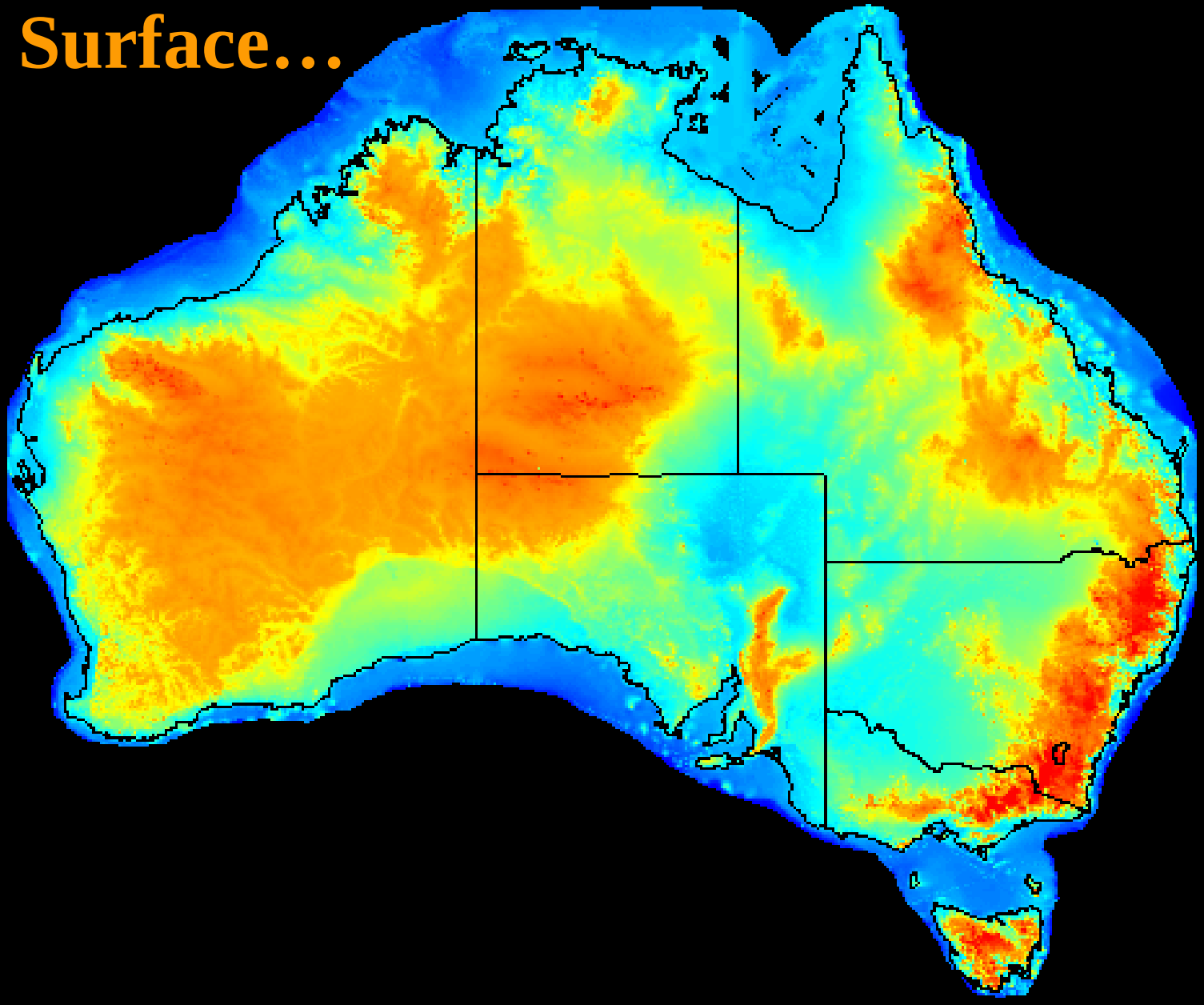
# The Physical Environment

## Seeing through the Surface

# The Surface…



# Geophysical Methods Lecture

**This lecture**

- **looks at applications of geophysics in environmental studies**

**Main objective**

- **to alert you to the possibilities of using geophysical data in problem-solving**

