جامعة الانبار

كلية العلوم -قسم الجيولوجيا التطبيقية

اسم المادة بالعربي: الجيوفيزياء الجهدية - الطرق الكهربائية

اسم المادة بالإنكليزي: Potential Geophysics- Electrical Methods

عنوان المحاضرة: Introduction

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Introduction

There are many methods of electrical surveying. Some the introduction of artificially-generated currents into the ground. The *resistivity* method is used in the study horizontal and vertical discontinuities in the electrical properties of the ground, and also in the detection of three-dimensional bodies of anomalous electrical conductivity. It is routinely used in engineering and hydrogeological investigations to investigate the shallow subsurface geology. The *induced polarization* method makes use of the capacitive action of the subsurface to locate zones where conductive minerals are dissemin-ated within their host rocks.The *self-potential* method makes use of natural currents flowing in the ground generated by electrochemical processes to locate shallow that are bodies of anomalous conductivity. Electrical methods utilize direct currents or lowfrequency alternating currents to investigate the electrical properties of the subsurface, in contrast to the electromagnetic methods discussed in the next chapter that use alternating electromagnetic fields of higher frequency to this end.

Resistivity method

Introduction

In the resistivity method, artificially-generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface. Deviations from the pattern of potential differences expected from homogeneous ground provide information on the form and electrical properties of subsurface inhomogeneities.

Resistivities of rocks and minerals

The *resistivity* of a material is defined as the resistance in ohms between the opposite faces of a unit cube of the material. For a conducting cylinder of resistance d*R*, length d*L* and cross-sectional area d*A* (Fig. 8.1) the resistivity r is given by

$$\rho = \frac{\delta R \delta A}{\delta L}$$

The SI unit of resistivity is the ohm-metre (ohm m) and the reciprocal of resistivity is termed *conductivity* (units: siemens (S) per metre; 1Sm-1 = 1ohm-1m-1; the term‘mho’for inverse ohm is sometimes encountered).

Electrical methods represent one of four principal groups of geophysical exploration techniques. The other three are: seismic, gravimetric and magnetic.The latter two differ in that they depend on naturally occurring physical fields. The seismic and most of electrical methods make use of artificial sources; the added control over source position and characteristics offers important advantages. Since each of the four techniques measure the effect of different physical properties ofthe subsurface materials, each has its field of application. Often a combination of techniques is more effective than one alone **(**Orellana and Mooney, 1966**)**. Resistivity method has its origin in the 1920’s due to the work of Schlumberger brothers. In this method the midpoint of the electrode array remains fixed, but the spacing between the electrodes increased to obtain more information about deeper sections of Subsurface. The most commonly used methods for measuring earth resistivity are those of four electrodes. Current is driven through one pair ofelectrodes and the potential is measured with second pair of electrodes (Keller and Frischknecht, 1970).

There are a number of ways in which electric current can be employed to investigate subsurface conditions in a certain area. In the most commonly used method the current is driven through the ground by using a pair of electrodes, and the resulting distribution of the potential in the ground is read by using another pair of electrodes connected to a sensitive voltmeter.

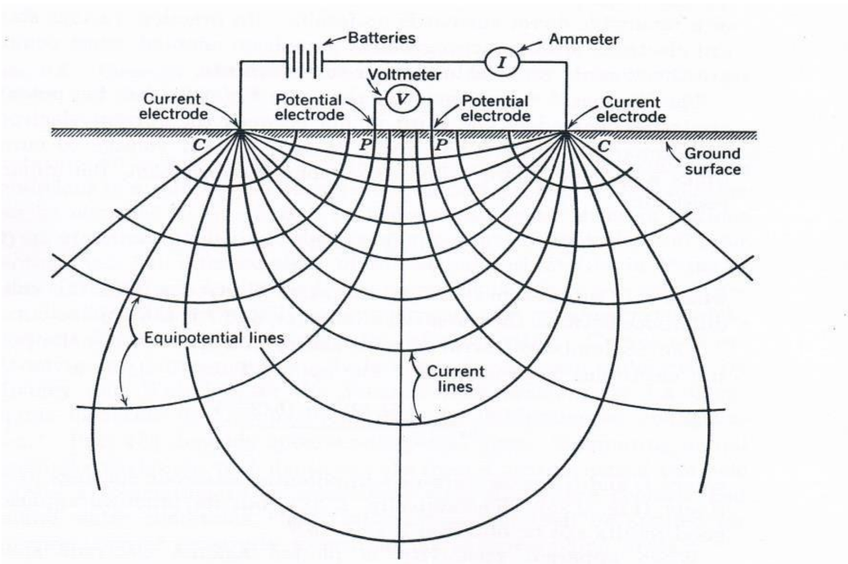

Figure (1): The geometry of current distribution within homogeneous and isotropic subsurface media (Todd, 1959).

