Introduction to Reisitivity

Introduction

Electrical and electromagnetic methods make up a large portion of all geophysical methods used. They also include some of the oldest methods used to explore the subsurface. Electrical methods can be used to measure different quantities including current flow, electrical potential and electromagnetic fields. The first electrical method to be used in this course will be direct current (DC) resistivity.

Theory

In a homogeneous earth, current flows radially outward from the source to dfine a hemispherical surface. The current distribution is equal everywhere on this surface which is also called an equipotential surface. Starting with Ohm's law ($V = IR$) and defining the resistance R in terms of the resistivity ρ and the area of the shell (equipotential surface), the potential difference across the shell is

$$dV = i(R) = I\left(\rho\,\frac{L}{A}\right) = I\left(\rho\,\frac{dr}{2\pi r^2}\right)$$

where V is the voltage (or electrical potential), I is the current, ρ is the resistivity, and r is the radius of the equipotential surface. Integrating the above equation and setting the potential at infinity to zero, the electric potential at a distance R from the source is given by

$$V = \frac{\rho\,I}{2\pi\,R}$$

Resistivity has units of *ohm m* and is not to be confused with *resistance* which has units of *ohms*. The *resistivity* of a material is defined as $\rho = \frac{RA}{L}$ where R is the resistance of the material, A is the cross-sectional area through which current flows and L is the length on the material.

The potential has been derived due to a single current source. The goal in resistivity surveying is to measure the potential different between two points due to the current from two current electrodes. The potential at each electrode is determined due to the current sources:

$$V_{P1} = \frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2}$$

$$V_{P2} = \frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4}$$

where the $r_{i's}$ are shown in Figure 1. The potential difference $\Delta V = V_{P1} - V_{P2}$ which simplifies to

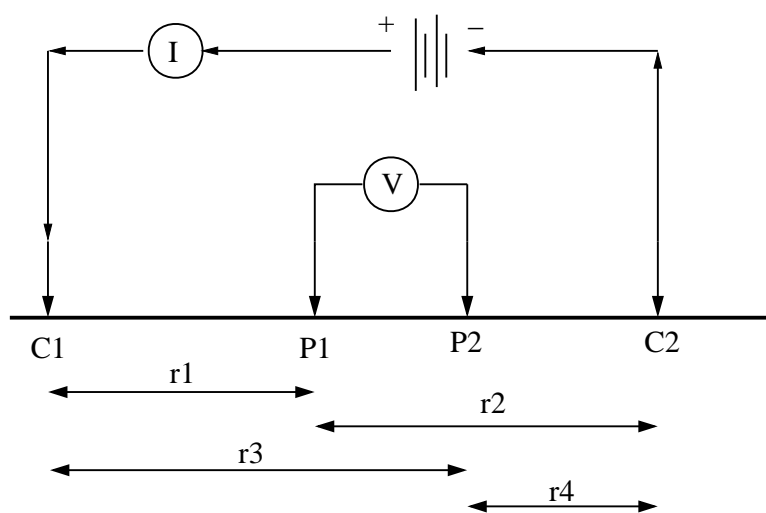$$\Delta V = \frac{I\rho}{2\pi} \left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4} \right)$$

The above equation can then be solved for the resistivity ρ. In a nonhomogeneous earth, the resistivity which is measured is not actually the true resistivity of the subsurface. For an earth with more than one layer, the *apparent resistivity* measured will be an average of the resistivities of the additional layers. The apparent resistivity data needs to be interpreted in terms of a subsurface model in order to determine the actual resistivities of the layers.

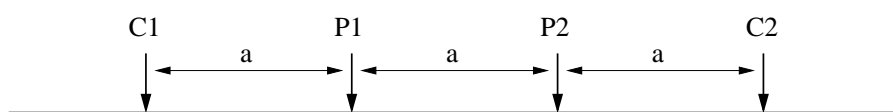**Survey methods and electrode configurations**

Resistivity surveys are conducted as either soundings or profiles. A sounding is used to determine changes in resistivity with depth. The electrode spacing is varied for each measurement, but the center point of the array is constant. A resistivity profile is used to detect lateral variations in resistivity. For this configuration, the electrode spacing is fixed while the center of the array is varied.

There are various electrode configurations which can be used in resistivity surveying. The apparent resistivity measured by the array depends on the geometry of the electrodes. The majority of resistivity surveys use two current electrodes and two potentiil electrodes. The two main array configurations are the Wenner array and the Schlumberger array.

The Wenner array has the simplest geometry, with all of the electrodes equally spaced. This is illustrated in figure 2. The Schlumberger array is more complex with the spacing between the current electrodes not equal to the spacing between the potential electrodes. The Schlumberger array is shown in figure 2. In general, the potential electrode spacing is negligible compared to the current electrode spacing for this type of array.

Wenner array

C1   P1   P2   C2

a a a

Schlumberger array

C1   P1   P2   C2

b

x

a