DC Resistivity
DC Resistivity

Reminder:

Ohm’s Law – $V = I \cdot R$

where
- $V =$ voltage
- $I =$ current
- $R =$ resistance
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We measure resistivity not resistance:

Resistivity $\rho = \frac{R A}{L}$

Resistance, $R$

Area, $A$

Length, $L$
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Current flow in the Earth:

Assuming homogeneous resistivity in the Earth!
DC Resistivity

Current flow in the Earth:

<table>
<thead>
<tr>
<th>Current Path</th>
<th>% of Total Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>32</td>
</tr>
<tr>
<td>3</td>
<td>43</td>
</tr>
<tr>
<td>4</td>
<td>49</td>
</tr>
<tr>
<td>5</td>
<td>51</td>
</tr>
<tr>
<td>6</td>
<td>57</td>
</tr>
</tbody>
</table>

Still with that homogeneous Earth!
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Current flow in the Earth:
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Current flow in the Earth:

Electrode Spacing = 10 m

Electrode Spacing = 25 m

Electrode Spacing = 50 m

Electrode Spacing = 75 m
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Current flow in the Earth:

For the arrangement below: \( \rho_a = 2\pi aR \)

Where R is the resistance \( \frac{V(P+) - V(P-)}{I} \)
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Electrode configurations:

General

Wenner

Dipole-dipole

Schlumberger
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Electrode configurations:

Choice of configuration to use

• Type of structure to be imaged
  Sensitivity of configuration to vertical and lateral variations in resistivity
  Depth of investigation required
  Resolution required

• Sensitivity and type of resistivity meter
  Number of channels

• Signal strength
  Background noise level
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Electrode configuration sensitivity:

Dipole Dipole
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Electrode configuration sensitivity:

a) Wenner alpha array
b) Wenner beta array
c) Wenner gamma array
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Electrode configuration sensitivity:

Wenner-Schlumberger array sensitivity sections

- $n = 1$
- $n = 2$
- $n = 4$

Sensitivity Values (x 0.01)

- 2048
- 1024
- 512
- 256
- 128
- 64
- 32
- 16
- 8
- 4
- 2
- 0
- -2
- -4
- -8
- -16
- -32
- -64
- -128
- -256
- -512
- -1024
- -2048
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Electrode configuration sensitivity:

Pole Pole
DC Resistivity Imaging:
Developments in multi-electrode systems has led to widespread use of imaging.

A series of measurements are collected at multiple electrode separations (i.e. different survey depths)
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Applications:

A pseudo section is produced using measured apparent resistivity's.
These data may be inverted to determine a resistivity model that is consistent with the data.
Note that the pseudo section doesn’t always show a structure that resembles the subsurface.

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Synthetic model

Wenner array pseudosection

Dipole-dipole array pseudosection
Note that the pseudo section doesn’t always show a structure that resembles the subsurface.
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Sources of noise and errors:

- Electrode polarization
- Contact Resistance
- Proximity to electrical conductors: buried pipes, chain link fences, etc will act as current sinks
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Electrode Polarization - possible solutions:
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Contact resistance – possible solutions
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Instruments:
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Applications:

Data collection speed will depend on:

- Number of channels in resistivity meter,
- Source frequency (i.e. duration of current injection),
- Stacking requirements

Single channel systems may only be capable of around 400 to 500 measurements per hour. Multi-channel systems can make around 2000 measurements per hour or faster.
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Applications:

Line 03 – Pole-Pole array

Log_{10} Resistivity (Ωm)

-2.0  2.0  2.2  2.4  2.6  2.8  3.0  3.2  3.4  3.6  3.8  4.0  4.2

bedrock  alluvial sediments
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Applications:
DC Resistivity

Applications: Continuous surface imaging for land and marine surveys
DC Resistivity

Applications: Continuous surface imaging for land and marine surveys
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Applications: Capacitively Couple Resistivity
DC Resistivity

Applications: Capacitively Couple Resistivity
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Applications: Borehole surveys

Electrodes in two (or more) boreholes can be used to improve resolution with depth – cross-borehole electrical resistivity tomography (ERT)

Stainless steel mesh, copper and lead are common electrode materials.
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Applications: Borehole surveys

Numerous different types of measurement schemes are possible.
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Applications: Borehole surveys
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Applications: Borehole surveys

Can be combined with surface based electrodes to improve resolution
Recall the expected response of the voltage measurement:
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Induced Polarization

In practice, there is a charge up and charge down response.

This forms the basis of time domain induced polarization measurements.
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Induced Polarization

Seigel (1959) defined the apparent chargeability as:

\[ ma = \frac{V_p}{V_s} \]

*Vp is the primary voltage and Vs is the secondary voltage*
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Induced Polarization

\[ m_a = \frac{1}{(t_2 - t_1)} \frac{1}{V_p} \int_{t_1}^{t_2} V(t) \, dt \quad \text{(units mV/V)} \]
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Induced Polarization: macro

Zone ore concentrate

Applied current

Polarisation current
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Induced Polarization: micro

Grain polarization

Electrolytic polarization
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Induced Polarization

Vault area IP January 2000

After Kemna, Binley & Slater (2004)
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Modeling:

**Forward Modeling** -
Calculating the resistances that would theoretically be ‘measured’ for a given resistivity distribution

**Inverse Modeling** –
Calculating the resistivity distribution that is ‘consistent’ with the observed (measured) resistances
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Modeling:

Forward Modeling -

Calculating the resistances that would theoretically be ‘measured’ for a given resistivity distribution

Data (d) \rightarrow \text{Model (m)}
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Modeling:

Inverse Modeling –

Calculating the resistivity distribution that is ‘consistent’ with the observed (measured) resistances.