الطرق الكهربائية والكهروكيميائية

ELECTRICAL & ELECTROCHEMICAL METHODS

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ELECTRICAL RESISTIVITY TECHNIQUES

Geophysical resistivity techniques are based on the response of the earth to the flow of electrical current. In these methods, an electrical current is passed through the ground and two potential electrodes allow us to record the resultant potential difference between them, giving us a way to measure the electrical impedance of the subsurface material. The apparent resistivity is then a function of the measured impedance (ratio of potential to current) and the geometry of the electrode array. Depending upon the survey geometry, the apparent resistivity data are plotted as 1-D soundings, 1-D profiles, or in 2-D cross-sections in order to look for anomalous regions.

In the shallow subsurface, the presence of water controls much of the conductivity variation. Measurement of resistivity (inverse of conductivity) is, in general, a measure of water saturation and connectivity of pore space. This is because water has a low resistivity and electric current will follow the path of least resistance. **Increasing saturation, increasing salinity of the underground water, increasing porosity of rock (water-filled voids) and increasing number of fractures (water-filled) all tend to *decrease* measured resistivity**. **Increasing compaction of soils or rock units will expel water and effectively increase resistivity**. Air, with naturally high resistivity, results in the opposite response compared to water when filling voids. Whereas the presence of water will reduce resistivity, **the presence of air in voids should increase subsurface resistivity.**

Resistivity measurements are associated with varying depths depending on the separation of the current and potential electrodes in the survey, and can be interpreted in terms of a lithologic and/or geohydrologic model of the subsurface. Data are termed *apparent* resistivity because the resistivity values measured are actually averages over the total current path length but are plotted at one depth point for each potential electrode pair. Two dimensional images of the subsurface apparent resistivity variation are called *pseudo*sections. Data plotted in cross-section is a simplistic representation of actual, complex current flow paths. Computer modeling can help interpret geoelectric data in terms of more accurate earth models.

Geophysical methods are divided into two types : Active and Passive

Passive methods (Natural Sources): Incorporate measurements of natural occurring fields or properties of the earth. Ex. SP, Magnetotelluric (MT), Telluric, Gravity, Magnetic.

Active Methods (Induced Sources) : A signal is injected into the earth and then measure how the earth respond to the signal. Ex. DC. Resistivity, Seismic Refraction, IP, EM, Mise-A-LA-Masse, GPR.

- ***DC Resistivity*** - This is an active method that employs measurements of electrical potential associated with subsurface electrical current flow generated by a DC, or slowly varying AC, source. Factors that affect the measured potential, and thus can be mapped using this method include the presence and quality of pore fluids and clays. Our discussions will focus solely on this method.
- ***Induced Polarization (IP)*** - This is an active method that is commonly done in conjunction with DC Resistivity. It employs measurements of the transient (short-term) variations in potential as the current is initially applied or removed from the ground. It has been observed that when a current is applied to the ground, the ground behaves much like a capicitor, storing some of the applied current as a charge that is dissipated upon removal of the current. In this process, both capacity and electrochemical effects are responsible. IP is commonly used to detect concentrations of clay and electrically conductive metallic mineral grains.

- ***Self Potential (SP)*** - This is a passive method that employs measurements of naturally occurring electrical potentials commonly associated with the weathering of sulfide ore bodies. Measurable electrical potentials have also been observed in association with ground-water flow and certain biologic processes. The only equipment needed for conducting an SP survey is a high-impedance voltmeter and some means of making good electrical contact to the ground.
- ***Electromagnetic (EM)*** - This is an active method that employs measurements of a time-varying magnetic field generated by induction through current flow within the earth. In this technique, a time-varying magnetic field is generated at the surface of the earth that produces a time-varying electrical current in the earth through induction. A receiver is deployed that compares the magnetic field produced by the current-flow in the earth to that generated at the source. EM is used for locating conductive base-metal deposits, for locating buried pipes and cables, for the detection of unexploded ordinance, and for near-surface geophysical mapping.
- ***Magnetotelluric (MT)*** - This is a passive method that employs measurements of naturally occurring electrical currents, telluric currents, generated by magnetic induction of electrical currents in the ionosphere. This method can be used to determine electrical properties of materials at relatively great depths (down to and including the mantle) inside the Earth. In this technique, a time variation in electrical potential is measured at a base station and at survey stations. Differences in the recorded signal are used to estimate subsurface distribution of electrical resistivity.

