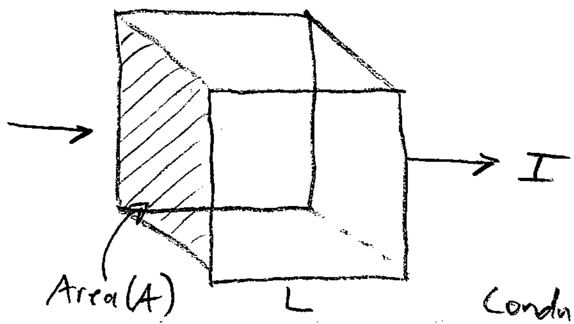
Principles of Conductivity/Resistance Methods

Conductivity/Resistivity Methods have been used since the 1900's

Remember Ohm's Law?

$$I = \frac{V}{R}$$ where: I ~ current [A]
V ~ voltage [V]
R ~ resistance [Ω]

We can use this as long as the current density [J] is not too high.



Passing current through this cube of resistive material we can see resistivity is proportional to length and inversely proportional to cross sectional area

Units of Resistivity : Ωm

Conductivity is $\frac{1}{\text{Resistivity}}$

Now we'll put this in mathematical notation!

ρ ~ true resistivity

$$R \propto \frac{L}{A} \qquad R = \rho\frac{L}{A}$$

From Ohm's Law: $R = \frac{V}{I}$ $\quad \rho = \frac{E}{J}$ (Ωm)

$$\rho = \frac{VA}{IL} \quad (\Omega m^{-1})$$

Next we must acknowledge 3 types/methods of conduction:

Electrolytic – movement of ions in an electrolyte

Electronic – movement as in metals, think 'electron sea'

Dielectric – occurs upon application of AC to an insulator.
(not important for us)

REMEMBER: Pore fluids account for most conduction

Now we'll look at current flow in a homogeneous Earth:

If we embed a single current electrode ...
- current flows away radially
- Voltage drop can be described as $-\frac{\delta V}{\delta x}$
- Equipotentials intersect lines of equal current at right angles

We can describe the potential difference (δV) across a hemisphere of thickness δr

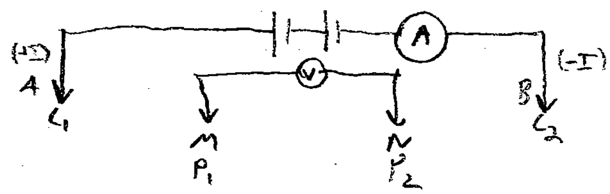
$$\frac{\delta V}{\delta r} = -\rho J = -\rho \frac{I}{2\pi r^2}$$

current density = current/area

So, voltage at radius (r) is:

$$V_r = \int \delta V = -\int \rho \frac{I}{2\pi r^2}\, \delta r = \frac{\rho I}{2\pi} \cdot \frac{1}{r}$$

So let's say we arrange an array of electrodes like this:



We input power and measure its current at electrodes A + B and measure the potential difference across M + N

$$V_m = \frac{\rho I}{2\pi}\left[\frac{1}{AM} - \frac{1}{MB}\right] \qquad V_n = \frac{\rho I}{2\pi}\left[\frac{1}{AN} - \frac{1}{NB}\right]$$

We can measure potential difference ($\delta V_{mn} = V_m - V_N$) and rearrange to solve for resistance

$$\rho = \frac{2\pi\, \delta V_{mn}}{I}\left[\left(\frac{1}{AM} - \frac{1}{MB}\right) - \left(\frac{1}{AN} - \frac{1}{NB}\right)\right]^{-1}$$

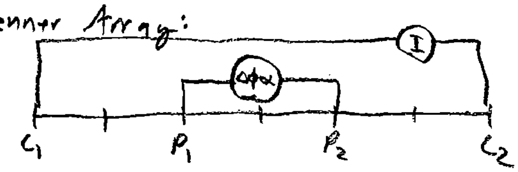
Pull out 2π and all this in brackets and call it K a 'Geometric Factor' describing our array

Finally we'll look at the array's we'll try

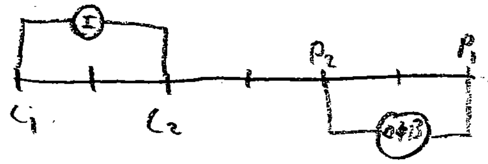
Wenner Array:

Rough Effective Depth

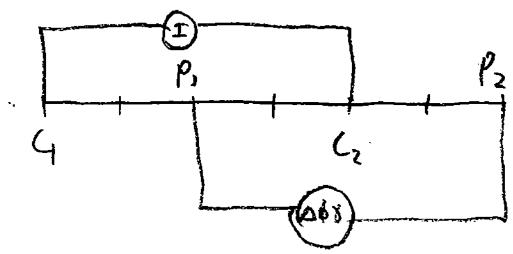
$z = \frac{3}{2} a$



'Alpha'

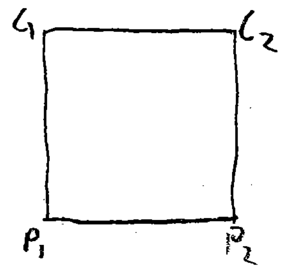


'Beta'



'Gamma'

Square Array:



This gives us easy gridding and by swapping P_1 & C_2 we get an orthogonal reading for resistivity anisotropy.

Great for shallow applications!

Our Setup

Automotive Power Inverter and Grounding Rods