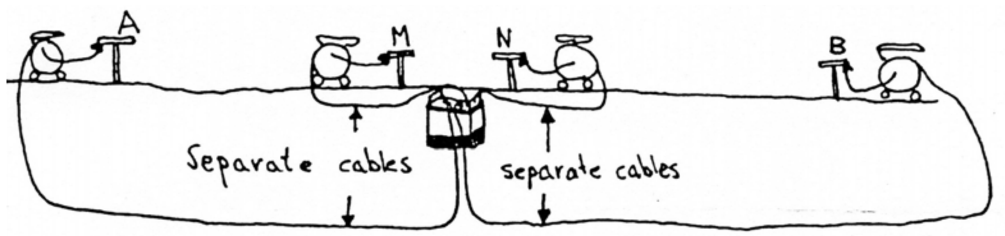
C5 Field techniques for DC resistivity exploration

C5.1 Instrumentation

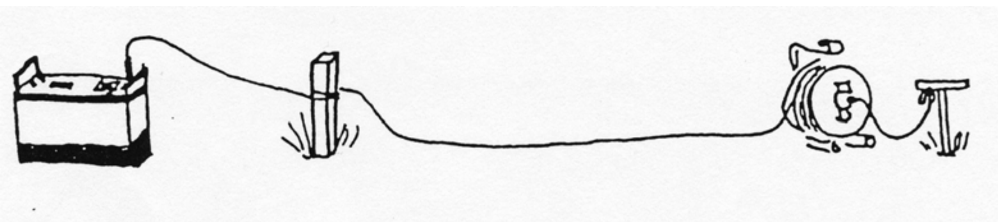
- Typical DC resistivity instruments are powered by an internal battery and generate up to 400 volts and a current of 1 amp. The control unit weights a few kilograms. Data is saved in the memory and can be downloaded to a computer at the end of the day.

- The electrodes are usually stainless steel stakes. If the surface is very dry, then salt water may need to be poured over the current electrodes (M and N) to lower the contact resistance.



- Cables carrying electric current to current electrodes (A and B) and those detecting voltages at the potential electrodes (M and N) should be separated to avoid cross talk.

- Reels of wire should not be placed close to the unit, as they act as electromagnets when current flows through the wire.



- Cables should be secured to stakes to prevent them being pulled loose.

- An accurate measurement requires that sufficient current can be made to flow in the ground. If the ground is very resistive, then 400 V may not be enough to get the current flowing. Additional power supplies can be used (car battery, 10kW generator)

- The voltage is switched +/- several times as the measurements are made. This avoids **polarization** of the electrodes when each electrode develops a static electric charge.

- A consequence of switching the current +/- is that the electric current is usually a square wave that reverses every 1-10 seconds. An estimate of apparent resistivity is made for each +/- cycle and allows an **error** to be estimated for each apparent resistivity measurement. A high error can indicate that insufficient electric current is flowing in the Earth (e.g. see notes on Schlumberger array below).

- There is sometimes a delay in the time taken for the current in the Earth to start flowing. This can be due to electric polarization in the Earth. Measurements of the rise and fall time are used in **the induced polarization** exploration technique.

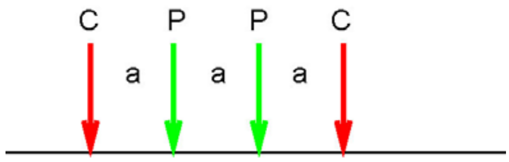
- Great care must be taken when working with **high voltages**, especially when watering electrodes. Animals and children need to be kept away.

- Most modern exploration uses an **array** of 100+ electrodes connected to a smart cable. Computer control and automatic switches allow any electrode to be activated as a current electrode or a voltage electrode. This allows 2-D and 3-D images of subsurface resistivity to be generated (see C6 and C7).

C5.2 Electrode arrays for DC resistivity exploration

C5.2.1 Wenner array

The **Wenner array** is widely used and apparent resistivity = $\rho_a = 2\pi a \left(\frac{\Delta V}{I}\right)$



Field procedure

Sounding Vary the *a*-spacing to get resistivity as a function of depth (C5.2 and C5.3)

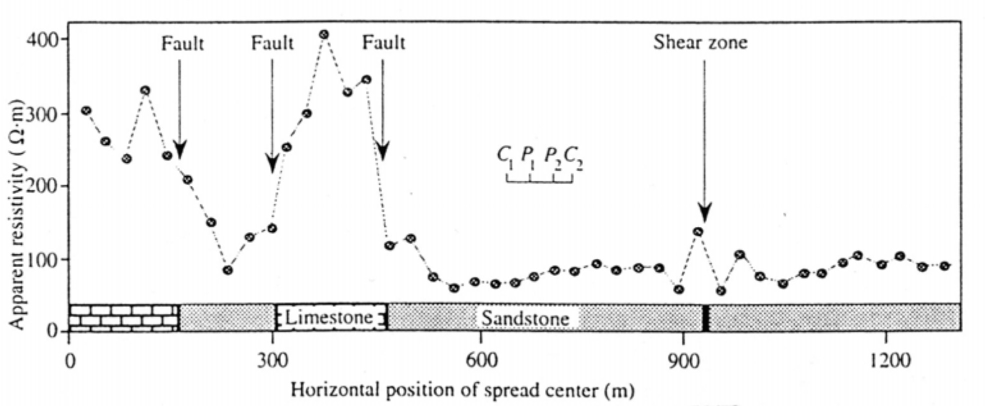
a-spacing is increased logarithmically, with 5-7 values per decade.

