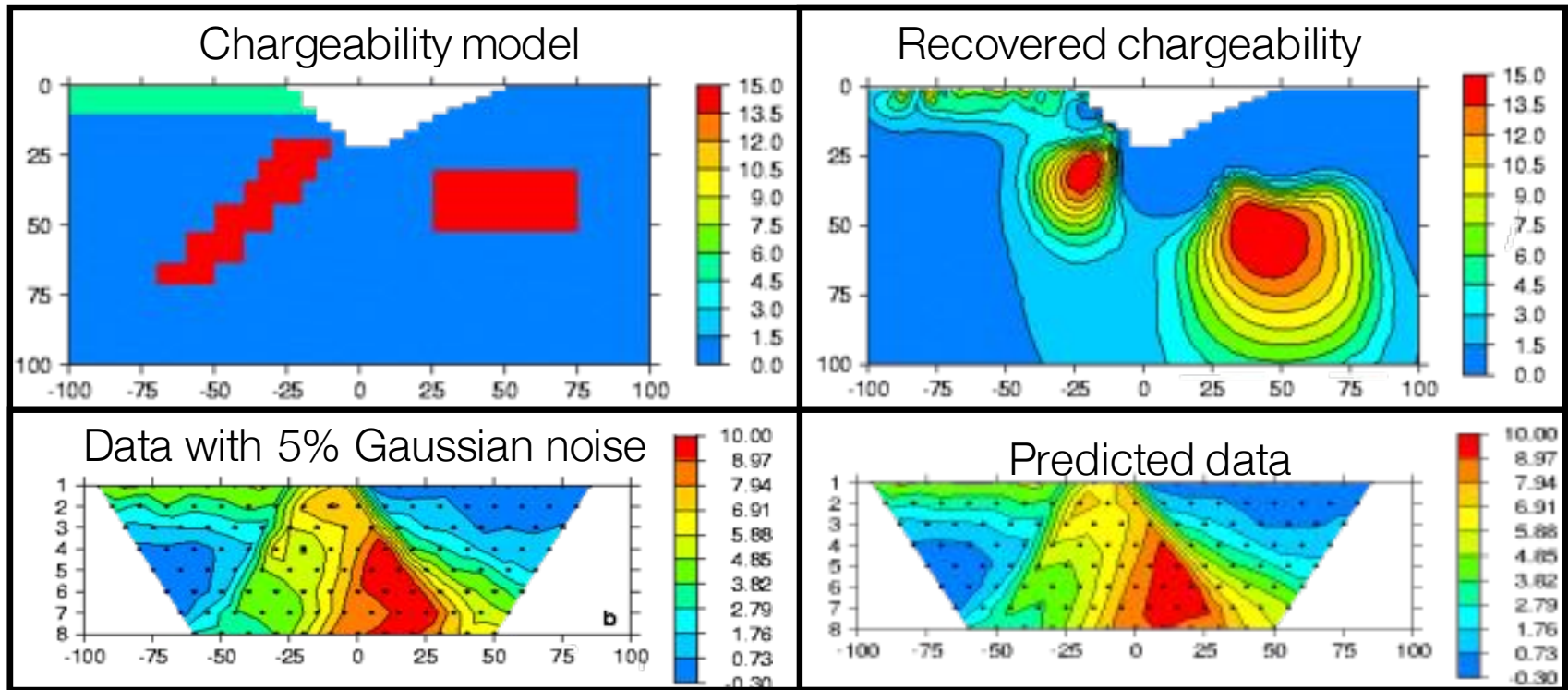
Pole-Dipole

• Pole-dipole;　n=1,8;　a=10m

Induced Polarization: Summary

- Sources of IP

- Conceptual model of IP

- Chargeability

- IP data

- Pseudosections

- Two stage DC-IP inversion
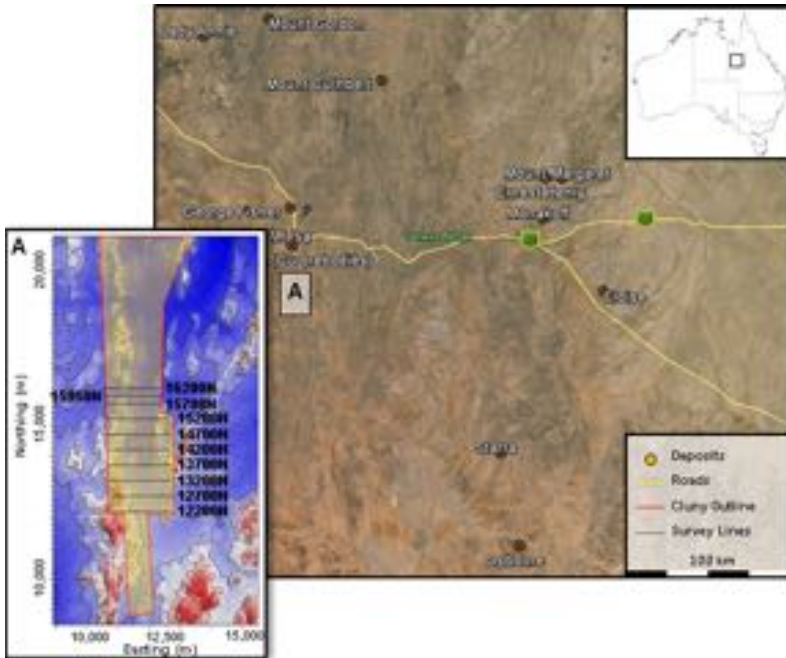
- Case history: Mt. Isa

- Questions