# Simple Textbooks

- **“*Principles of Applied Geophysics” (Parasnis)***
- **“*Field Geophysics”* (Milsom)**
- **“*Introduction to Geophysical Exploration”* (Keary & Brooks)**
- **“*Geotechnical and Environmental Geophysics*” (ed. Ward)**
  - ***or any text in the same part of the Library!***
    - **DDC 622.15 or 551.15**

# What is it?

- **Geophysics is**
  - **“The use of observations of physical phenomena to infer the structure of the Earth.”**
- **Geophysics observes**
  - **the effects of differences in *physical* properties of rocks of different kinds.**

# Why do it?

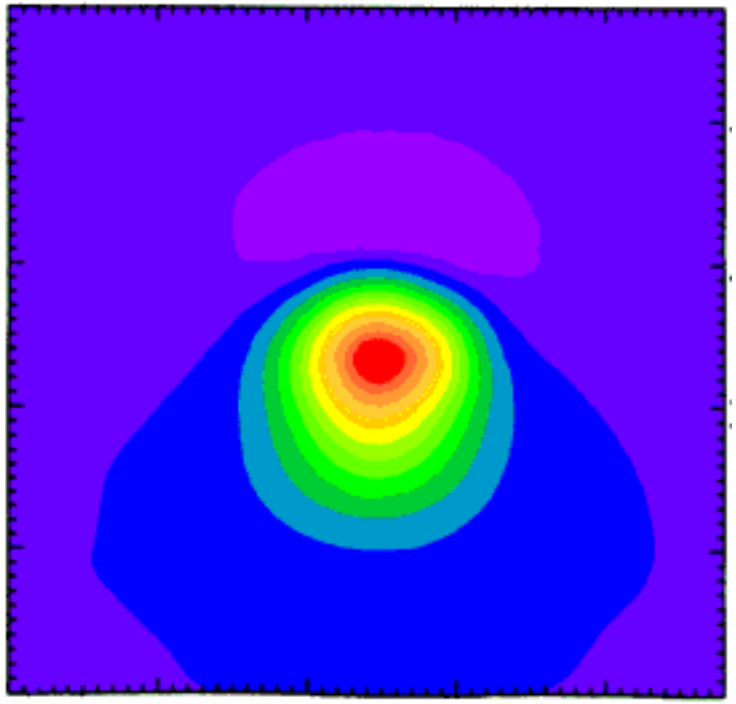
- **Geophysics uses**
  - **Measurements made at, or near, the surface (or in boreholes)**
- **Geophysics produces**
  - **Models showing physical property distributions below the surface**
- **These distributions are interpreted in terms of other information about the soil or rock.**

# A simple example

- **Locating waste buried in steel drums**
- **Steel affects the Earth's magnetic field in its vicinity**
- **Easily measure changes in the magnetic field strength at the surface**
- **Shape and size of anomalies indicates location of drums**

# Magnetic Field Map over Steel Drum

- **Map is ~ 15 m square**
- **Drum is ~ 3 m below ground surface**
- **Signal is about 1000x measurement noise**
- **Location is obvious!**



# Rock Property Examples

| | Compare… | with… |
|---|---|---|
| Elasticity | Brown Coal | Hornfels |
| Electrical Resistance | Mica | Copper |
| Magnetism | Limestone | Basalt |
| Density | Scoria | Granite |

# Physical Fields

| | |
|---|---|
| Elasticity | Seismic Waves |
| Electrical Resistance | Electrical Resistivity |
| Magnetism | Magnetic Field |
| Density | Gravity |

# Geophysical Methods

- **allow “remote sensing” of rocks below the surface, by measuring these physical fields.**

- **Fields usually measured at the Earth’s surface, but give rise to a third-dimensional view.**

# Anomalies

- **Geophysics widely used in resource exploration**
- **Effort is put into locating “anomalies” as in the drum example**
- **Environmental studies often involve imaging “all” of the subsurface**
- **Still a developing sub-branch of Geophysics**

