SAGA

The Soil Science & Archaeo-Geophysics Alliance

Training School 1

Earth Resistance

for Archaeological Prospection

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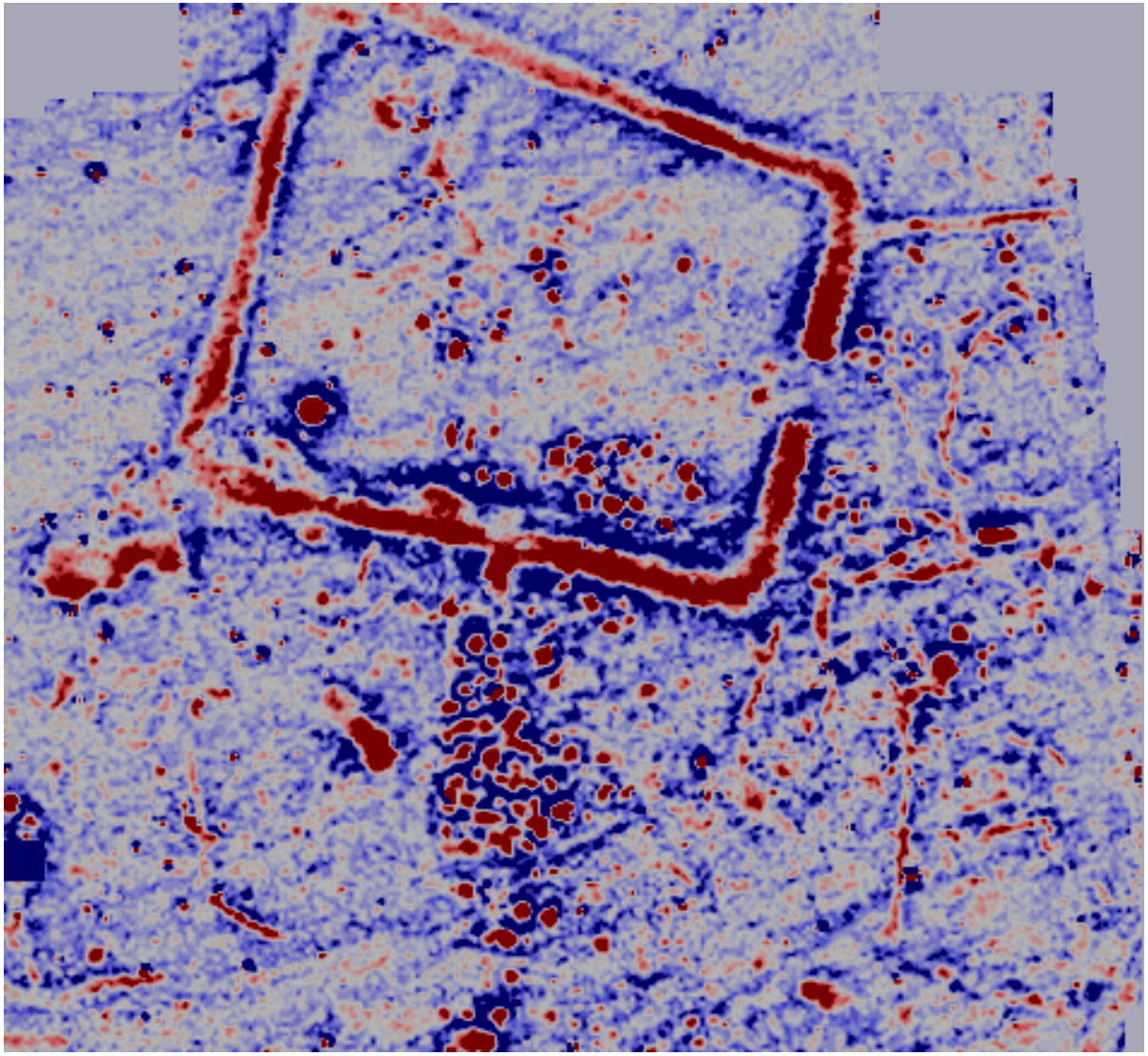
ISAP

Magnetometer Survey



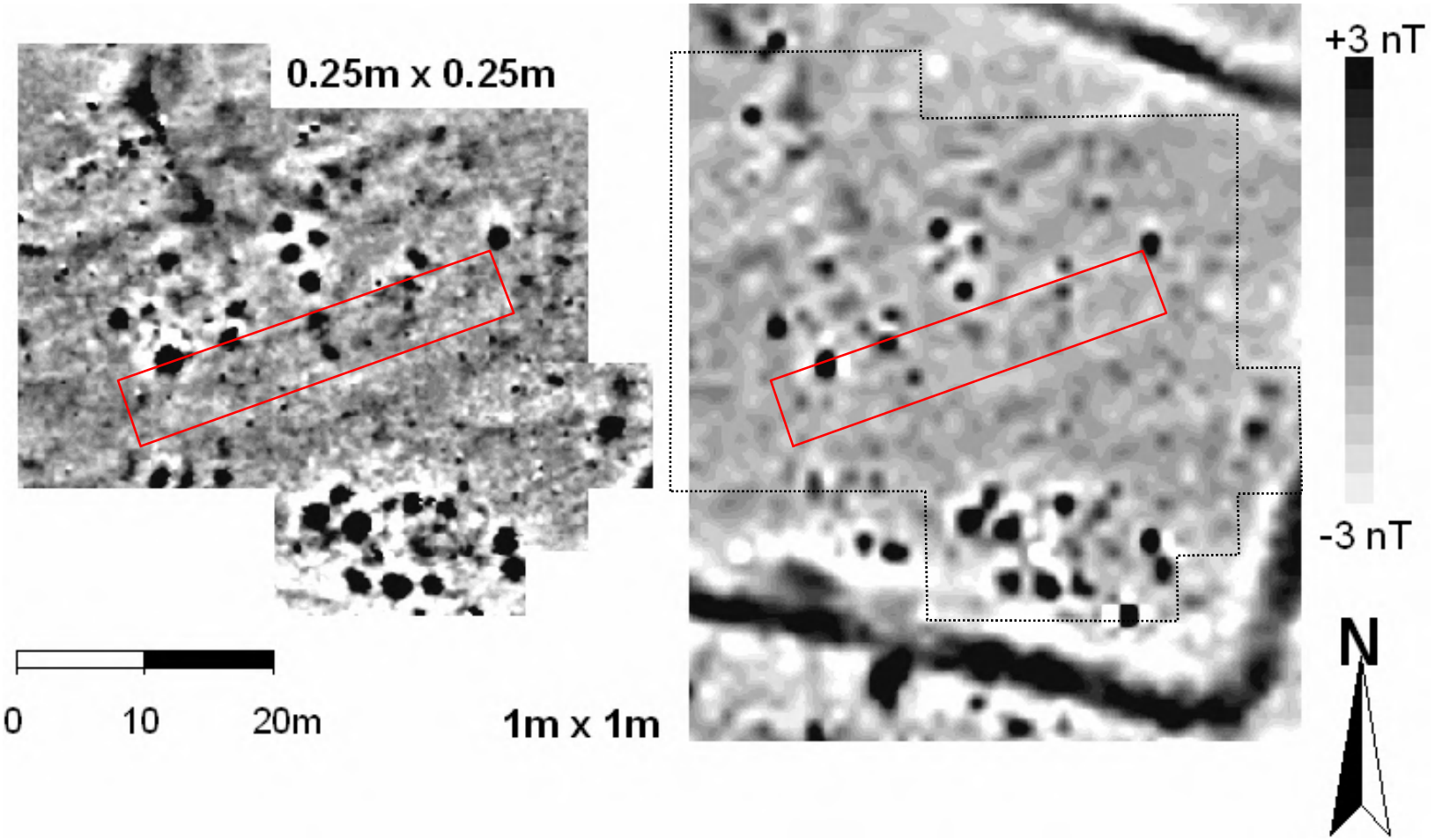
Temple Guiting
Middle Ground

+3 nT

-4 nT

0 40m

Sampling Resolution



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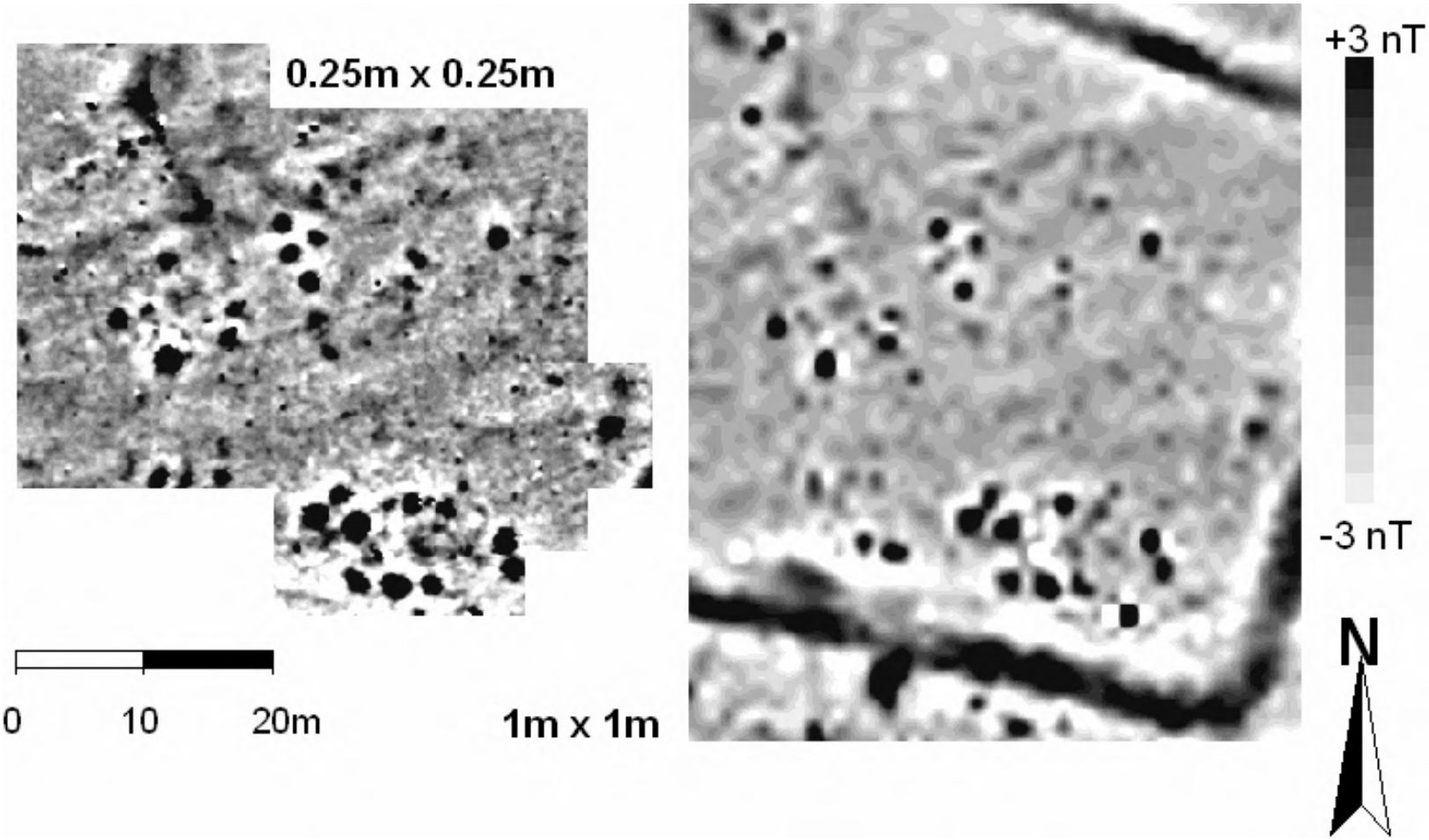
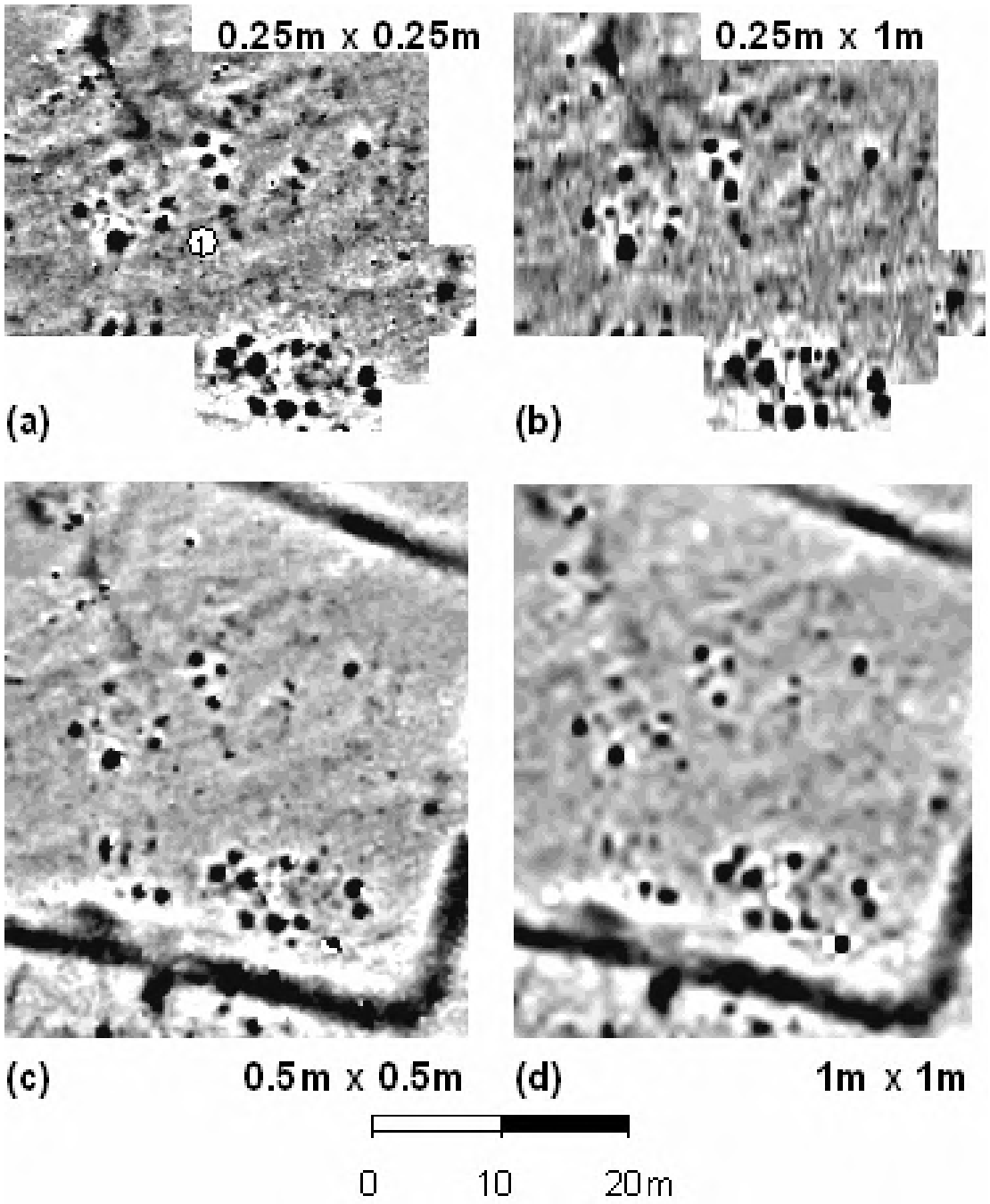
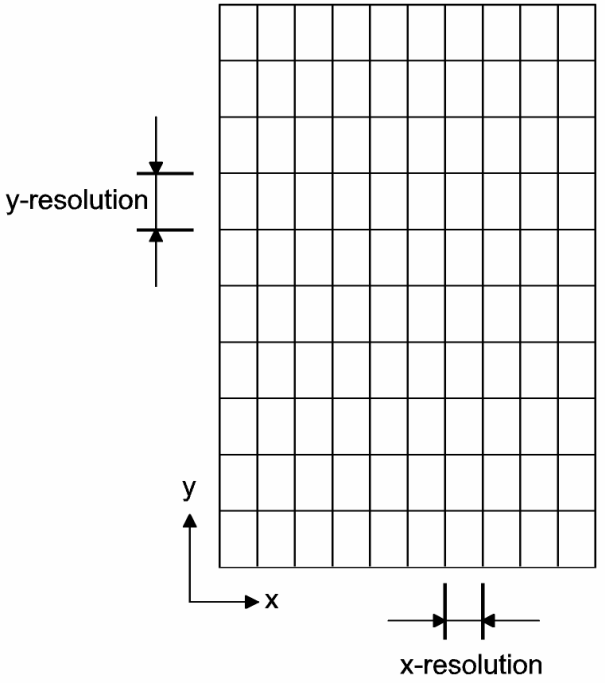