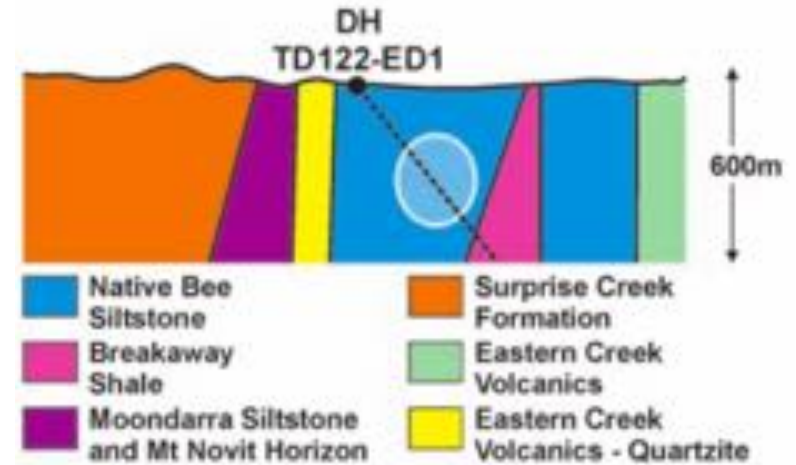- Case history: Mt. Isa

Case history: Mt. Isa

Rutley et al., 2001

Setup

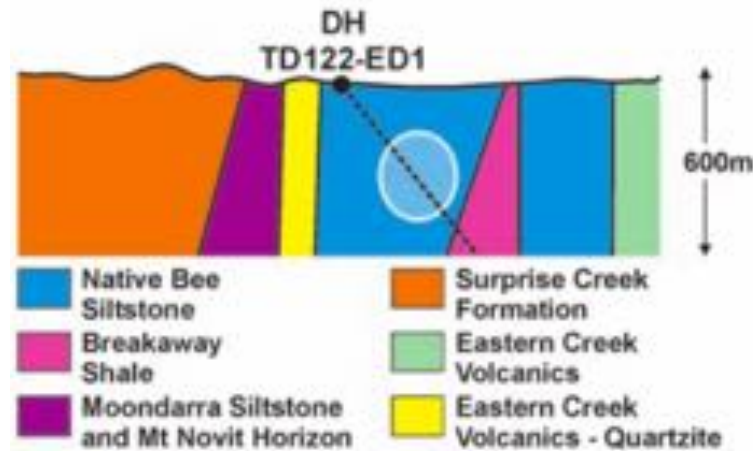- Mt. Isa (Cluny propect)

- Geologic model

Question

- Can conductive, chargeable units, which would be potential targets within the siltstones, be identified with DC / IP data?