# Way to go…

- **Time is limited, so we will look at**
- **Electrical Methods**
  - **Leading into later section on groundwater**
- **But there's more**
  - **Seismic, Magnetic and Gravity field measurements also directly applicable, but … some other time!**

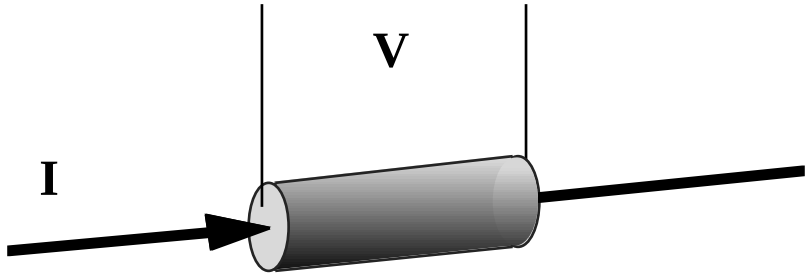
# Electrical properties

- **Soils and rocks show differences in electrical resistivity, due mainly to their porosity and saturating fluids.**

- **Fluids especially important, since these carry the electrical current.**

# Ohm's Law and Resistance

- **If current I flows through an object, voltage drop V is observed.**




- **V is proportional to I (Ohm's Law)**
- **Constant of proportionality is Electrical Resistance of object.**

# Property of Matter

- **For extended volumes (e.g. soil, rock, water) “resistor” model is inappropriate**

- **Resistivity is the material property.**
  - **Conductivity (the inverse) is also used**

# Matter Resistivities

- **Units of resistivity are Ohm.m (Ω.m)**
- **Insulators have very high resistivities**
  - **$10^{12}$-$10^{15}$ Ω.m is possible**
- **Conductors have very low resistivities**
  - **$10^{-8}$ Ω.m is possible at ordinary temperatures**
- **The range is extremely wide !**

