Induced Polarisation (IP)

Induced Polarisation (IP) effects were first reported as early as 1912 and the method has been in use since the late 1940s. IP is used primarily for mineral exploration, and is also being developed as a tool for geothermal, hydrological and environmental applications. There are several types of IP techniques, but essentially IP is an extension of traditional resistivity surveying. The ground is characterised not only by its resistivity, but also by its chargeability (how well it holds electrical charge). This means that the geophysicist has at least two diagnostic tools for the ground, making interpretation of the subsurface more certain.

Principles of operation

The IP method involves passing a current through the ground through two current electrodes ('C') and measuring a voltage across two potential electrodes ('P'). The same configurations of electrodes, or arrays, can be used as in resistivity surveying, but the most popular are the dipole-dipole and pole-dipole arrays (Figure 1). The depth of investigation for any electrode spacing *a* is increased by using greater electrode pair separation *n* values.

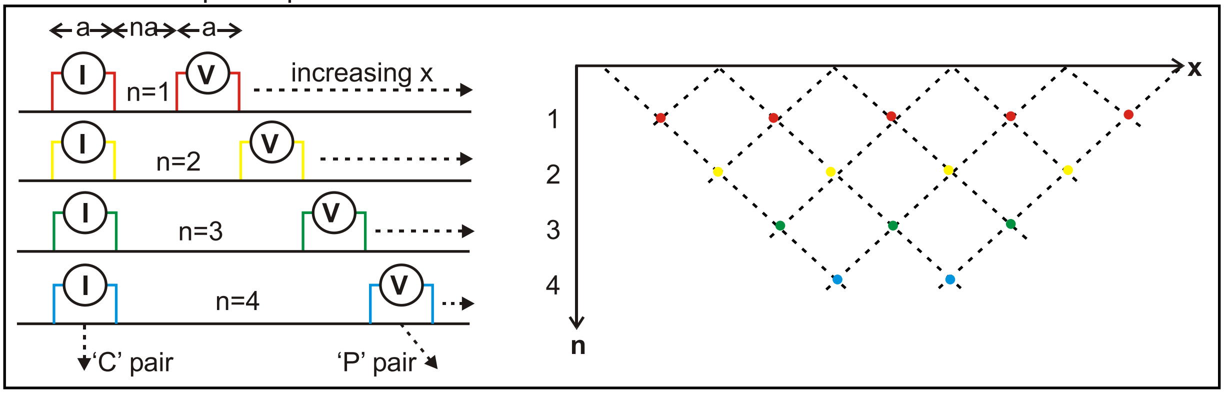

Figure 1: The dipole-dipole array. *Left*: Electrode positions on the ground. *Right*: Plotting positions for each *x,a,n* combination.

When a current is injected into the ground, the ground charges up, or polarises, like a capacitor. When the current is turned off, the induced charge takes a finite time to dissipate. The amount of charge that the ground will hold and the time it takes to acquire and dissipate that charge is diagnostic of the materials in the ground. In IP surveying, non-polarisable electrodes are used (electrodes that do not retain any charge) so that all the signal observed comes from the ground itself. IP surveying can be carried out in vertical sounding, horizontal profiling or 2D and 3D tomography modes. The majority of IP surveys are carried out using either *time domain* or *frequency domain* IP techniques.

Time-domain/pulse transient IP surveying

When a current being injected into the ground is turned off, the observed voltage between the potential electrodes, V_O, does not immediately drop to zero. Rather, it drops by V, the voltage caused by the applied current, leaving a residual or polarisation voltage, V_P, caused by the polarisation of the ground (Figure 2). The voltage then decays over a finite and measurable time. When the current is switched on again, the voltage takes the same time to build up from zero to its maximum amplitude.

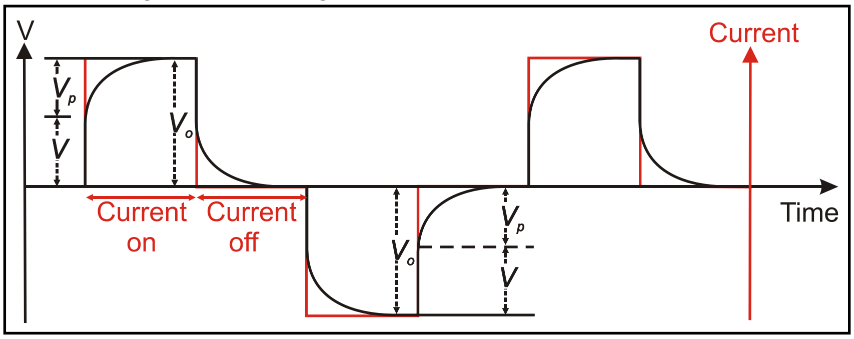

Figure 2: The observed voltage varying as the current is switched on and off.

The resistance (R) is calculated using Ohm's law, which states that the electrical resistance of a circuit component (in Ohms,) is equal to the ratio of the potential drop across the component (Volts), divided by the current passed through it (Amps). The voltage used to calculate the resistance is V_O. The resistance value resulting from this calculation is specific to the spacing of the electrodes; to obtain a unit value of resistivity ( ) the effects of electrode geometry are corrected using a standard geometric factor. The resultant resistivity value is a non-geometric average of the resistivity of the volume of ground sampled, called the *apparent resistivity* ($_a$).