Properties

Geologic model

Resistivity and Chargeability

| Rock Unit	Conductivity	Chargeability
Native Bee Siltstone	Moderate	Low
Moondarra Siltstone	Moderate	Low
Breakaway Shale	Very High	Low-None
Mt Novit Horizon	High	High
Surprise Creek Formation	Low	None
Eastern Creek Volcanics	Low	None

Recap: Synthesis from DC

- Identified a major conductor → black shale unit
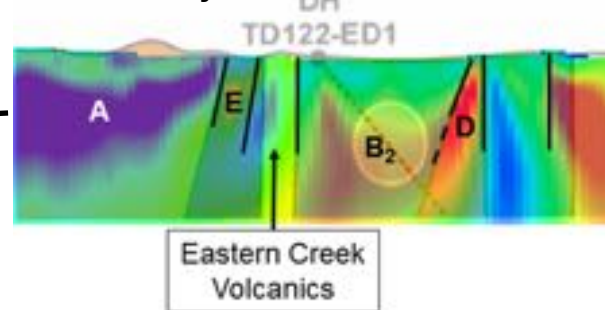- Some indication of a moderate conductor
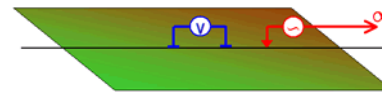
3D resistivity model

Geologic section

Native Bee Siltstone	Surprise Creek Formation
Breakaway Shale	Eastern Creek Volcanics
Moondarra Siltstone and Mt Novit Horizon	Eastern Creek Volcanics - Quartzite
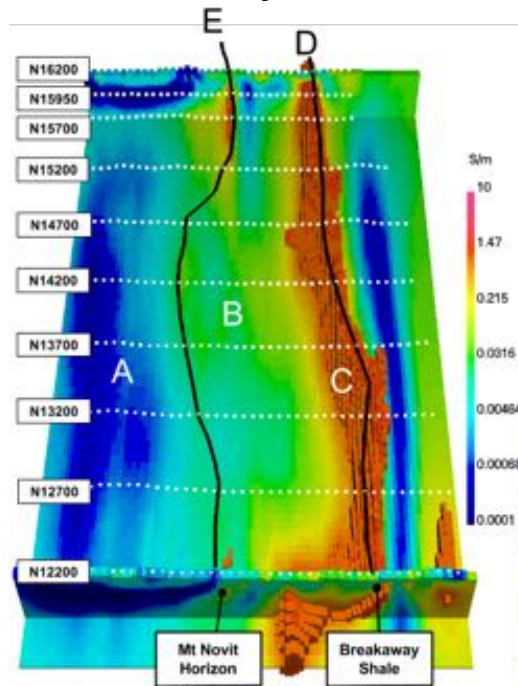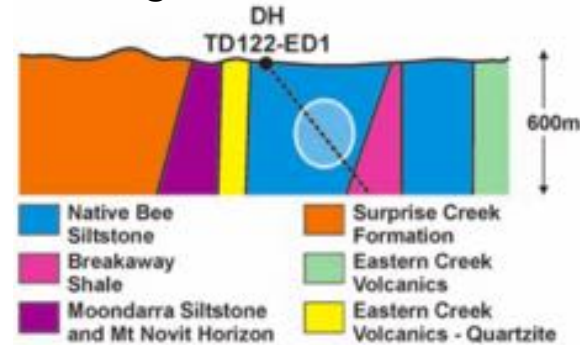
Resistivity section