0.25m x 0.25m
(a)
0.25m x 1m
(b)
(c)
0.5m x 0.5m
(d)
1m x 1m
0
10
20m

Effective Resolution

- Size of archaeological features should relate to “effective resolution” of methodology
- The *larger* of the x- and y-resolution, possibly reduced down to 2/3 of this, if the orthogonal resolution is correspondingly smaller

Survey resolution	Effective spatial resolution
1.0 m × 1.0 m	1.00 m
0.5 m × 1.0 m	0.67 m
0.125 m × 1.0 m	0.67 m
0.5 m × 0.5 m	0.50 m
0.25 m × 0.5 m	0.33 m



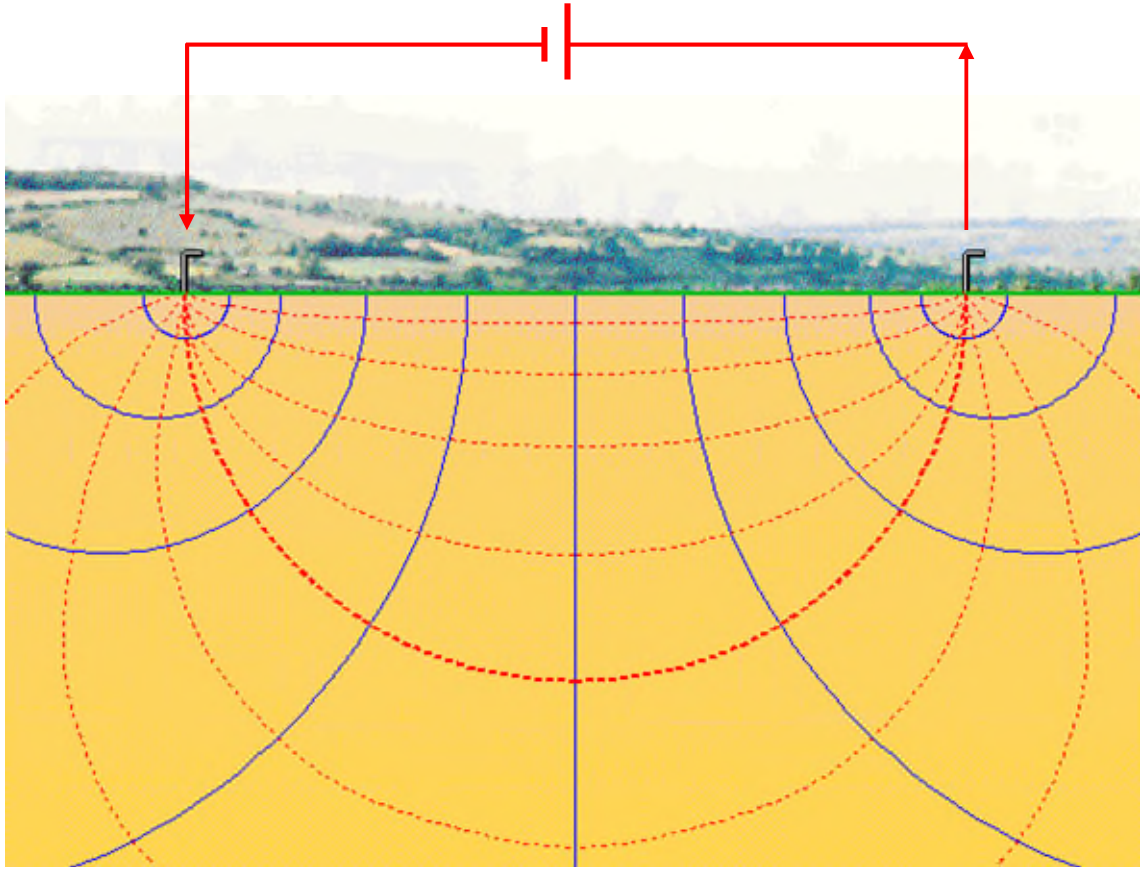
Survey Purpose

- Effective resolution should match purpose
- Level of investigation
  - Level 1 – ***Prospection***
    areas of archaeological potential
  - Level 2 – ***Delineation***
    delimit and map archaeological sites and features
  - Level 3 – ***Characterisation***
    analyse in detail the shape of individual anomalies

Earth Resistance Surveying

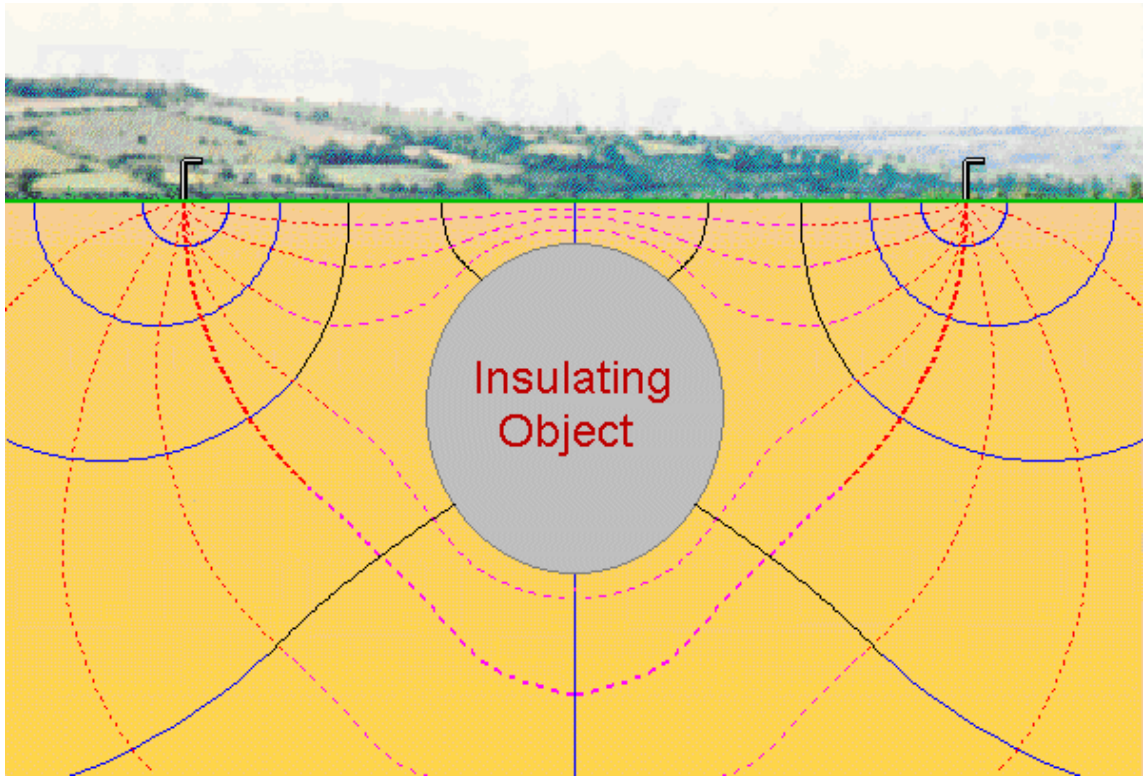
Basic Idea

- Homogenous earth:
  current will spread evenly in the ground



Basic Idea

- Homogenous earth:
  current will spread evenly in the ground
- Buried features: enforce a distortion of current flow