Position of Electrical Methods in:

(1) Petroleum Exploration.

The most prominent applications of electrical techniques in petroleum expl. Are in well logging. Resistivity and SP are standard Logging techniques.

The magnetotelluric method has found important application for pet. Exploration. In structurally complex region (EX. Rocky Mountains).

(2) Engineering.

D C. Resistivity and EM have found broad use in civil Engineering and groundwater studies. Saturated / Unsaturated, Saltwater / freshwater

(3) Mineral Expl.

Electrical methods interpretation difficult below 1000 to 1500 ft. Electrical

exploration methods are the dominant geophysical tools in Mineral Expl.

Ohm's Law

Ohm's Law describes the electrical properties of any medium. **<u>Ohm's Law, V = I</u>** R, relates the voltage of a circuit to the product of the current and the resistance. This relationship holds for earth materials as well as simple circuits. **Resistance(R)**, however, is not a material constant. Instead, resistivity is an intrinsic property of the medium describing the resistance of the medium to the flow of electric current.

Resistivity ρ is defined as a unit change in resistance scaled by the ratio of a unit cross-sectional area and a unit length of the material through which the current is passing (Figure 1). **Resistivity** is measured in ohm-m or ohm-ft, and is the reciprocal of the conductivity of the material. Table 1 displays some typical resistivities.

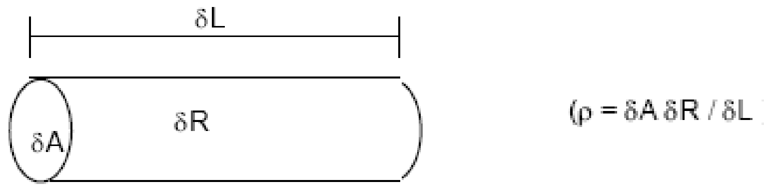


Figure 1. Resistivity is defined based on the change in resistance δR for a given change in length δL and cross-sectional area δA of material.

Table 1

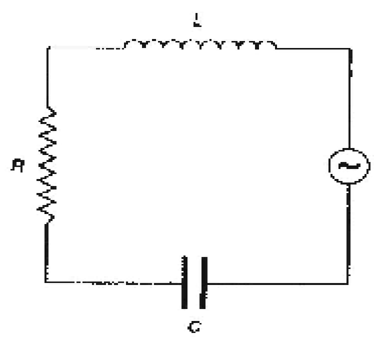
Common Resistivities (ohm-m)

Material Value	Resistivity range	Typical
Igneous & Metamporphic rocks	10^2 - 10^8	10^4 10^3
Sedimentary rocks	10 - 10^8	10^3
Unconsolidated	10^{-1} - 10^4	10^3
Groundwater	1 - 10	5
Pure water		10^3

Note that, in Table 1, the resistivity ranges of different earth materials overlap. Thus, resistivity measurements cannot be directly related to the type of soil or rock in the subsurface without direct sampling or some other geophysical or geotechnical information. Porosity is the major controlling factor for changing resistivity because electricity flows in the near surface by the passage of ions through pore space in the subsurface materials. The porosity (amount of pore space), the permeability (connectivity of pores), the water (or other fluid) content of the pores, and the presence of salts all become contributing factors to changing resistivity. Because most minerals are insulators and rock composition tends to increase resistivity, it is easier to measure conductive anomalies than resistive ones in the subsurface. However, air, with a theoretical infinite resistivity, will produce large resistive anomalies when filling subsurface voids.

Electric circuit has three main properties:

- **Resistance (R):** resistance to movement of charge
- **Capacitance (C):** ability to store charge
- **Inductance (L):** ability to generate current from changing magnetic field arising from moving charges in circuit



Resistance is NOT a fundamental characteristic of the metal in the wire.