Can a **chargeable**, moderate conductor in the siltstones be identified?
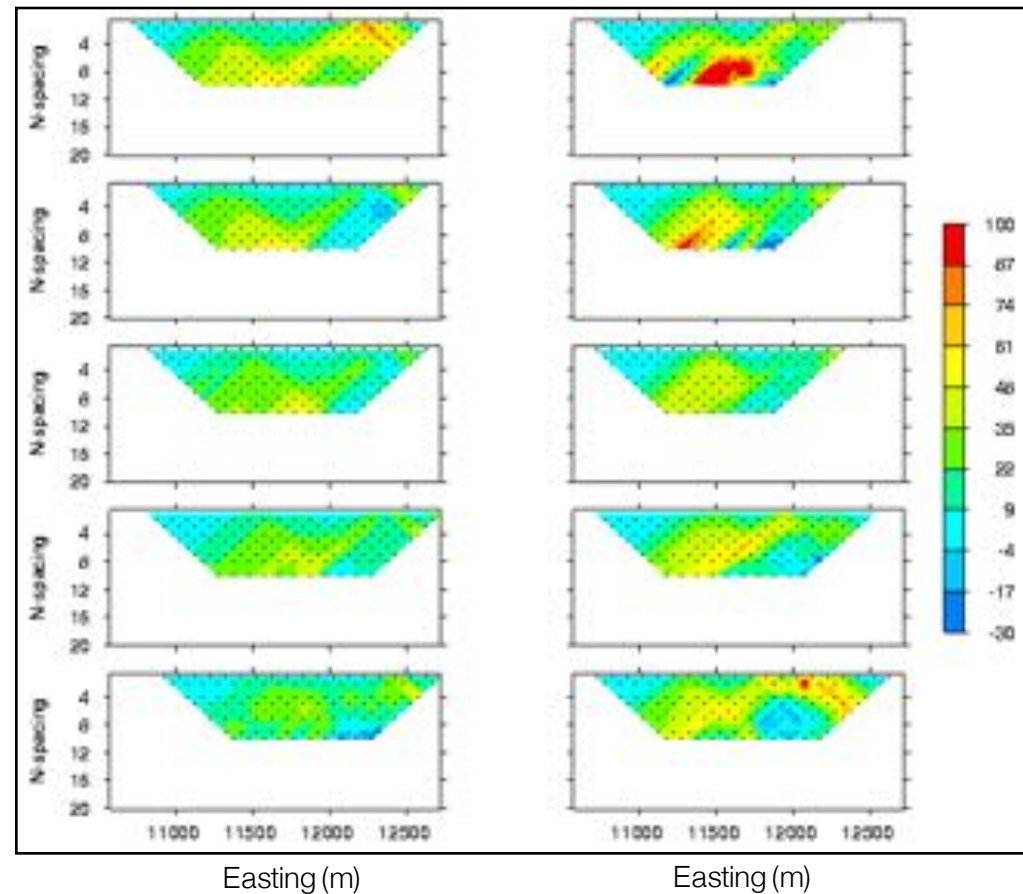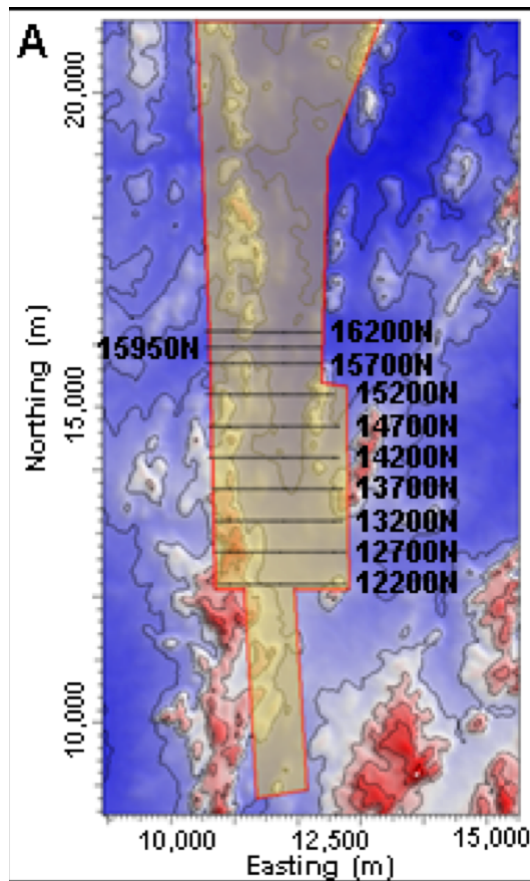
Survey and data