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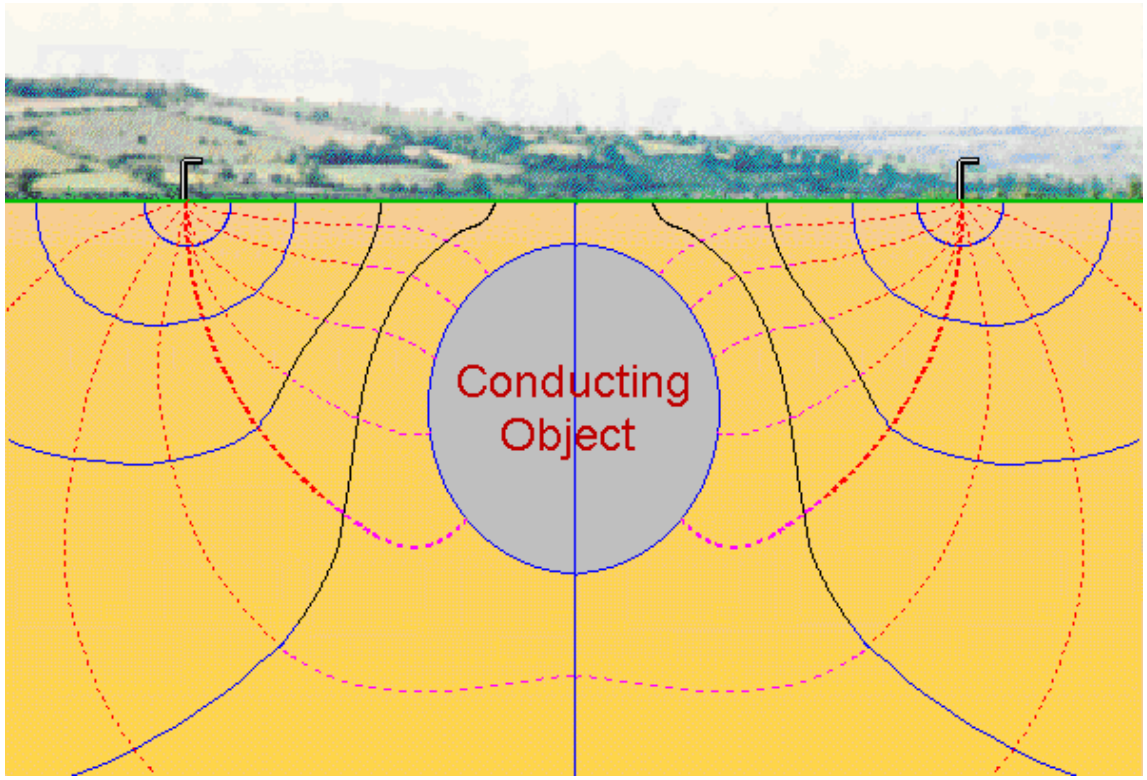
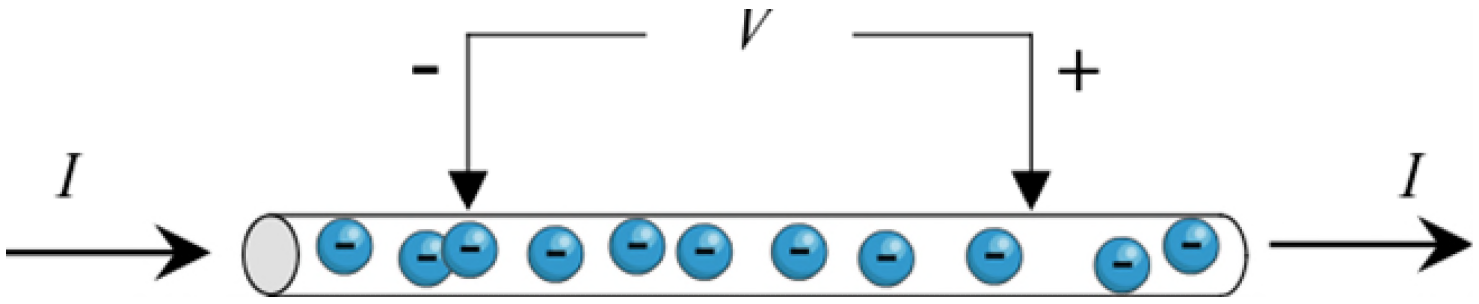


Forward

- Human habitation
  ↓ *reasonably well understood*
- Soil contrast (e.g. mineralogy)
  ↓ *well understood*
- Geophysical contrast (e.g. magnetic susceptibility)
  ↓ *very well understood*
- Geophysical measurement (e.g. magnetic anomaly)

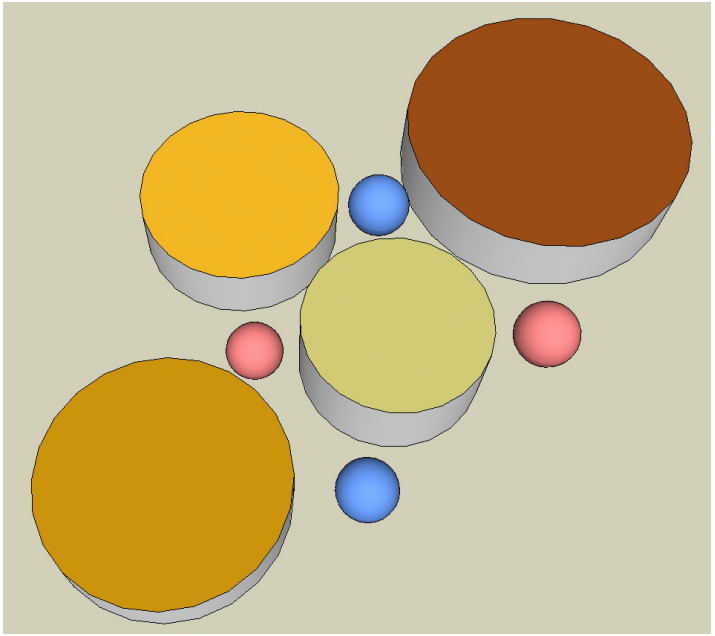
Electronic Conductivity

- Current in metallic wire is carried by electrons



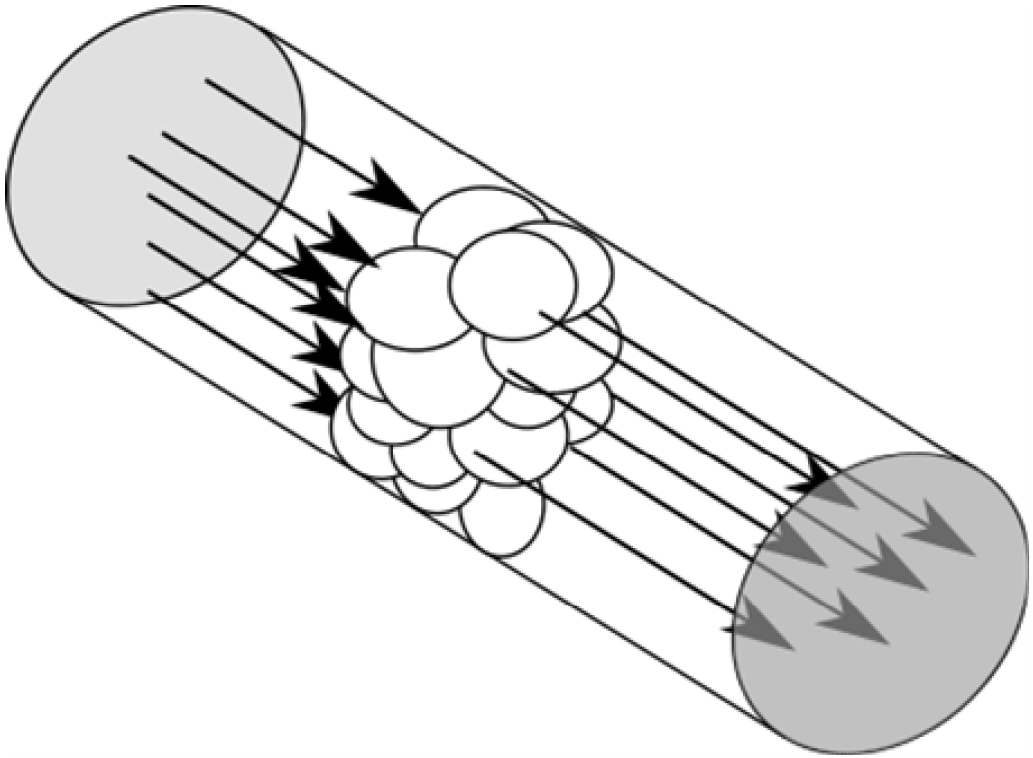
Electrolytic Conductivity

- Current in soil is carried by ions in the ground
  e.g. Na^+/Cl^-
- Mobility depends on:
  - amount of dissolvable salt
  - water for dissolving and for transport
  - pore size / grain size
  - temperature
- Simplified:
  - moisture content



Resistivity / Conductivity

- Restricting current flow:
  electrical resistivity = 1 / electrical conductivity



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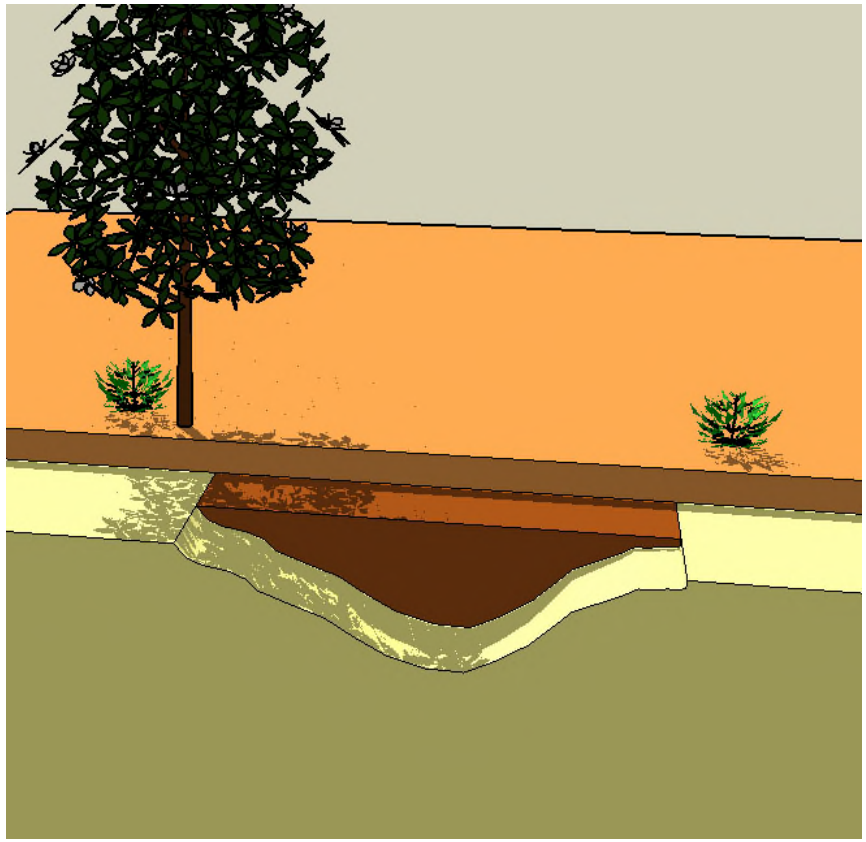
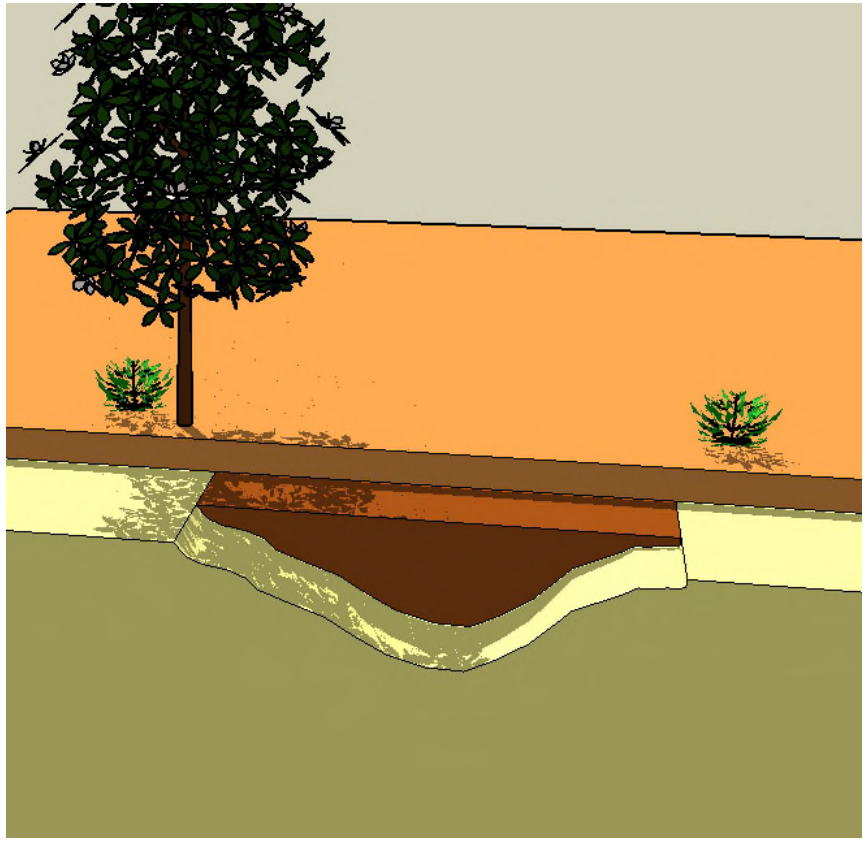
Archaeology and Earth Resistance

- Ditch
  - filled with topsoil
  - looser packing
  - larger pores
  - holds more water
  - wetter
  - low resistivity
- Contrast in electrical resistivity



Archaeology and Earth Resistance

- Influence of weather
  - moisture content changes
  - different changes in feature or surrounding soil
  - contrast can invert