The ratio V_P/V_O is the *apparent chargeability* (M_a), in mV/V. It is difficult to measure V_P directly, so the chargeability is usually found by integrating the voltage decay curve with respect to time then dividing the integral by V_O, and is measured in milliseconds (ms). The measured chargeability depends on both the nature of the ground and on the characteristics of the input current, so it is often normalised to a standard current in order to compare chargeabilities between surveys.

Frequency-domain/variable frequency IP surveying

The voltage across the potential electrodes is measured for currents of at least two different frequencies of less than 10 Hz. The calculated apparent resistivity will be different for each frequency. From the known current frequencies and measured apparent resistivities, the *frequency effect (FE)* or *percentage frequency effect (PFE = 100*FE)* can be calculated, which is equivalent to the chargeability. The *Metal Factor (MF)* can also be calculated, using a slightly different formula.

Processing and interpretation

The apparent resistivity and chargeability (or frequency effect or metal factor) data are carefully processed (inverted) , using specialist software. Figure 3 shows resistivity and chargeability models of the ground resulting from the inversion of time domain IP data that were collected over a zone of suspected porphyry copper deposits, which typically have low resistivity and high chargeability.

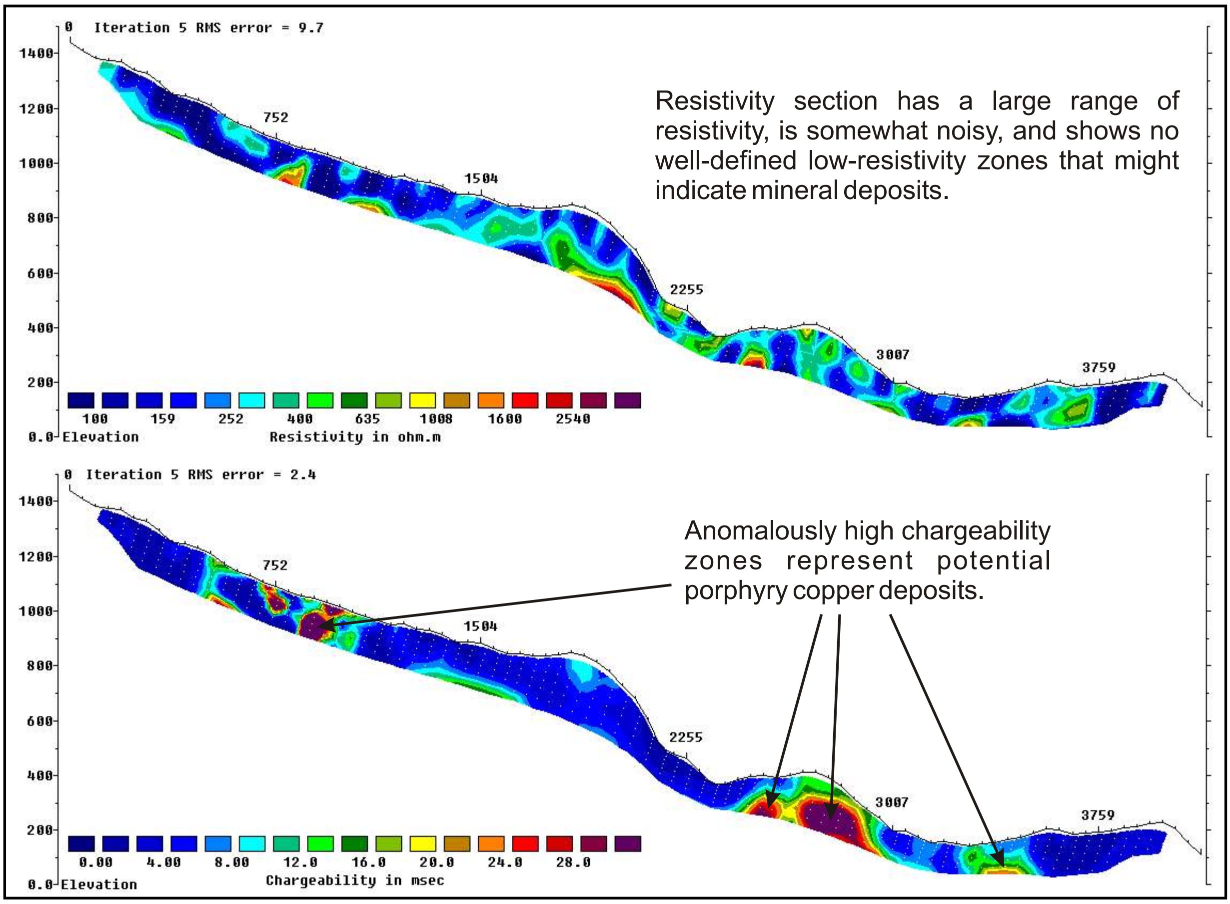

Figure 3: Inverted resistivity and chargeability sections over a suspected porphyry copper deposit.