This technique is sometimes called **electric drilling**.

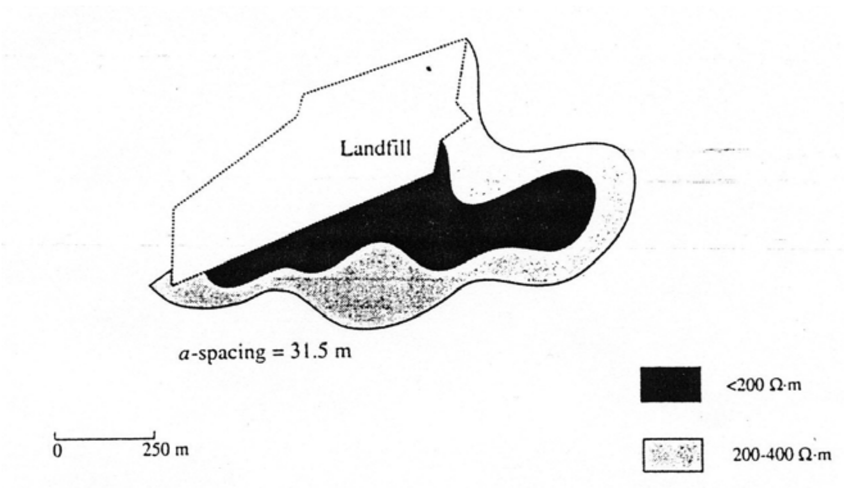
The maximum value of *a*-spacing should be at least 3-5 times the maximum depth of investigation.

Profiling Fix *a*-spacing and move whole array along a transect

The *a*-spacing should be approximately equal to the depth of investigation



Profiling can also be used to produce **a map** of subsurface resistivity. The figure below shows a low resistivity contaminant plume that has leached from landfill.



Producing a map like this requires that the 4-electrode Wenner array is moved across a grid of points on the surface. Similar results can be obtained with much less field effort using shallow **electromagnetic** exploration systems (e.g. Geonics EM31 and EM34). These instruments do not require electrodes to be placed in the ground and are essentially large metal detectors. For more details see below and in Geophysics 424.

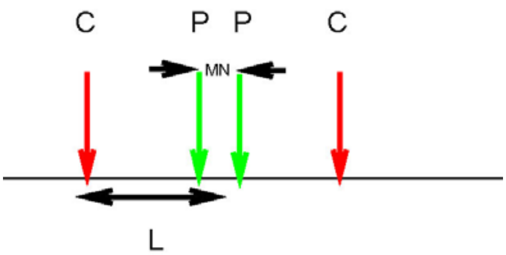
Advantages of Wenner array

- Simple to compute apparent resistivity
- Strong electric fields between current electrodes

Disadvantages of Wenner array

- High sensitivity to local variations in resistivity structure near the potential electrodes (*e.g.* rock, wet soil)
- Need to move 4 electrodes for each measurement (slows down fieldwork)
- Long-wires for deep sounding (overcome by dipole-dipole method)

C5.2.2 Schlumberger array



Field procedure

This array keeps the potential electrodes (P) stationary while the current electrodes (C) are moved out. The array is symmetric with current electrodes a distance L from the centre. The potential electrodes are separated by a distance MN.

As the current electrodes are moved out, ΔV becomes smaller and ultimately becomes too small to measure. At this point, the current electrodes are moved out and measurements continue.

To account for the changing spacing of potential and current electrodes, a more complicated formula is needed for apparent resistivity.

Apparent resistivity = $\rho_a \approx \frac{\pi L^2}{MN}\left(\frac{\Delta V}{I}\right)$

Sounding Vary the *a*-spacing to get resistivity as a function of depth

a-spacing is increased logarithmically, with 5-7 values per decade.