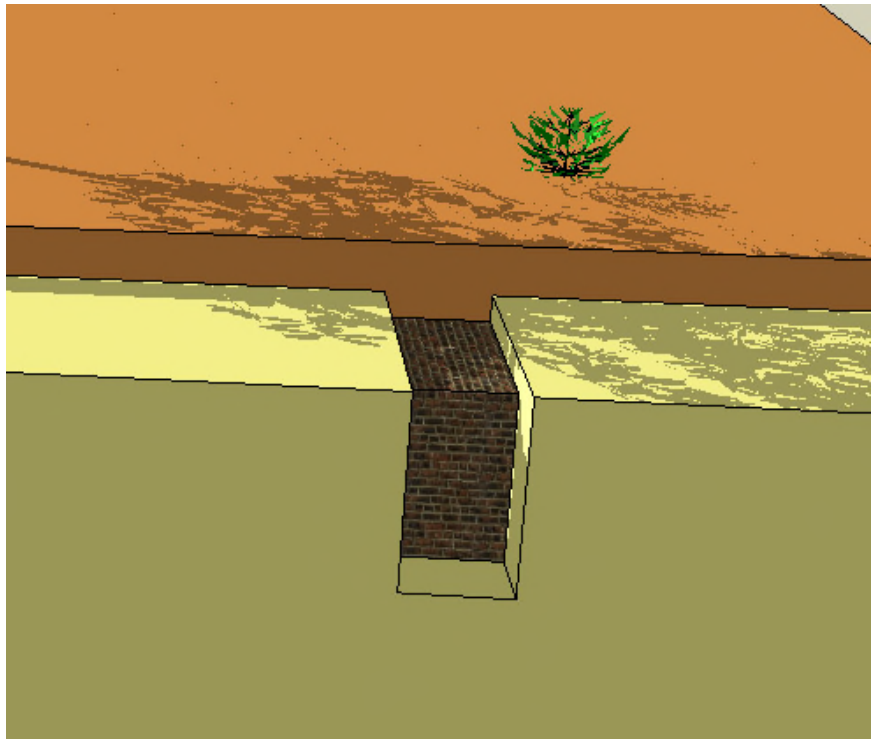


Archaeology and Earth Resistance

- Possible scenario for ditch:
  - normal conditions in spring
  - period of prolonged rain, all is wet - little contrast
  - sun comes out, wind
  - it gets even hotter, everything is dry - little contrast

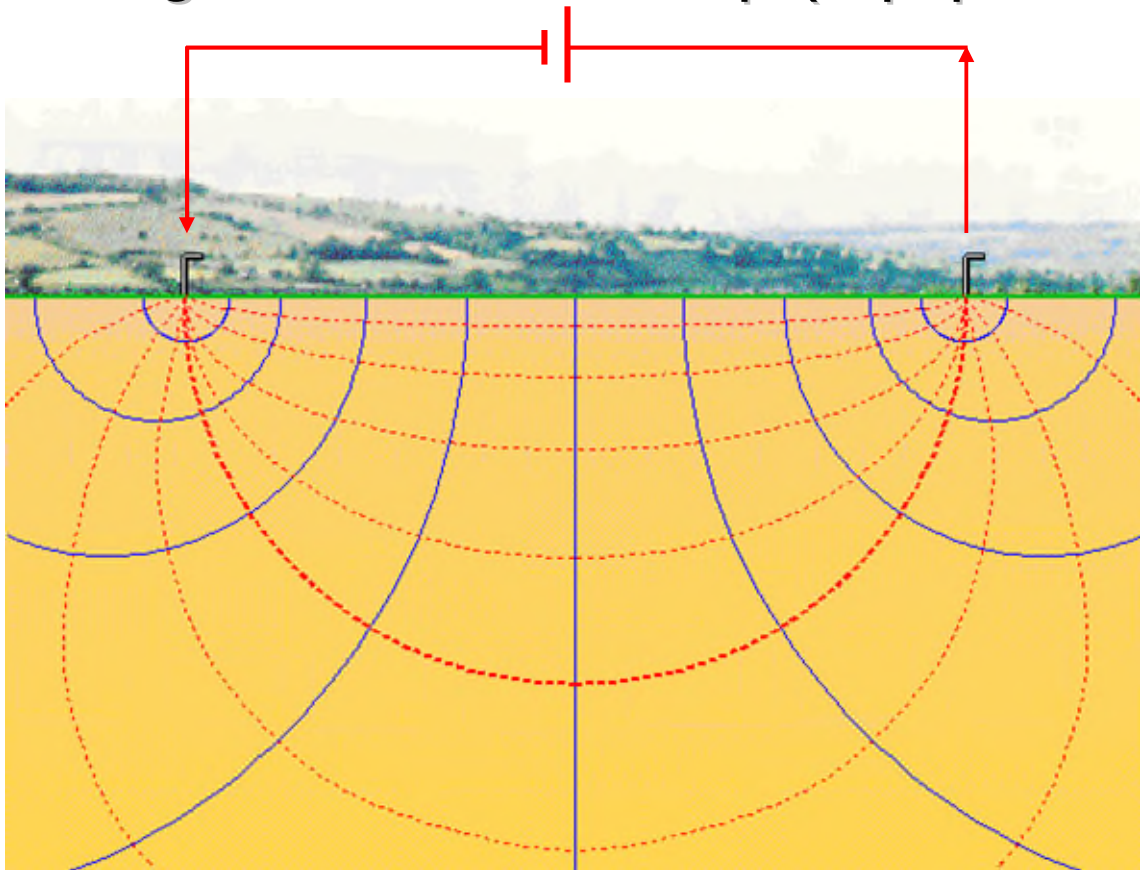
Archaeology and Earth Resistance

- Foundation wall
  - dense
  - low moisture
  - high resistivity contrast
  - less dependent on weather



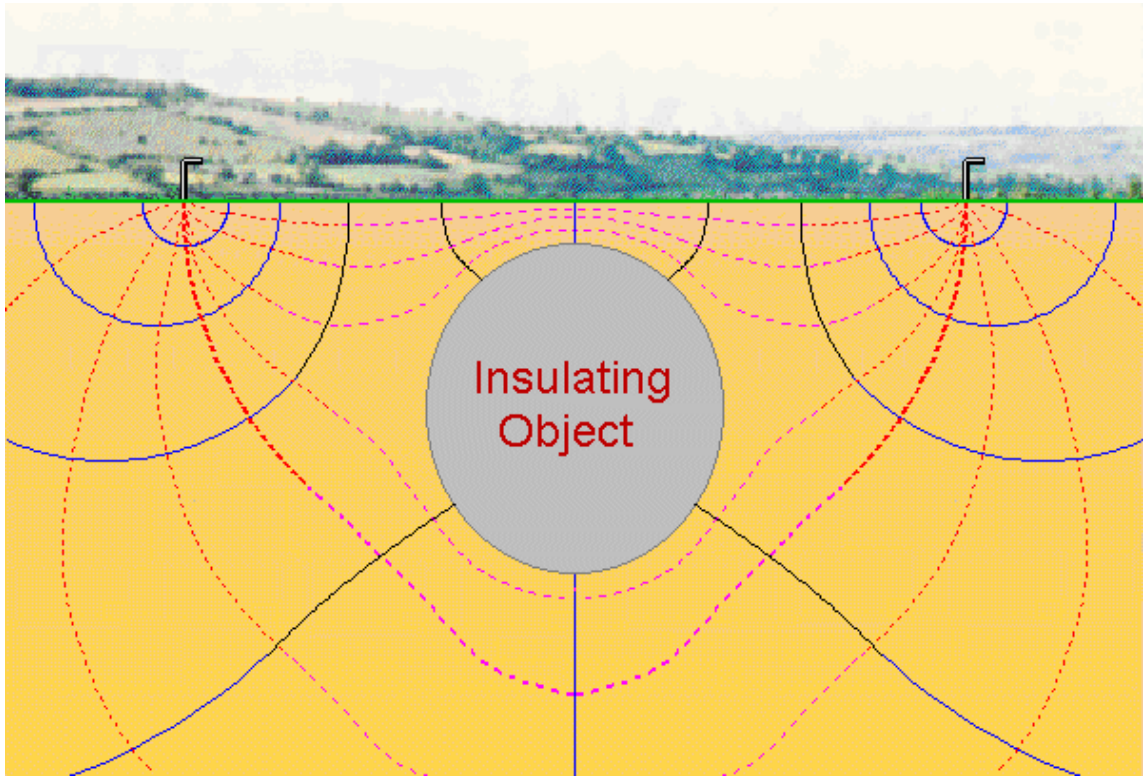
Measurements

- Inject current
- Voltage lines will develop (equipotentials)



Measurements

- Equipotential lines are distorted by features with resistivity contrast



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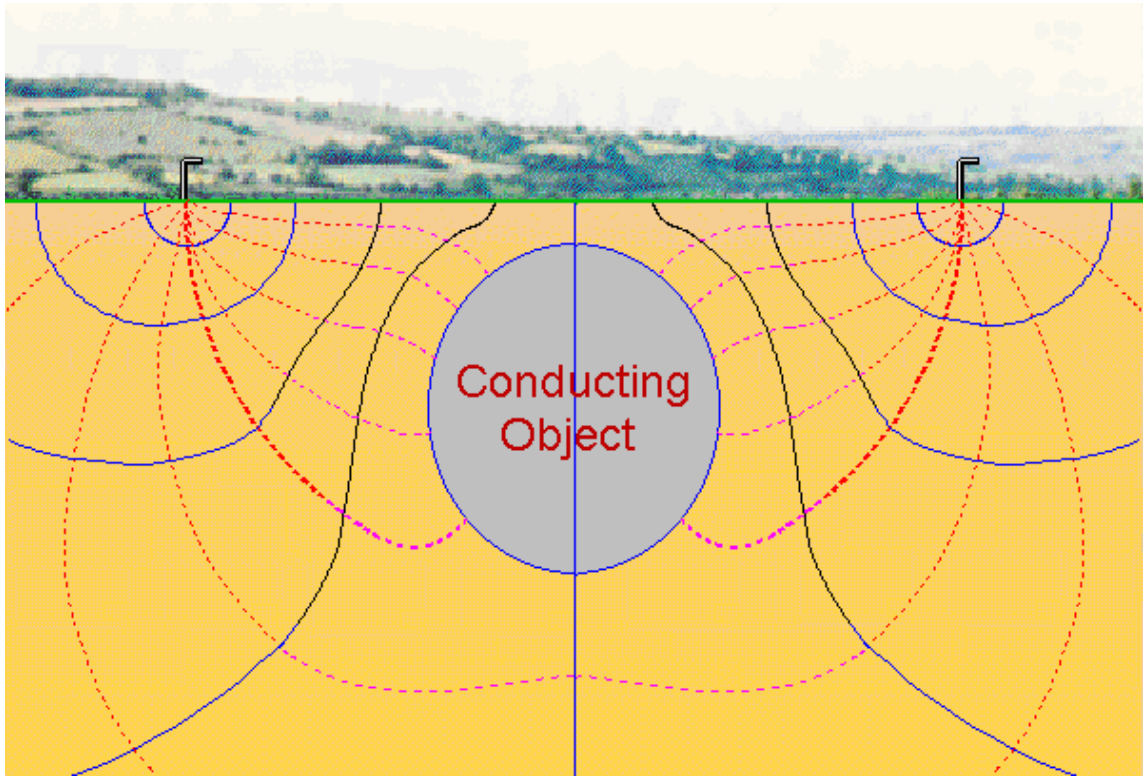