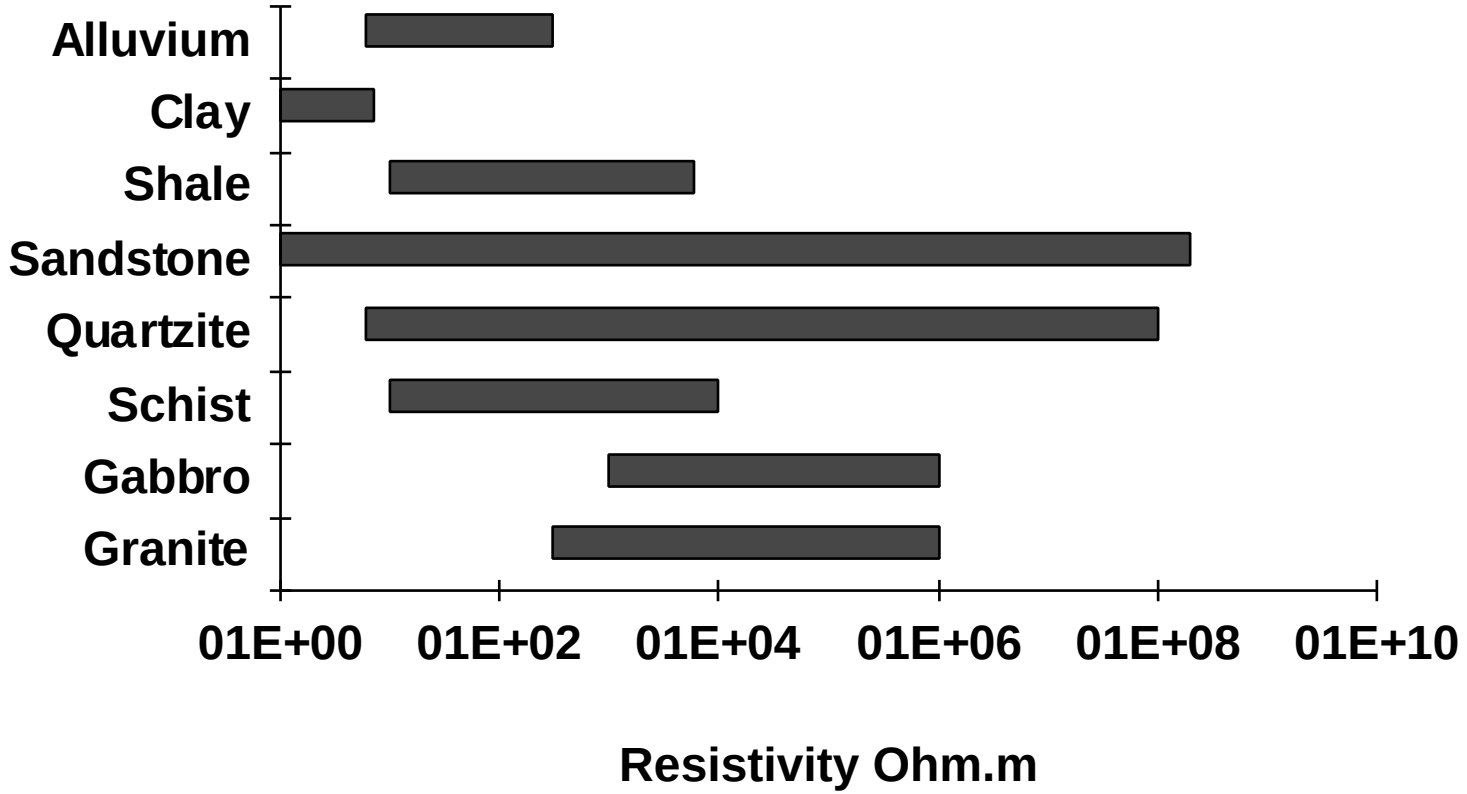
# Fluid Resistivities

- **Resistivity of groundwater depends on salinity, temperature**
  - **For Salinity S in g/l**
  - **Temperature 20 C**

$$\rho \approx \frac{5}{S}$$

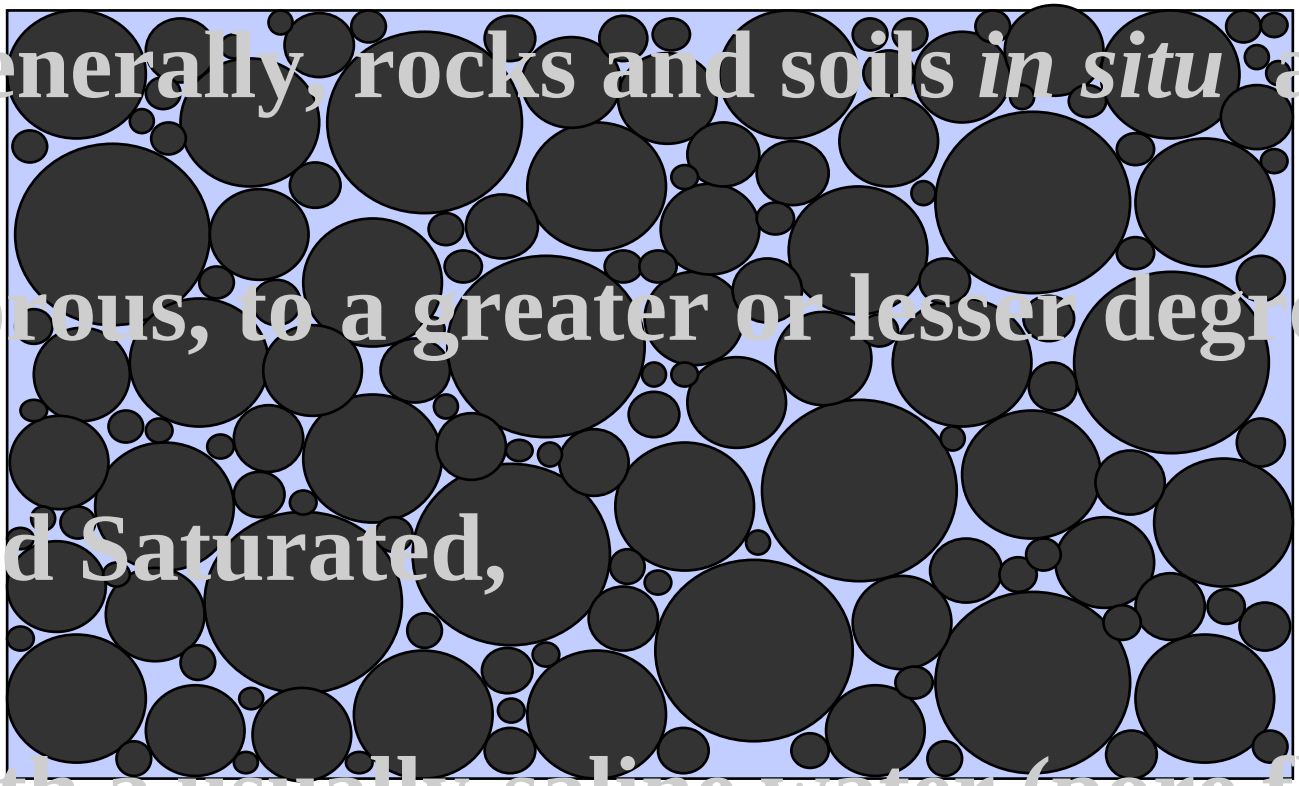
- **Resistivity of hydrocarbons generally very high - good insulators**