From the magnitude of the current applied and from the knowledge of the current electrode separation it is possible to calculate the potential distribution and the path of the current flow if the underground materials were homogeneous. Anomalous conditions or inhomogeneities within the ground, such as electrically better or poorer conducting layers, are inferred from the fact that they deflect the current and distort the normal potentials. This represents briefly the principle of measuring subsurface variation in the electrical resistivity, which is the (reciprocal of conductivity) within the earth. In 1920's the technique of the method was perfected by Conrad Schlumberger, who conducted the first experiments in the field of Normandy (Sharma, 1986). In some surveys a combination of drilling and geophysical measurements may provide the optimum cost benefit ratio. The proper design of a geophysical survey is important not only in insuring that the needed data will be obtained but also in controlling costs, as the expense of making a geophysical survey is determined primarily by the detail and accuracy required **(**Zohdy, et.al.,1990).The electrical methods of geophysical exploration include a variety of techniques employing both natural and artificial sources, of which the latter has wider application. Within the artificial source group a distinction may be made between inductive and conductive methods. The inductive methods uses frequencies up to a few thousands cycles per second and the measurement of the electromagnetic field set up by the induced earth currents. The conductive methods involve the use of direct current (DC), or alternating current (AC) with frequencies up to few tens of cycles per second to study the electrical field **(**Orellana and Mooney, 1966**).**

Major Applications of Electrical methods

1- Detecting Lateral and vertical changes of soil and subsurface rock properties.
2- Detecting faults, weakness zones and cavities and any other subsurface geological structures.
3- Detecting groundwater table, aquifers thickness and its physical properties and groundwater pollution with salts and hydrocarbons.
4- Exploring subsurface sources of mineral ores.
5- Detecting underground seepages near earth filled dams and sewer leakages and groundwater pollution with chemical fluid seepages and achieving Earthling surveys related to civil engineering and building projects.
6- Detecting subsurface archeological remains.
7- Monitoring subsurface seepages for environmental applications.

Rocks Electrical Conductivity

With the exception of clays and certain metallic ores, the passage of electricitythrough rocks takes place by way of the groundwater contained in the pores and fissures, while the rock matrix being non conducting. All other factors being constant an increase in the concentration of dissolved salts in the groundwater leads to decrease in resistivity. In general way the resistivity is also controlled by the amount of water present. The more porous or fissured a rock the lower the resistivity. Degree of saturation also affects resistivity which increases with decrease in the amount of water in the pore spaces and fissures (Griffiths and King,1981).

Most rocks conduct electricity only because of mineralized water in pores and fissures (Brine). This property is called (electrolytic conductivity). Their conductivity depends on the conditions of contained water, the amount of water that is contained, and the manner in which the water is distributed (Kunetz, 1966).

Rocks Bulk or Total Resistivity (ρ_s)

Rocks bulk or total resistivity of rocks (ρ_s) could be expressed as a function of many variables as following:

$$\rho_s = f(c, n, S_w, T_p, Q, \rho_m, \rho_w)$$

Where: c=clay content, n = porosity , S_w=degree of rock saturation with brine, T_p= temperature, Q= Ionic exchange, ρ_m= solid part or rock grains resistivity, ρ_w= Brine resistivity.

Current Behavior In Homogeneous Ground

The property of the electrical resistance of a material is usually expressed in terms of its resistivity. If the resistance between opposite faces of a conductive cylinder of length (L) and cross sectional area (A) is (R), (Figure (2)), the resistivity (ρ) is expressed as:

$$\rho = R\ A/L$$

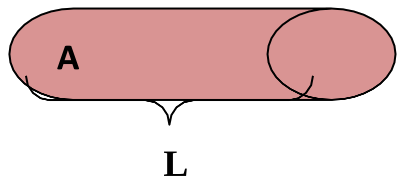

Figure (2): The resistivity of a conductive cylindrical body.