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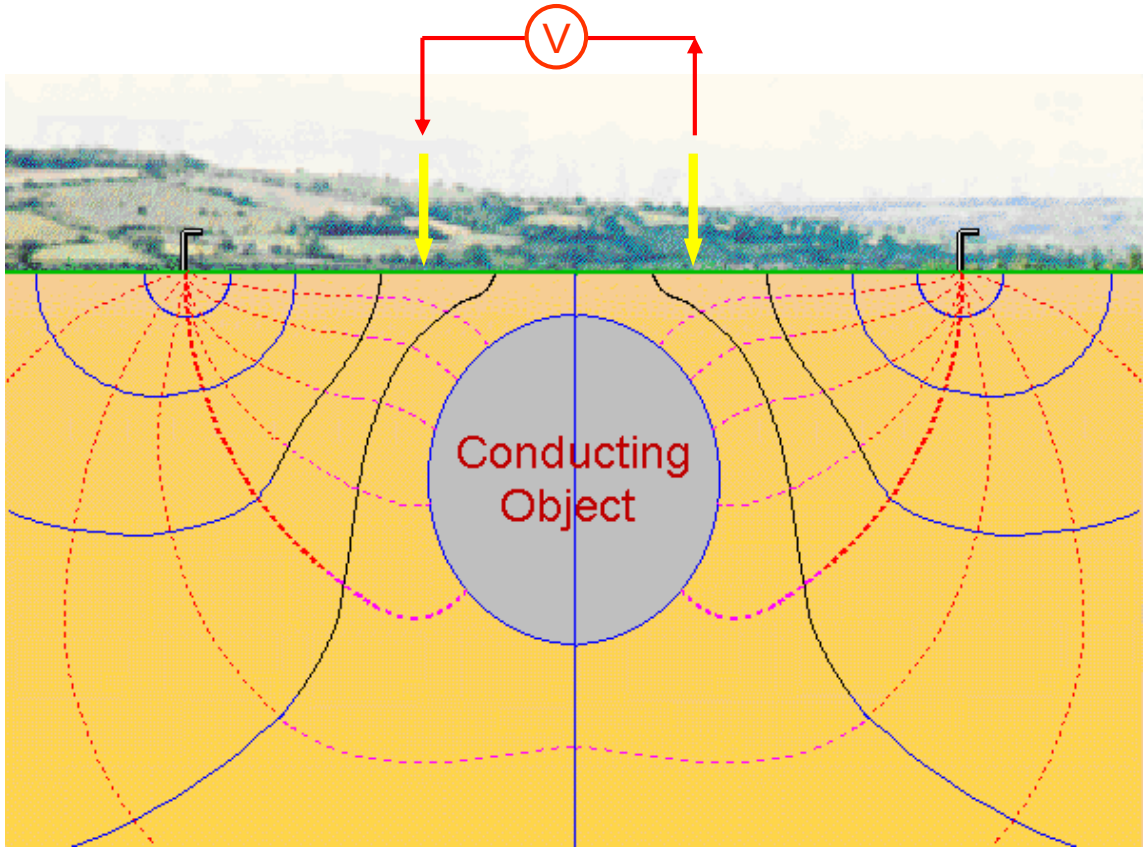
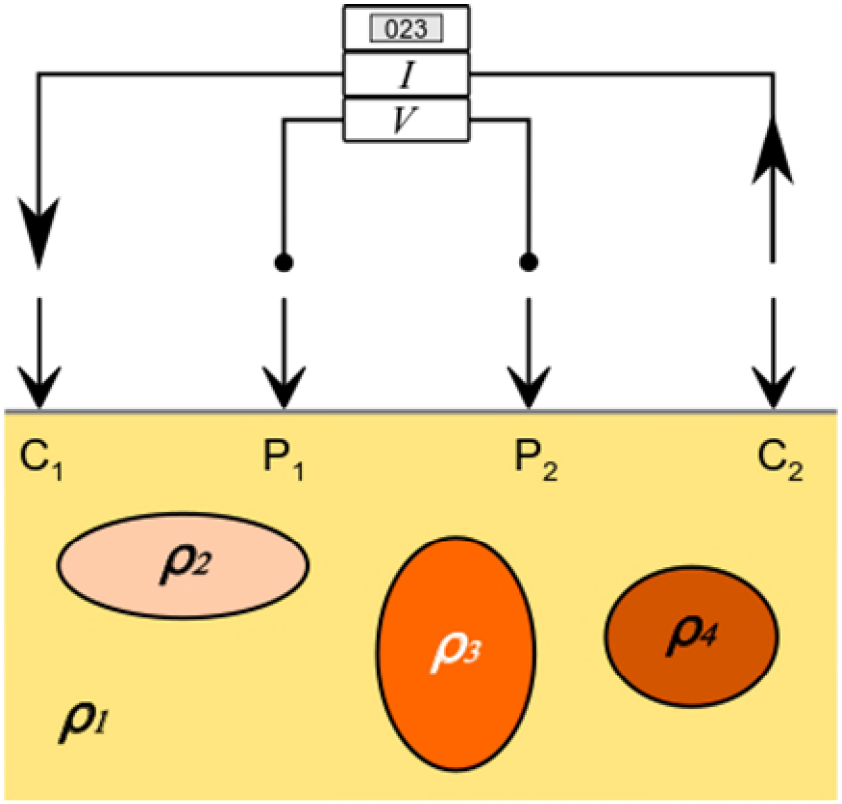


Measurements

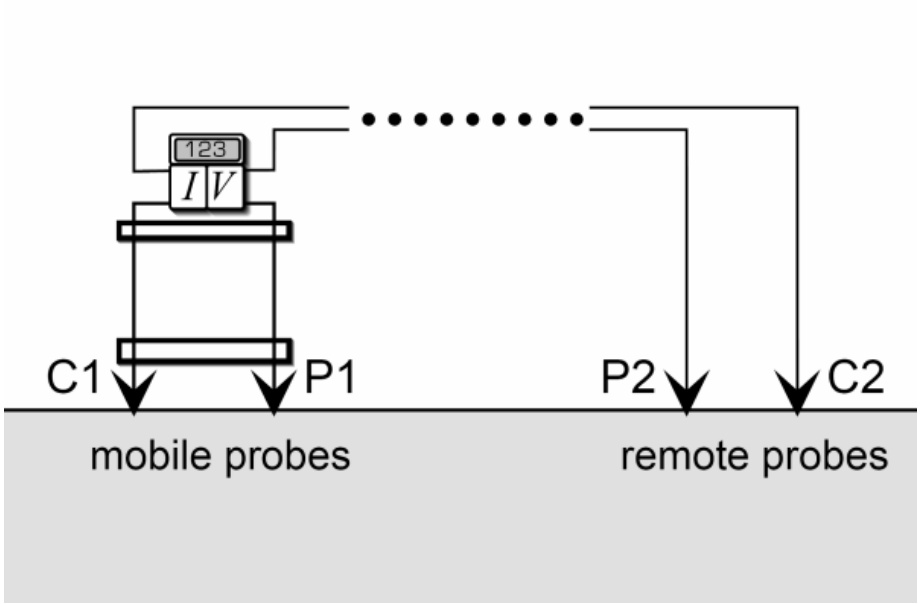
- Require four electrodes



- Different configurations are possible

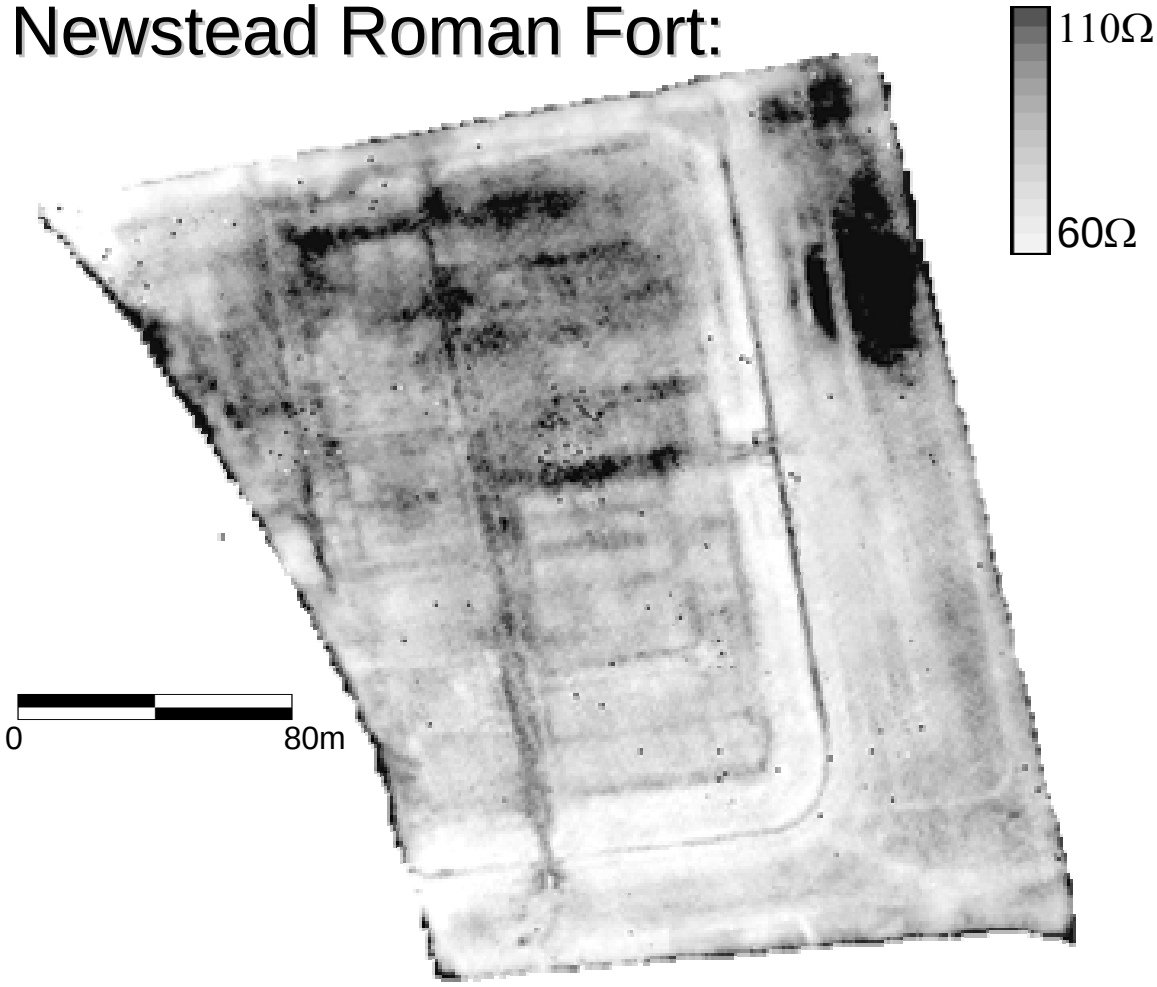
Measurements

- Twin-probe array
  most common in archaeology



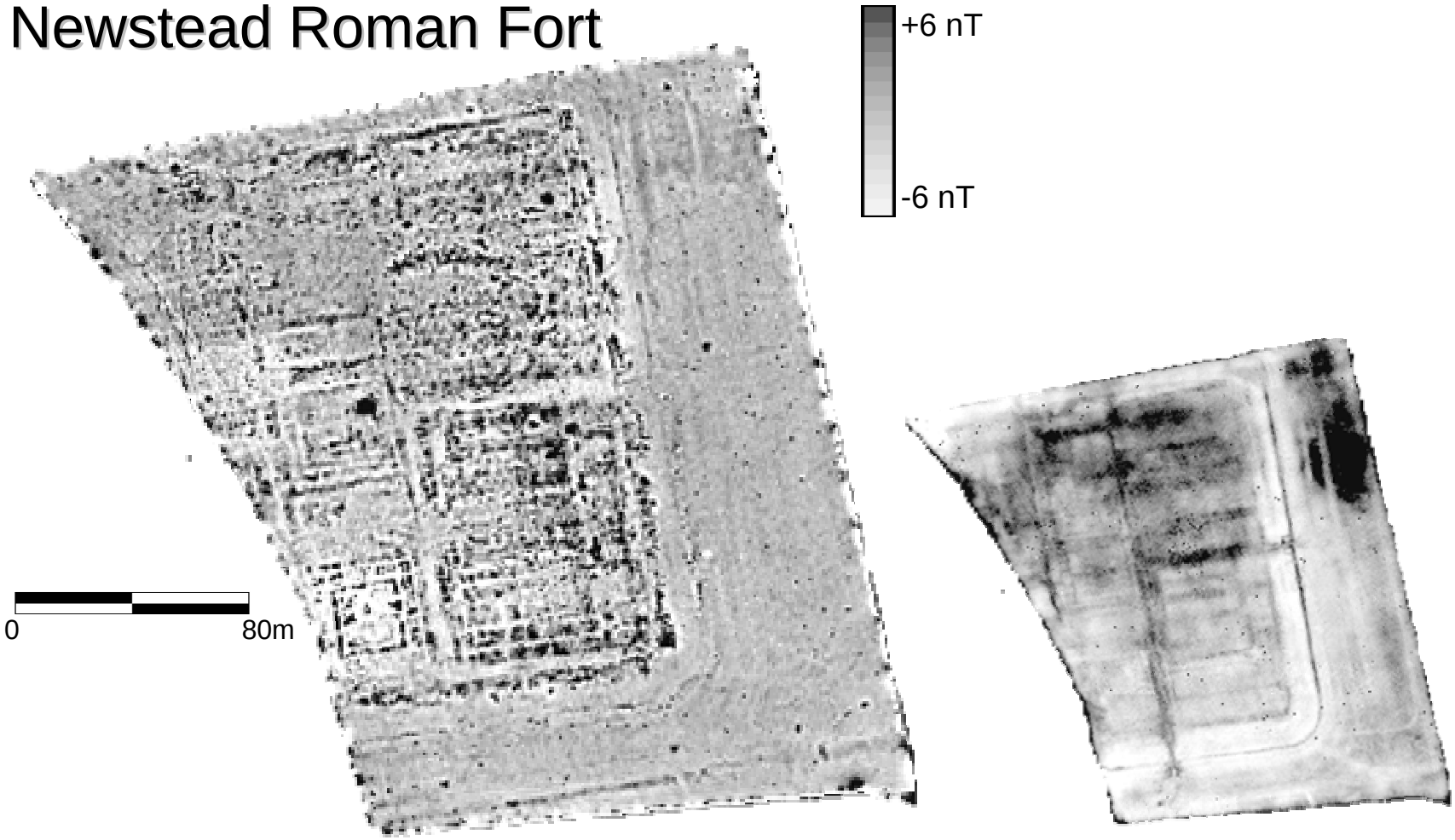
Measurements

- Grid of measurements points (e.g.1m x 1m)
- Newstead Roman Fort:



Measurements

- Magnetometer
- Newstead Roman Fort

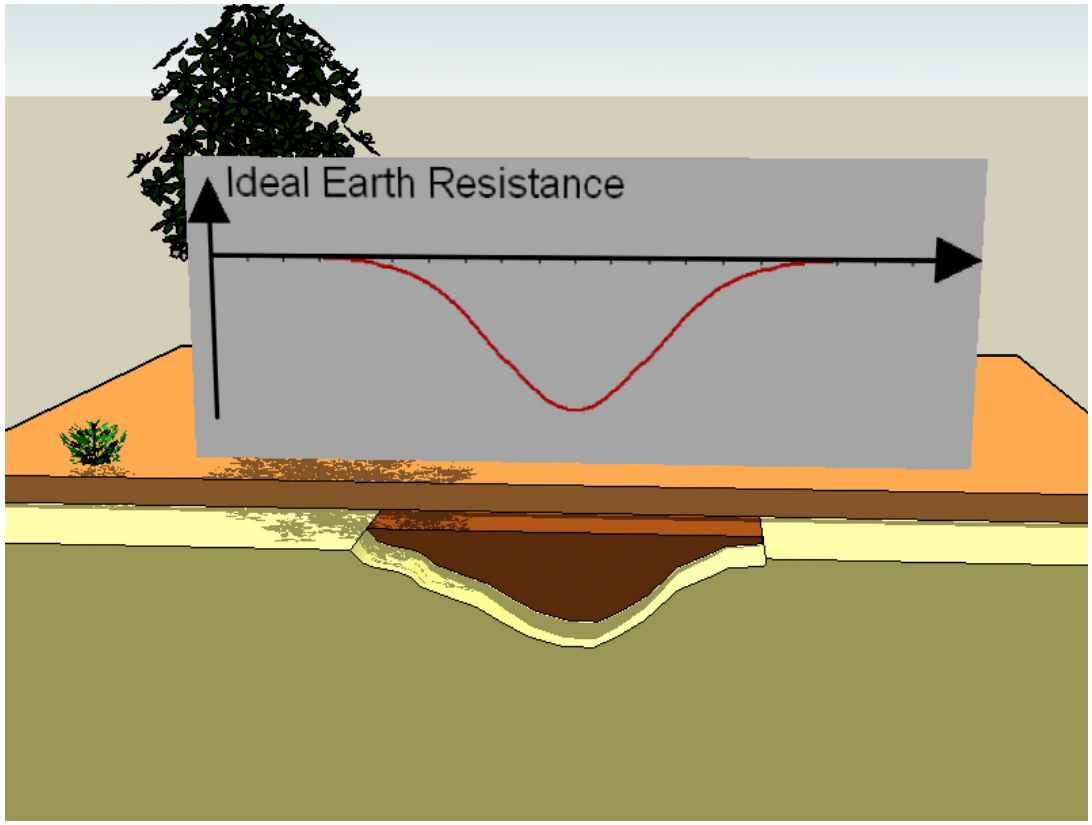


Forward

- Human habitation
  ↓ *reasonably well understood*
- Soil contrast (e.g. mineralogy)
  ↓ *well understood*
- Geophysical contrast (e.g. magnetic susceptibility)
  ↓ *very well understood*
- Geophysical measurement (e.g. magnetic anomaly)

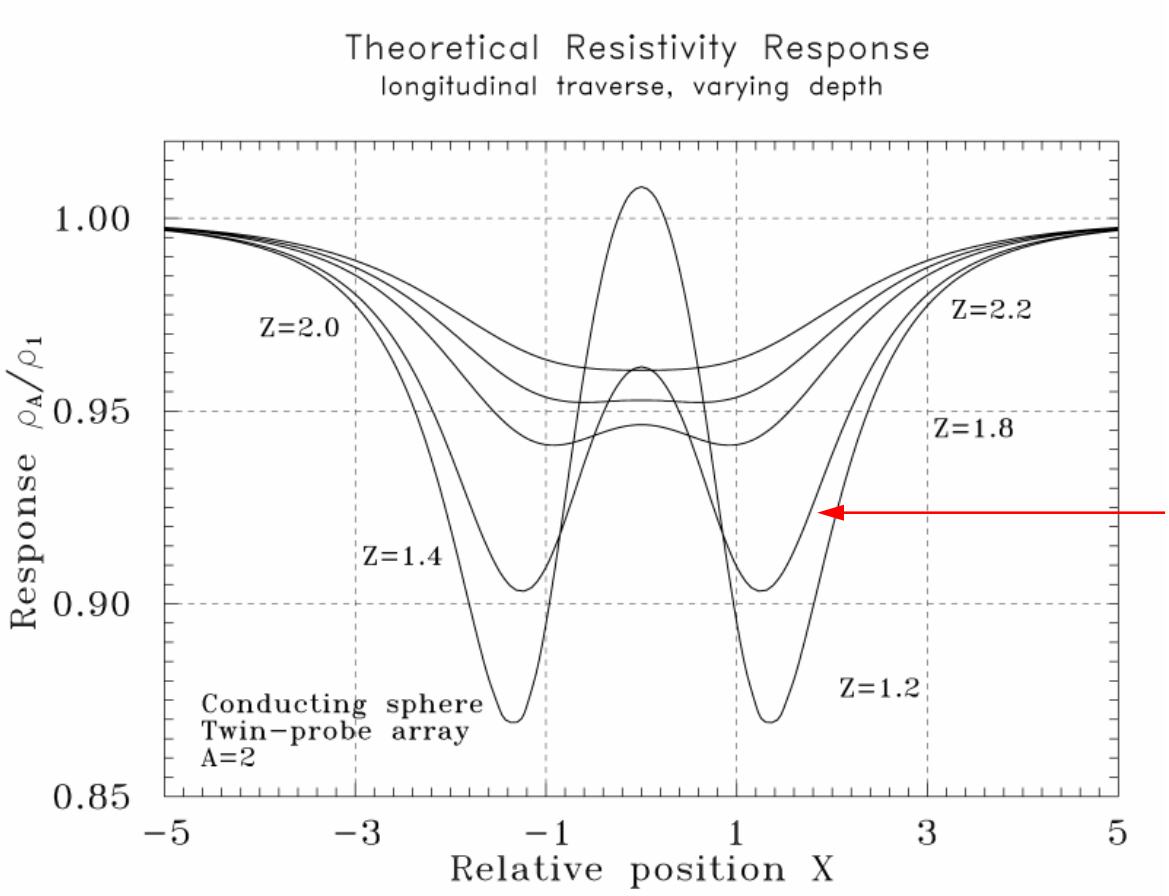
Anomalies

- Ideally the measurement would reflect the feature's shape



Anomalies

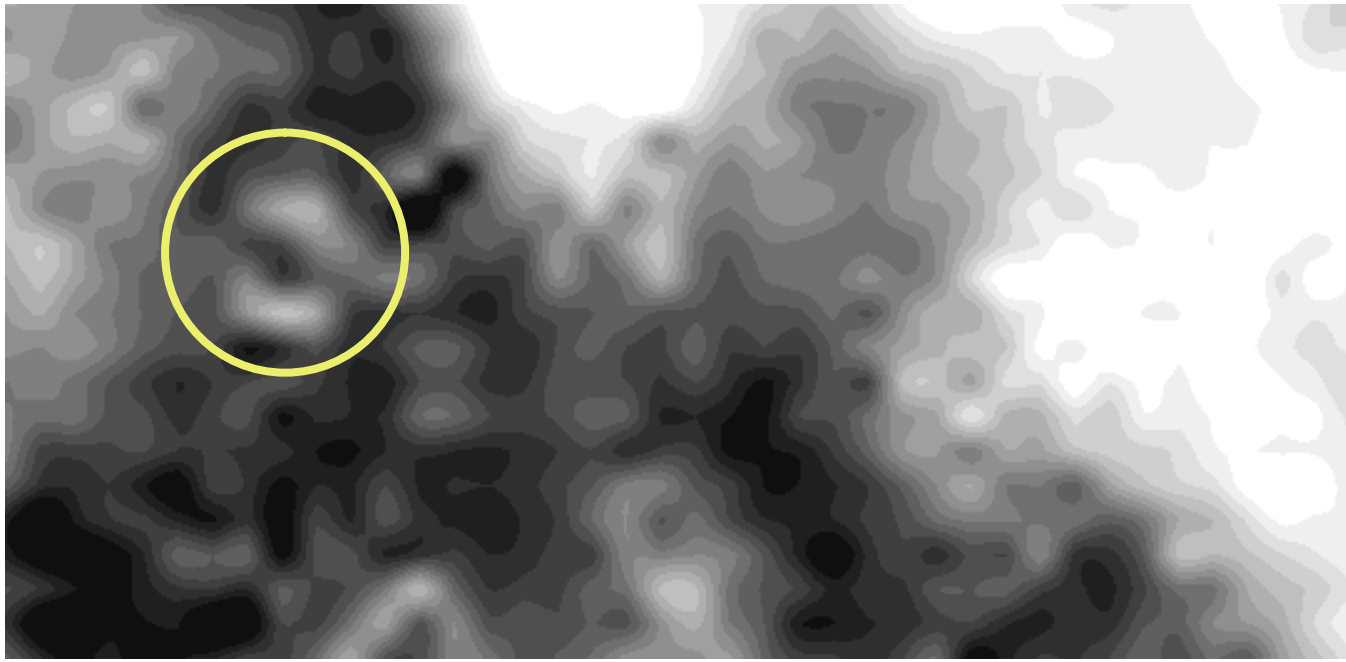
- In reality complex anomaly for small shallow features



0.5m twin-probe
Feature width 0.5m
Depth to top 0.2m

Interpretation

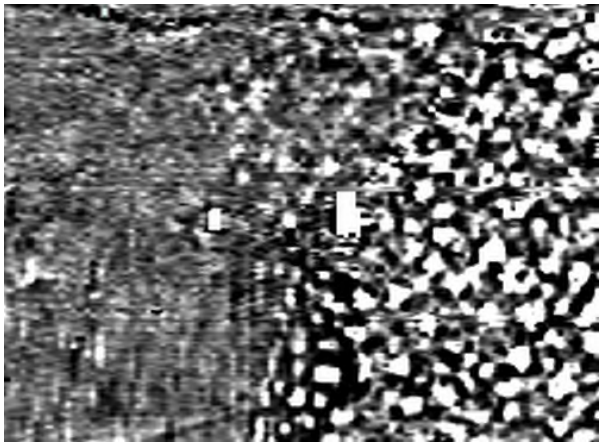
- Response may have complex shape
- Careful interpretation is required



- Area plot of response is not an ‘image’ but ‘data’