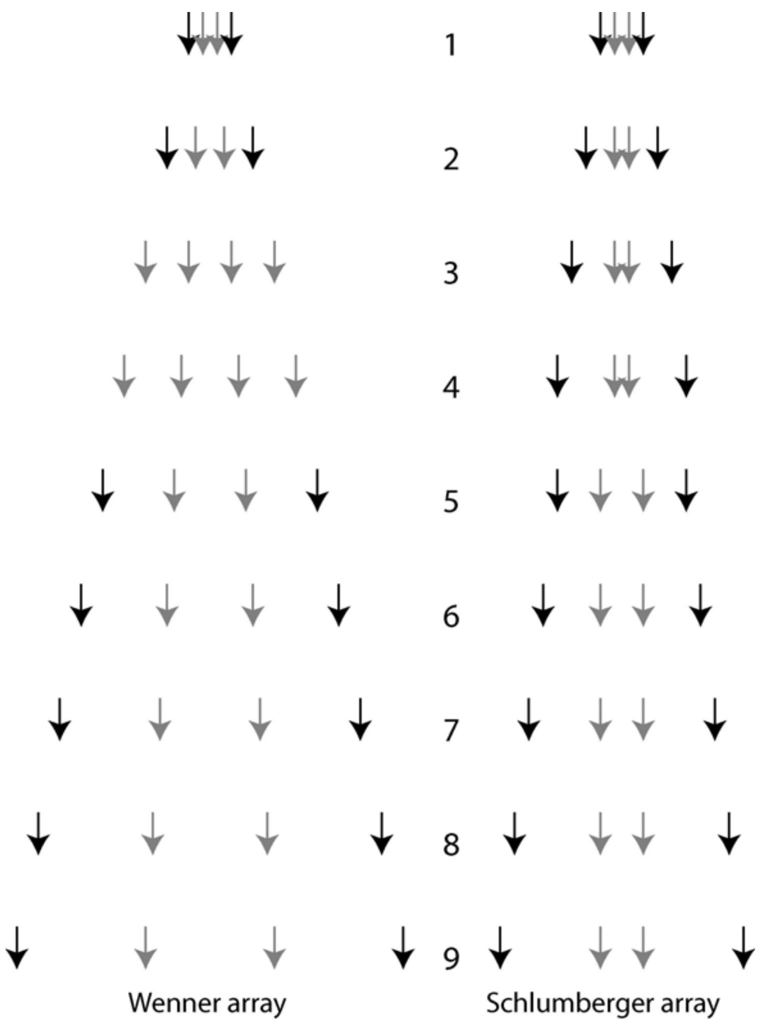
The maximum value of *L* in a Schlumberger array should be at least 3-5 times the maximum depth of investigation.

Advantages of Schlumberger array

- Only move **two electrodes** for each data point.
- Potential electrodes **moved less often** than in the Wenner array. This reduces the noise due to near surface heterogeneity.

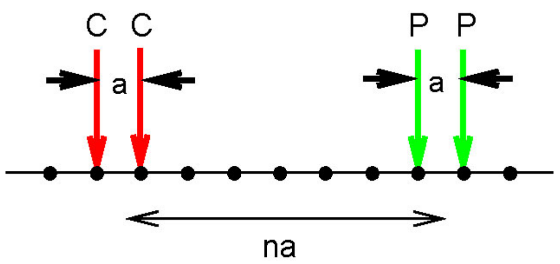
Disadvantages of Schlumberger array

- Complications of computing the apparent resistivity
- Long-wires for deep sounding (overcome by dipole-dipole method)



Potential electrodes shown in grey, current electrodes in **black.**
Note that in the Schlumberger array, the potential electrodes only move at step 5

C5.2.3 Dipole-dipole array



$$\rho_a \approx 2\pi n^3 a(\frac{\Delta V}{I})$$

Advantages of dipole-dipole array

- Short wires can be used to achieve deep penetration

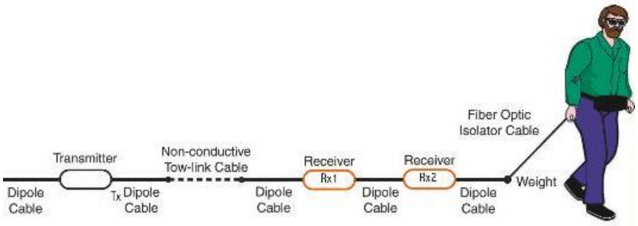
Disadvantages of dipole-dipole array

- Electric fields at potential electrodes can be quite weak

5.3 Inductive methods of measuring resistivity

DC resistivity measurements require direct electrical contact with the Earth. This can make resistivity surveys quite time-consuming. An alternative approach uses **electromagnetic induction** to measure the electrical resistivity of the Earth. This uses a **time-varying** magnetic field to generate **electric currents** in the Earth.

It has been applied to shallow exploration in the OhmMapper system produced by Geometrics (www.geometrics.com). Different transmitter-receiver distances can be used to measure the resistivity of the subsurface at different depths.



The Geonics EM31 and EM34 systems mentioned above can also give similar data (www.geonics.com). A small transmitter and receiver are placed at each end of the boom.

Electromagnetic explorations can image geoelectric structure deeper in the Earth and will be discussed in detail in Geophysics 424. These systems can operate from low flying aircraft and rapidly cover a large survey area.

http://www.fugroairborne.com.au/