# Rock resistivities - overview



# Real Rocks

- Generally, rocks and soils *in situ* are:
- Porous, to a greater or lesser degree,
- and Saturated,
- with a usually-saline water (pore fluid)



# Archie's Law

$$\rho = \rho_f \varphi^{-2}$$

$\rho$ is rock resistivity

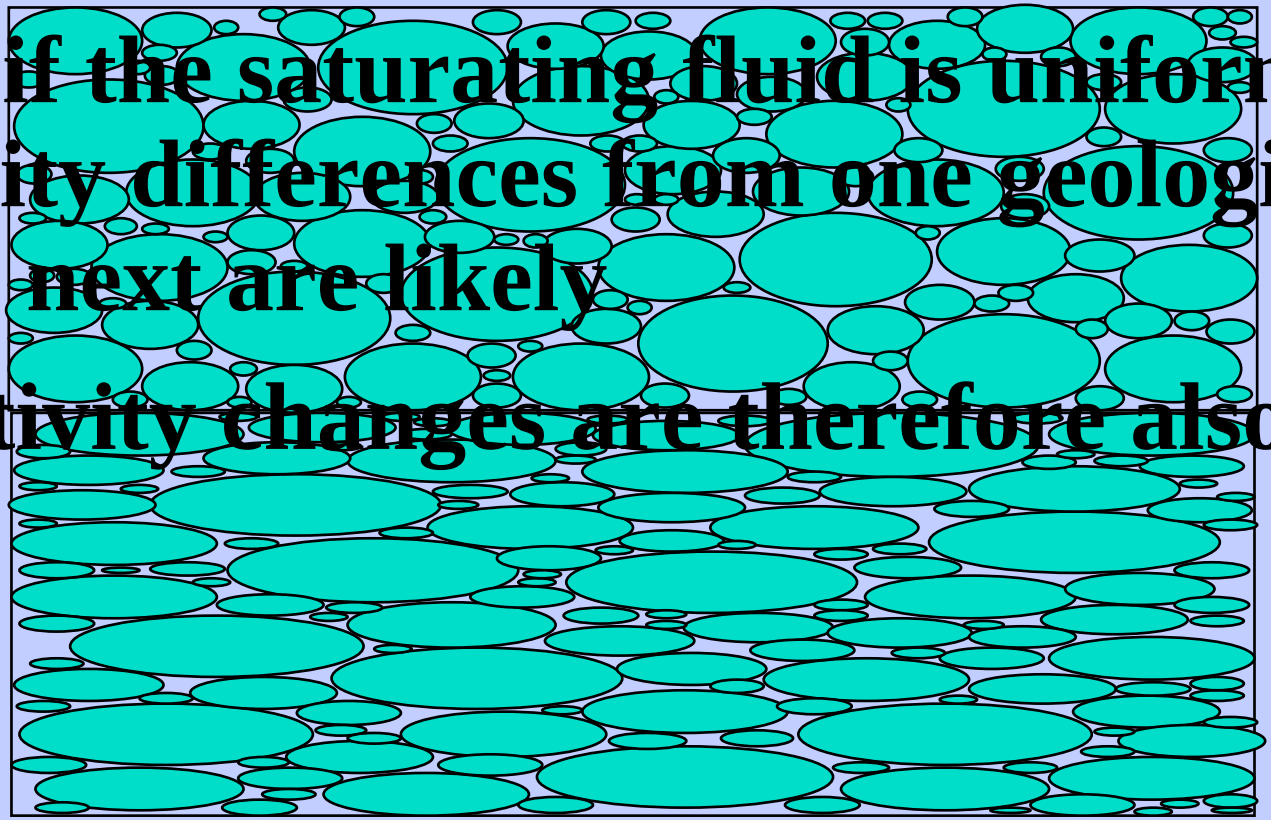
$\rho_f$ is saturating fluid resistivity