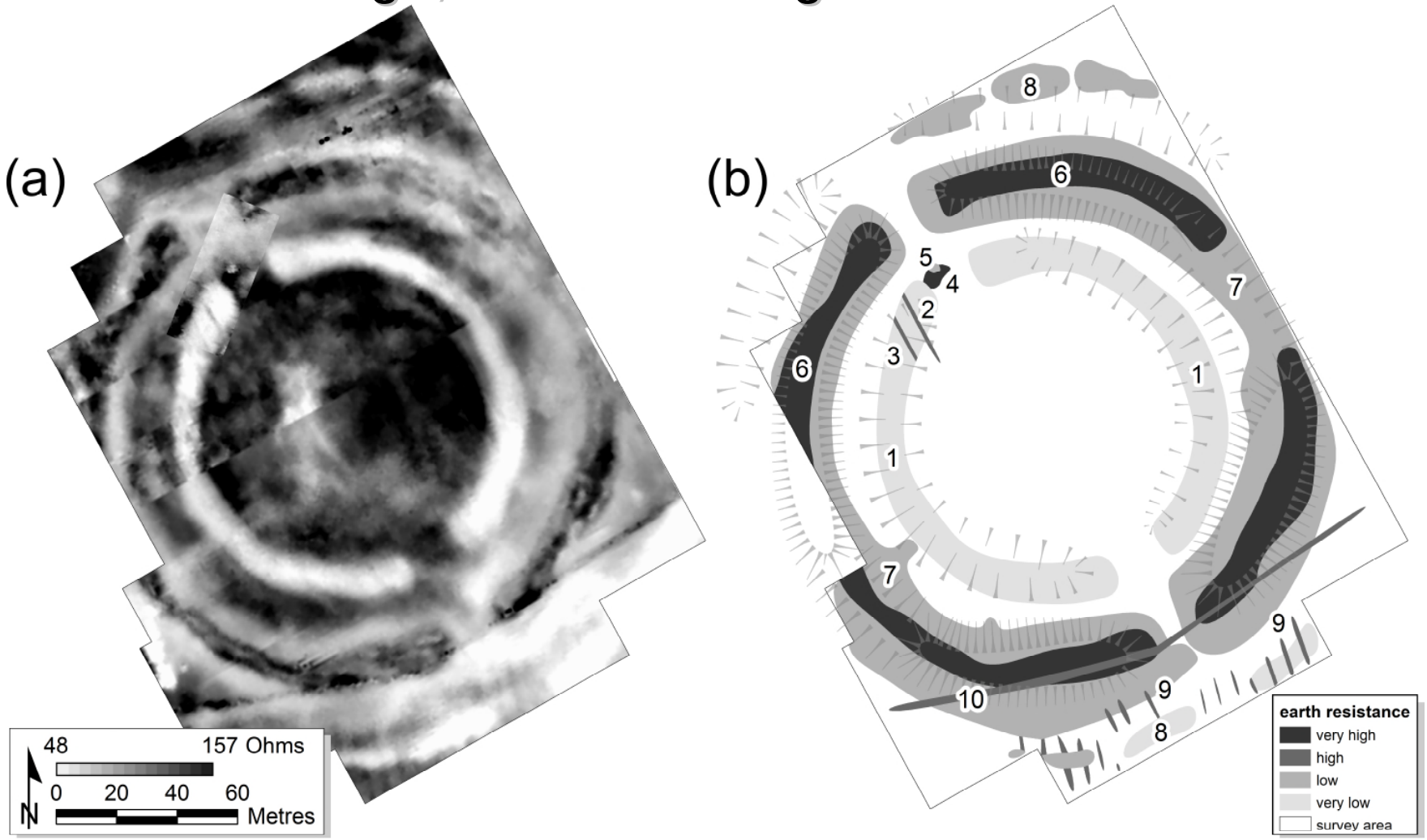
Inverse

- Human habitation
  ↑ *interpretation*
- Soil contrast (e.g. mineralogy)
  ↑ *not unique, but reasonable assumptions*
- Geophysical contrast (e.g. magnetic susceptibility)
  ↑ *not unique, especially with noise*
- Geophysical measurement (e.g. magnetic anomaly)



Interpretation

- Thornborough, southern henge



Interpretation

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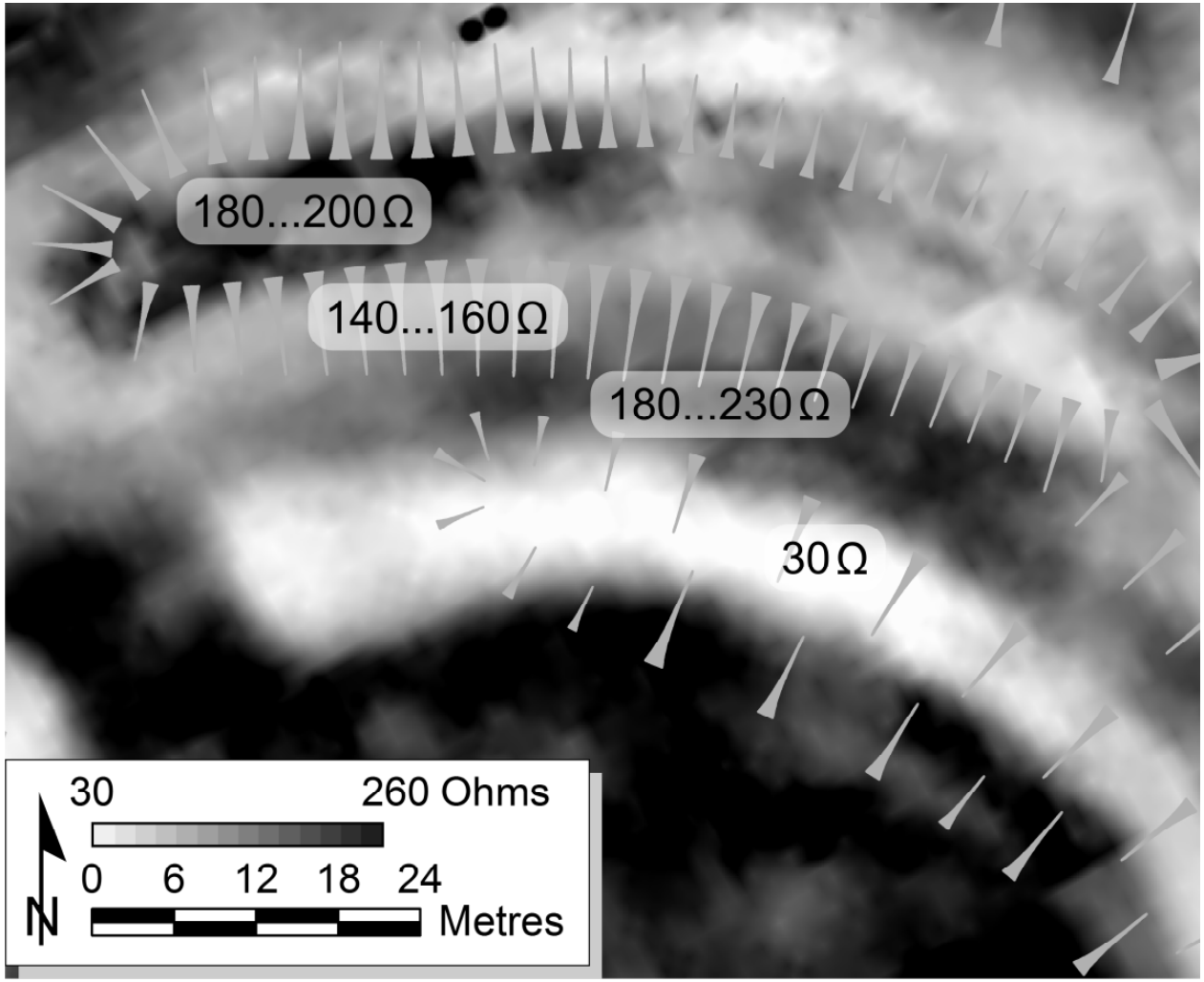
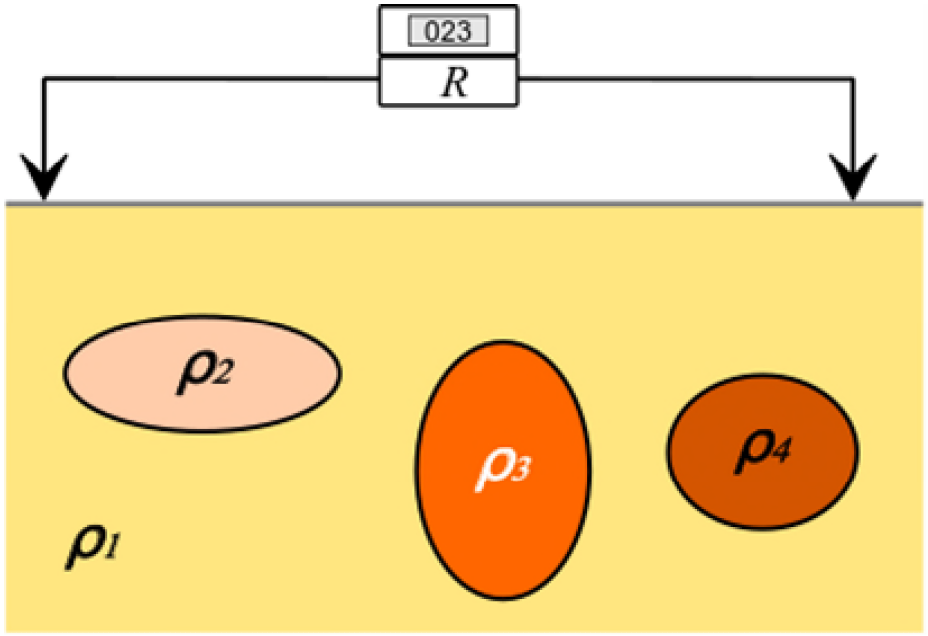


Resistance / Resistivity

- Earth resistance
  - measured: $R = V / I$ [in Ohms, Ω]
  - depends on material property ***and*** electrode arrangement
- Electrical resistivity
  - material property: ρ [in Ωm]
  - difficult to derive, cannot be measured directly

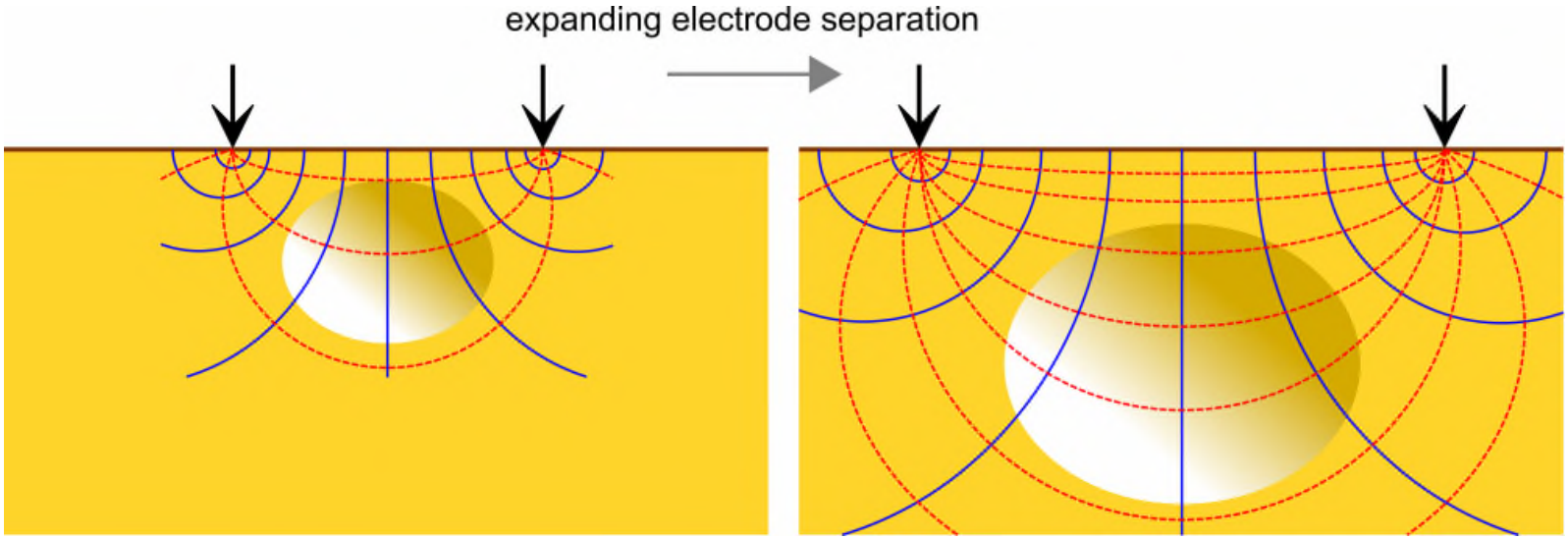
Apparent Resistivity

- Measured resistance is affected by all resistivities in the ground.
- It is some sort of ‘average’
- “If the ground were homogeneous, the measured resistance R could have been caused by the constant resistivity ρ_A (apparent resistivity)”
- Equations to convert measured resistance into apparent resistivity



Depth

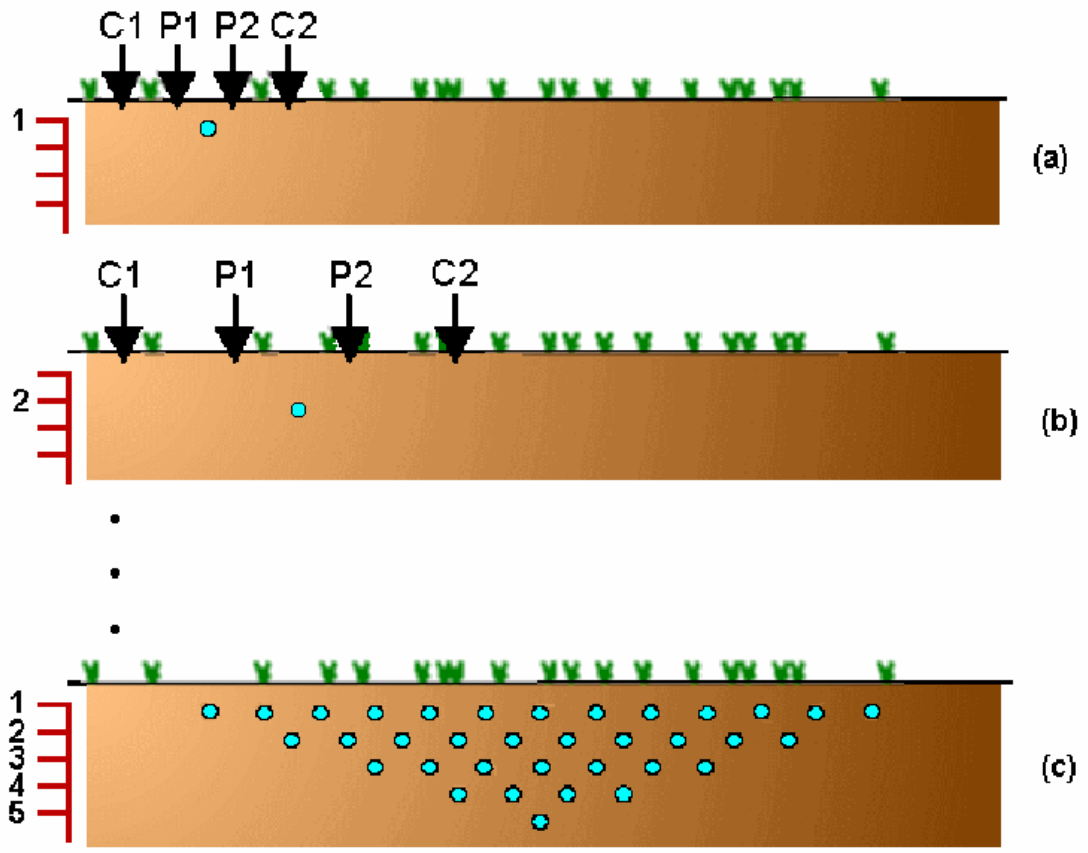
- Measurement depth depends on electrode spacing