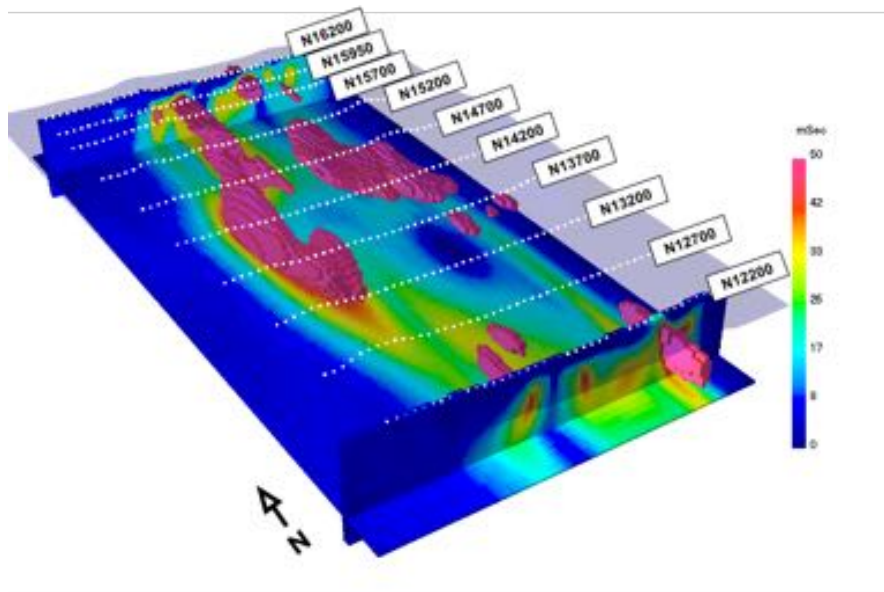- Eight survey lines
- Two configurations

Apparent chargeability, dipole- pole.