$\varphi$ is porosity

- **Based on observations of saturated sediments**
- **Observational, empirical**
- **Consistent with theory that current flows through fluid, not "rock"**

# Distinguishing between earth materials

- **(In sediments) the dependence on porosity is both crucial and sufficient**
- **Even if the saturating fluid is uniform, porosity differences from one geological bed to the next are likely**
- **Resistivity changes are therefore also likely**

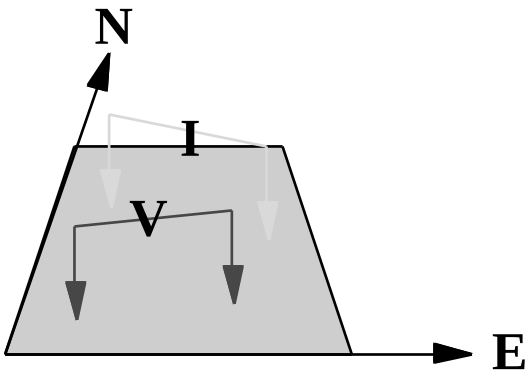


# Distinguishing between earth materials

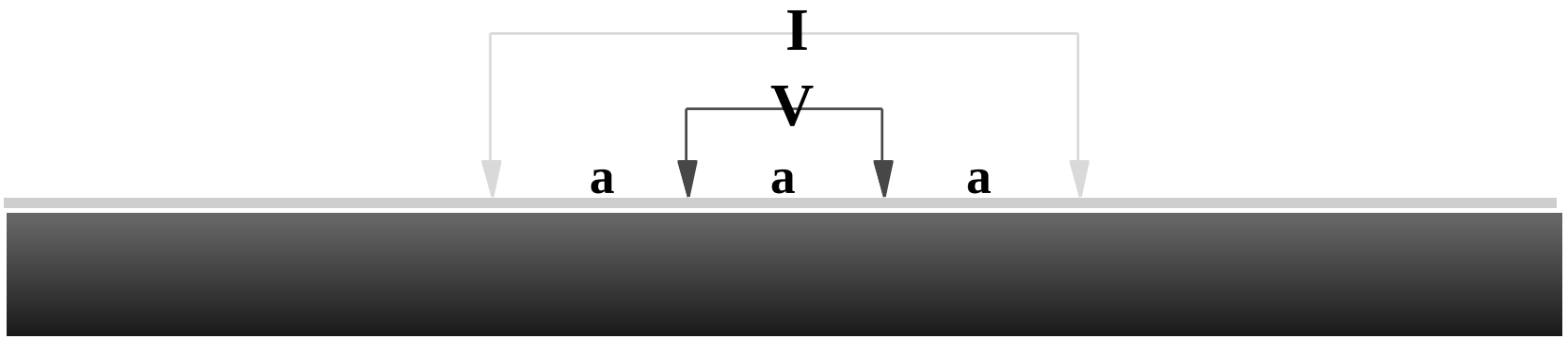
- **Environmental studies often interested in water properties explicitly**
- **Even if porosity is uniform, salinity differences in time or space can occur**
- **Resistivity changes therefore also likely**