- Wider spacing probes deeper ground

Depth

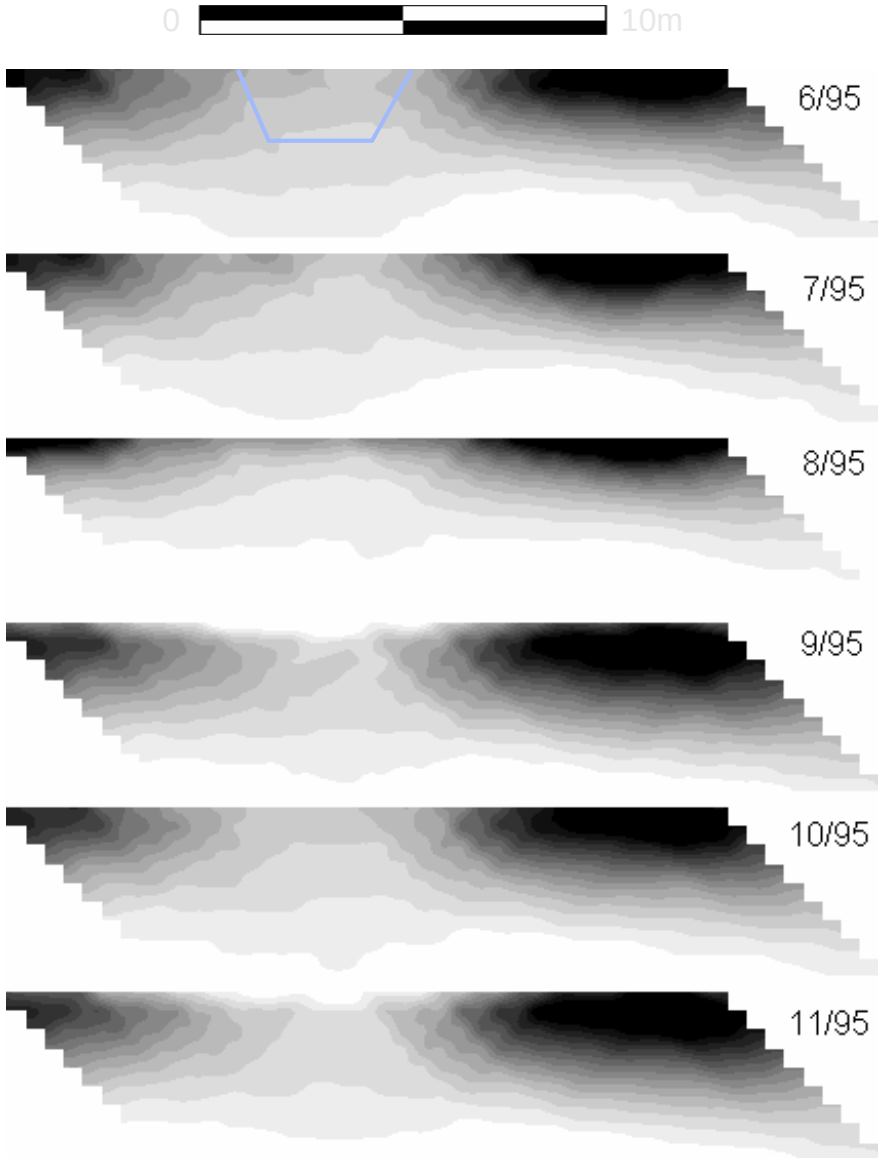
- Pseudosections
  - Systematically increase electrode separation
  - Convert all to apparent resistivity
  - Display at presumed depth
  - ERI (ERT)
  - Inversion



Depth

- Ditch at
  Caistor Roman Fort

- Vertical
  pseudosections



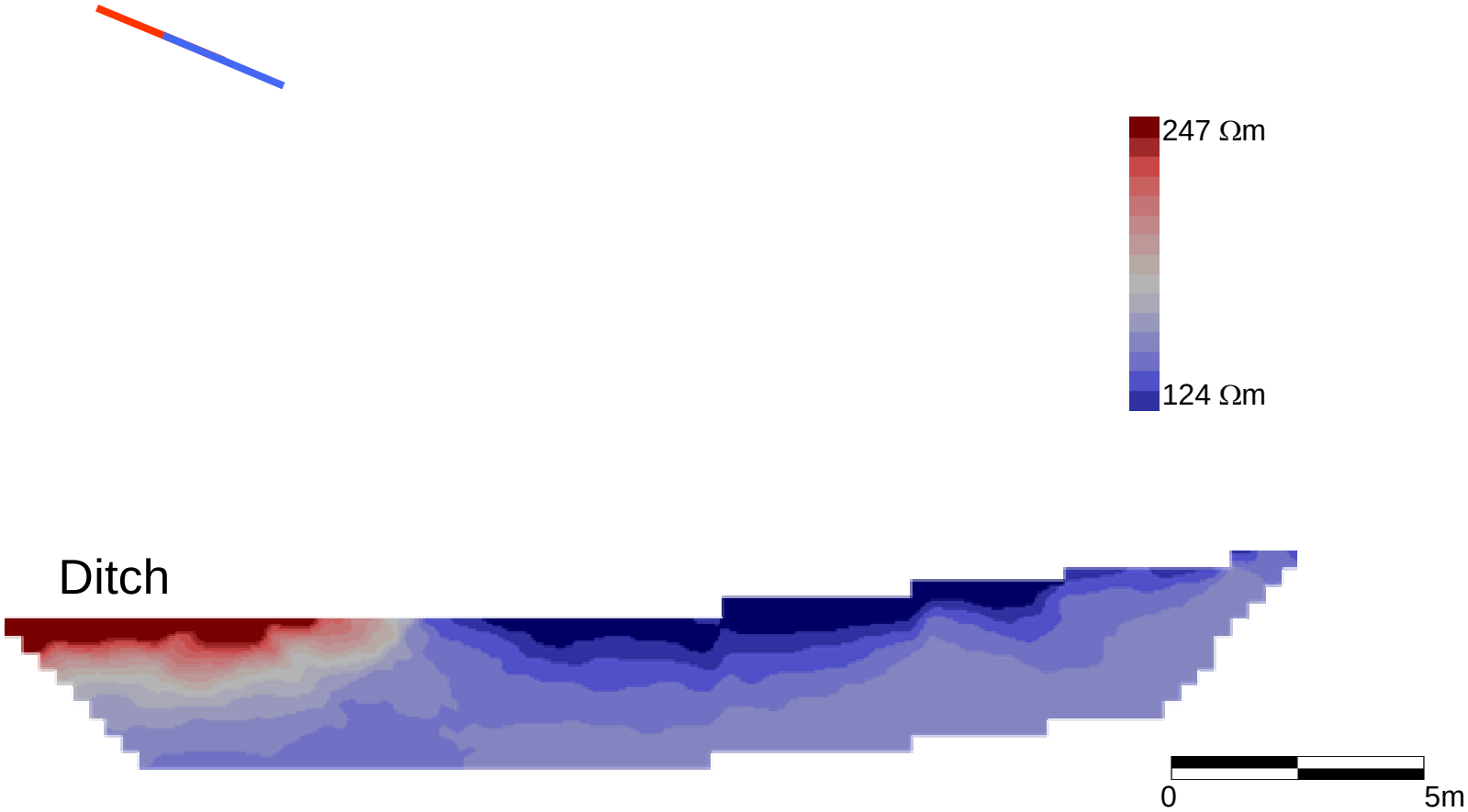
Black is high (different ranges)

Depth

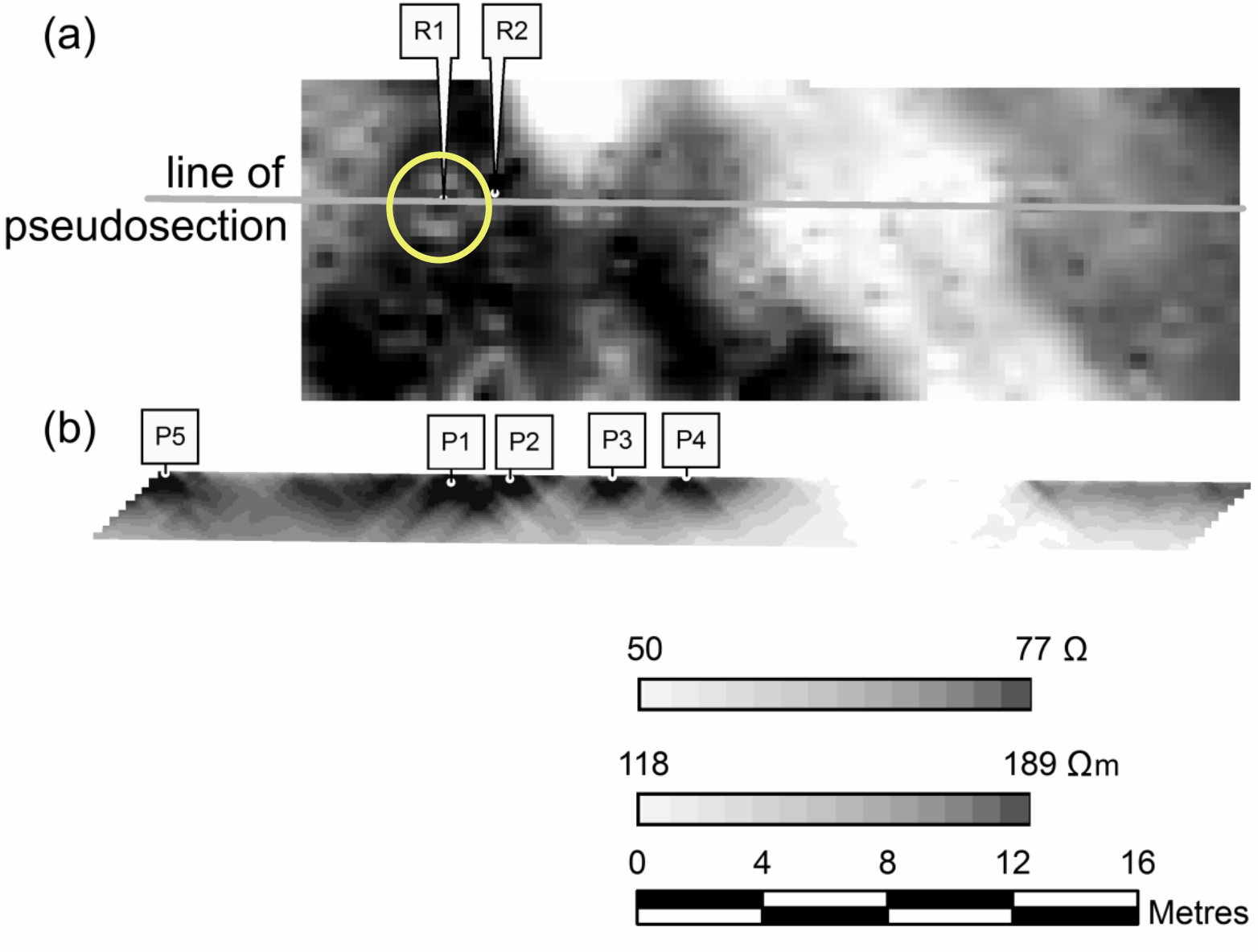
- Manual expansion is cumbersome

Depth

- Scatness, Shetland: Iron Age Broch



Depth


(a)
R1
R2
line of
pseudosection
(b)
P5
P1
P2
P3
P4
50
77 Ω
118
189 Ωm
0
4
8
12
16
Metres

Four Electrodes

- Why four electrodes?
- Handheld multimeter only needs two.

Four Electrodes

- Contact Resistance between electrodes and soil.