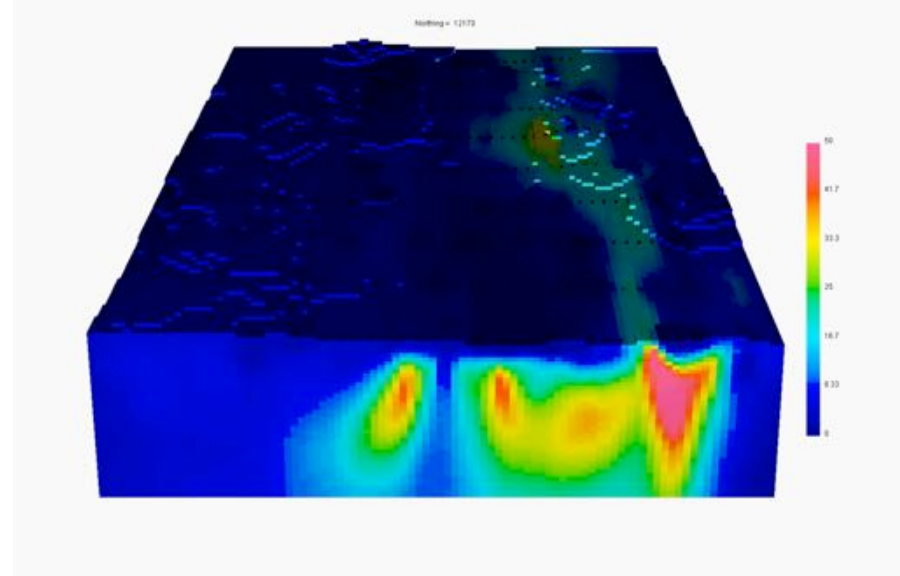Surface topography

Processing
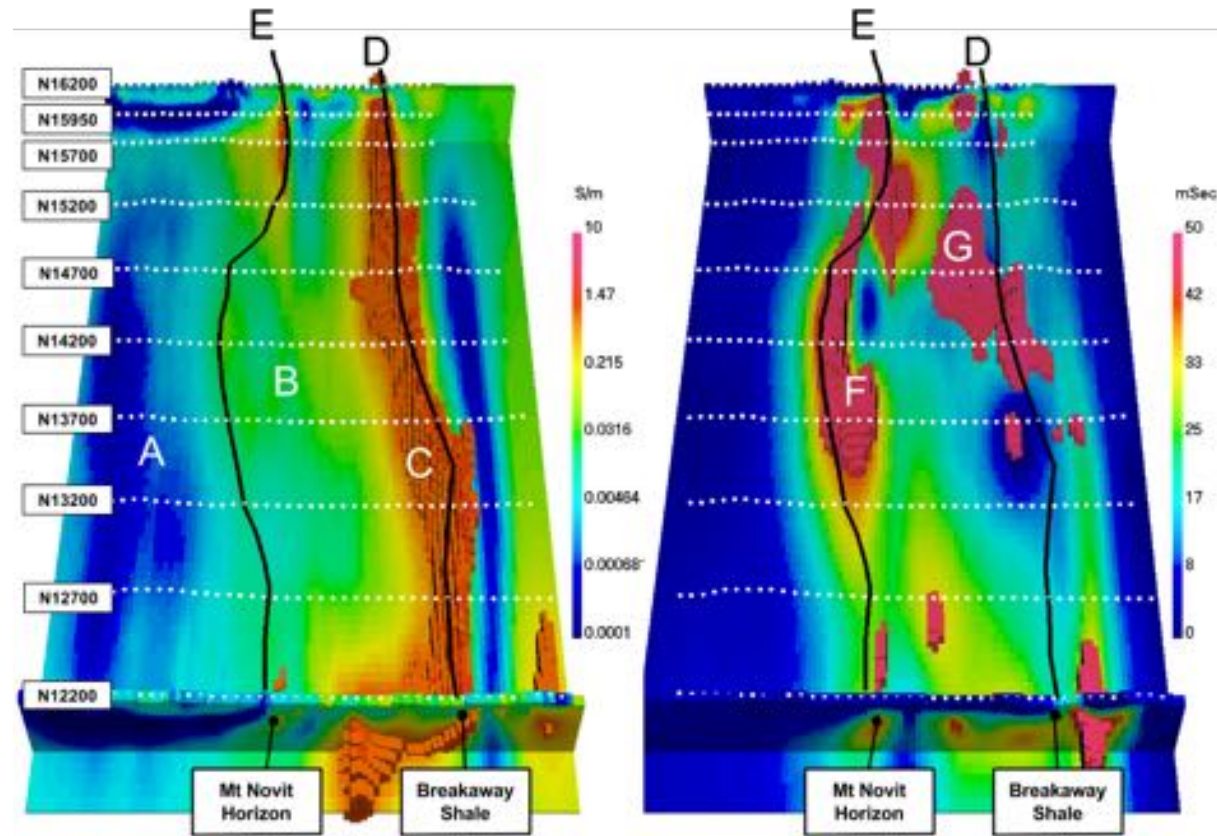
3D chargeability model

Animation

Interpretation

Resistivity model   Chargeability model

A: Resistive, Non-chargeable

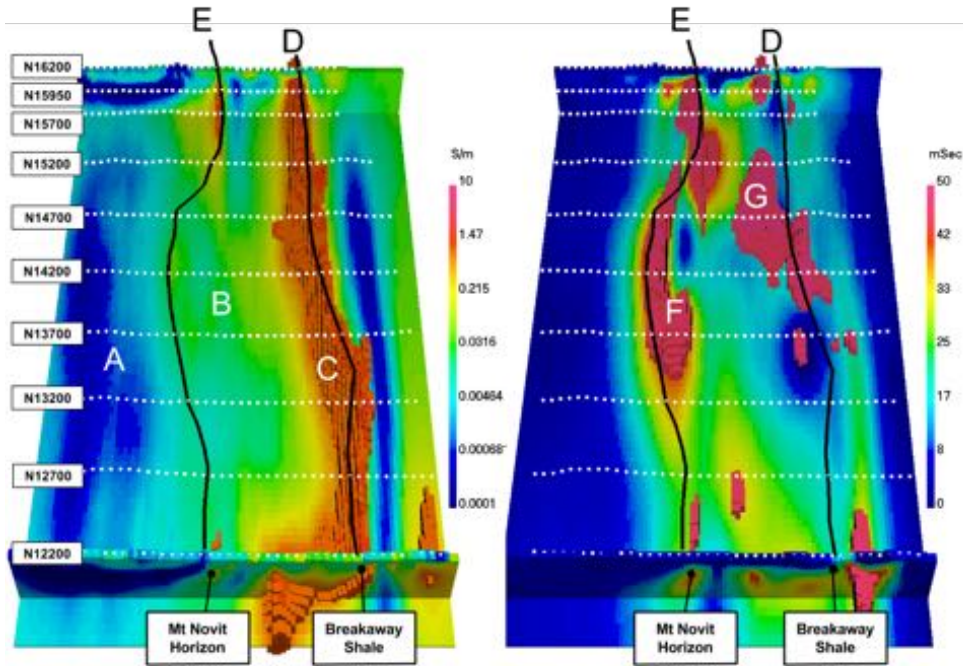B: Moderate conductivity; low chargeabilty

C: Very high conductivity (> 10 S/m)

E and F: High conductivity and high chargeability

G: Other chargeable regions

Synthesis

Resistivity model   Chargeability model
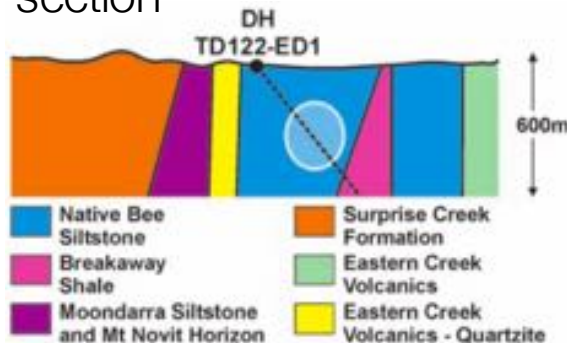

A: Surprise Creek Formation
– Resistive, non-chargeable

B: Moondarra and Native Bee siltstones
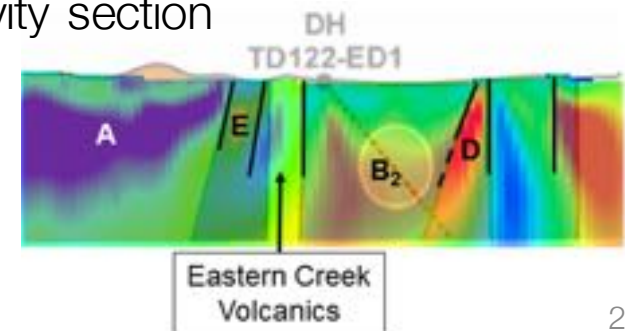
C: Breakaway Shales
– Very high conductivity

E and F: Mt Novit Horizon
– High conductivity and high chargeability

G: Other chargeable regions within siltstone complex

Geologic section

Native Bee Siltstone
Breakaway Shale
Moondarra Siltstone and Mt Novit Horizon
Surprise Creek Formation
Eastern Creek Volcanics
Eastern Creek Volcanics - Quartzite

Resistivity section

Eastern Creek Volcanics

Induced Polarization: Summary

- Sources of IP

- Conceptual model of IP

- Chargeability

- IP data

- Pseudosections

- Two stage DC-IP inversion

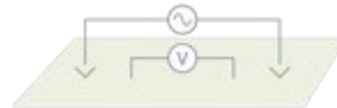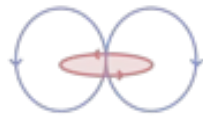- Case history: Mt. Isa

- Questions

End of IP

DC Resistivity | EM Fundamentals | Inductive Sources | Grounded Sources | Natural Sources | GPR | Induced Polarization | The Future

Next up

Lunch: Play with apps