# Resistivity layouts

**General case: 4 electrodes (2 current, 2 potential) on ground surface**




## Wenner Array (seen in cross section)



# Surface electrical mapping.

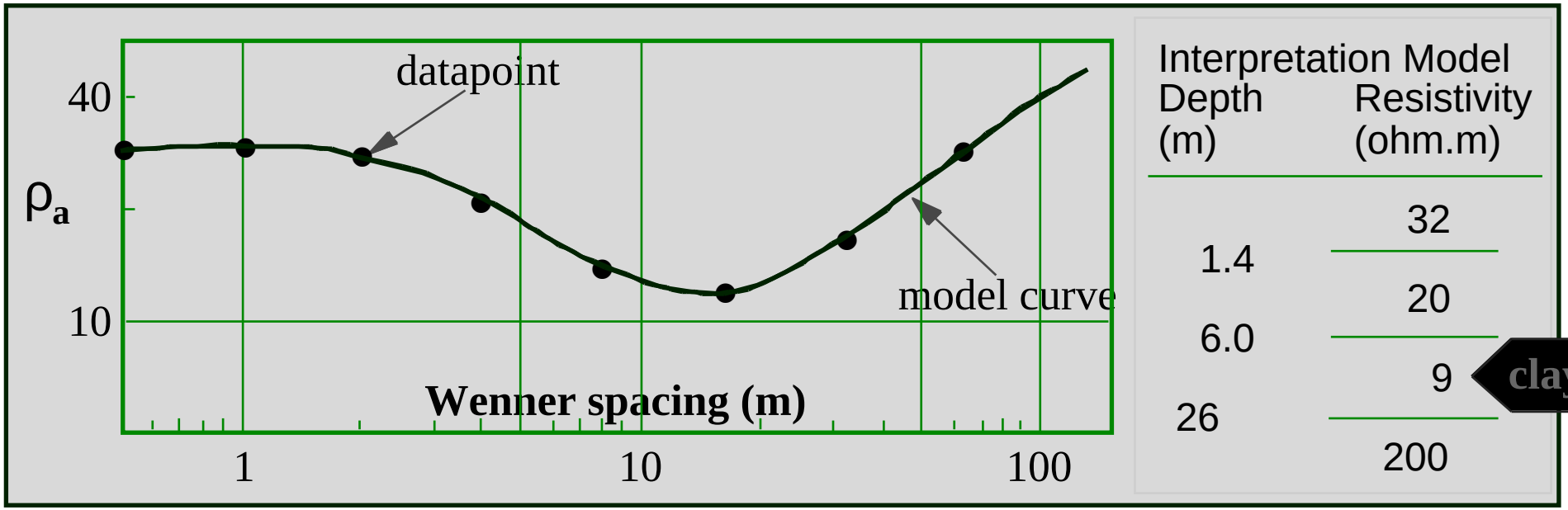
- **Resistivity of rocks-in-place can be measured with simple experiments**
- **Because electrical currents pass through “all” of the rocks, the result is an average resistivity.**
- **Average is interpretable with simple analysis**

# Array size and response to layers

- **If Earth truly uniform, this process reports resistivity, independent of array size a**
- **If Earth layered, however, response will depend on layer thicknesses and resistivities, and change with array size**
- **We use this to perform Electric Drilling**

# Landfill study — Data example

**“Electrical Sounding” at station S7, and interpretation**




**As the array spacing gets larger, deeper rocks are sampled**

# Landfill study

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- **Client claimed landfill secured by clay seal (host rocks)**
- **Resistivity experiment shows low resistivity values below landfill — clay?**
- **Subsequent drilling showed no clay, no seal**
- **low ρ below landfill results from leachate contaminating sandstone**

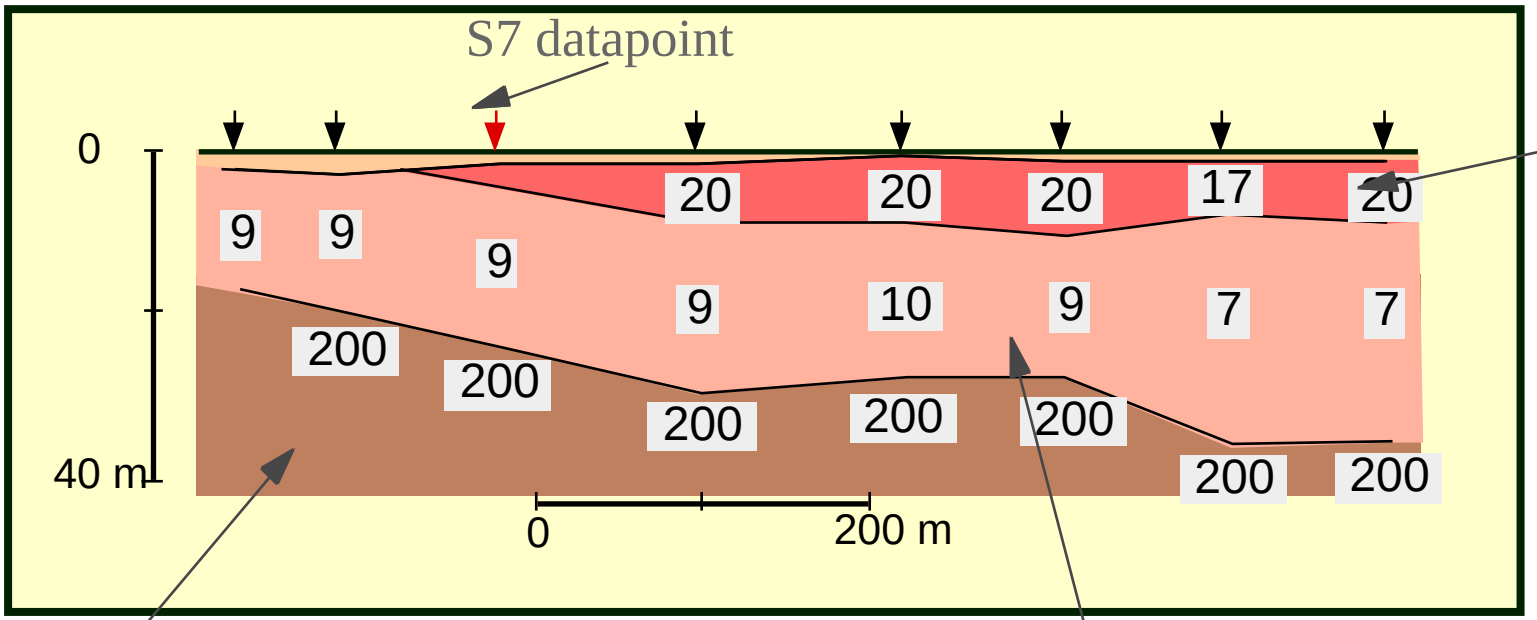
# Array position and effect of lateral variations

- **If Earth truly uniform, this process reports resistivity, independent of array size a**
- **If Earth varies horizontally, however, response will depend on resistivities near the array, and change with array position**

- **We use this to perform Electric Trenching.**

# Landfill study — Interpretation

**Figures are resistivities, in Ohm.m; boundaries are interpolated between electrical sounding points**



# Remote Sensing

- **Measurement of resistivity from aircraft possible**
- **Currents induced in ground by electromagnetic field from aircraft**
- **Response detected by aircraft depends on ground resistivity**
- **Increasing use in Australia for salinity studies**

# Web Page Reference

- **A more-extensive version of these notes is available from**

  **http://www.met.unimelb.edu.au/Thomas/ltcw/phengpcs.html**

- **Feel free to email comments or questions to me at**

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