The simplest approach to the theoretical study of the current flow in the earth is to consider first the case of completely homogeneous isotropic earth layer of uniform resistivity. For a quantitative treatment, let us consider a homogeneous layer of length (L) and resistance (R) through which a current (I) is flowing. The potential difference across the ends of the resistance is given by Ohm's law and is:

$$\Delta V = RI$$

While: $\rho = R\ A/L$

The resistance, R, of the layer is specified by its length (L), of cross section area (A), and the resistivity (ρ). By definition: $R = \rho\ L / A$, and, therefore the equation can be written as the following:

$$\Delta V / L = \rho\ I / A$$

Where: I= current in Ampere (A) or mille Ampere (mA), L= length of the bead orlayer,

ΔV= potential difference in Volts (V)

The current density for each cross-sectional unit could be defined as (i), and the potential gradient could be expressed as (grad V), where:

$$\text{Grad } V = \rho i$$

If a semi-infinite conducting layer of uniform resistivity bounded by the groundsurface and a current strength (+I) enters at point (A) on the ground surface,

(Figure 3).The current will flow away radially from the point of entry and at any instant its distribution will be uniform over a hemispherical surface of the underground resistivity (ρ).

At a distance (r), away from the current source, the current density (i) would be (Sharma, 1986):

$$i = I / 2\pi r^2$$

A

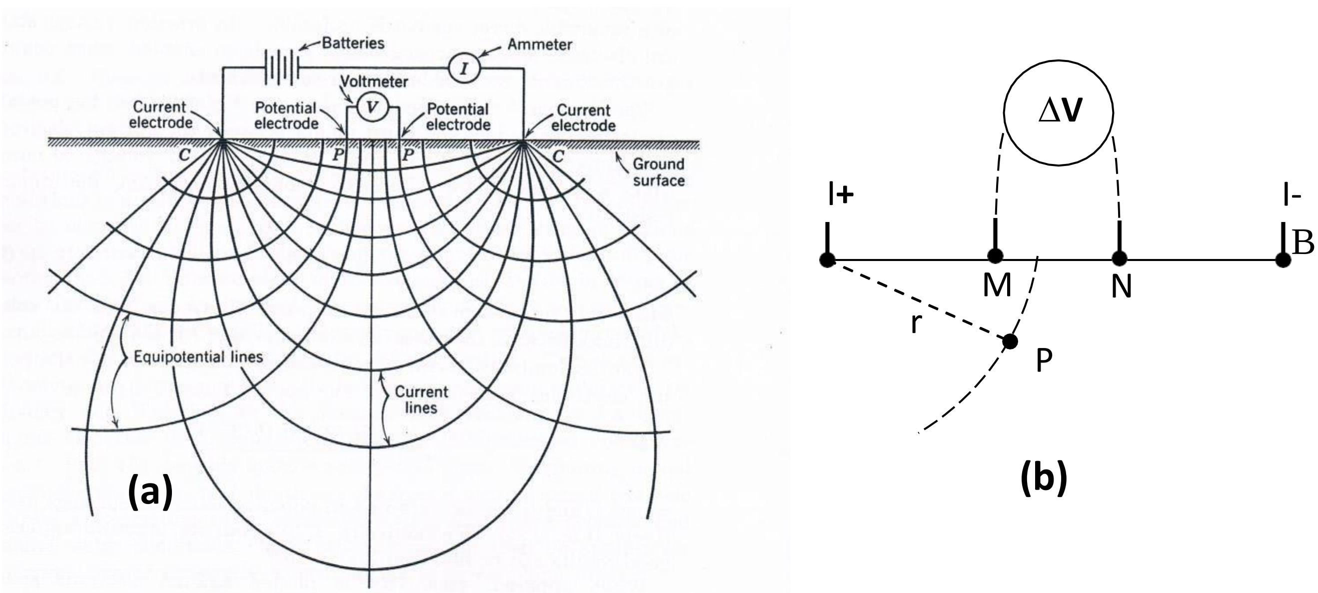

Figure (3): (a) The geometry of current distribution within homogeneous and isotropic subsurface media (Todd, 1959).

(b) Method of calculating potential distribution due to a current source in a homogeneous medium (Sharma, 1986).

$$\text{as: Grad } V = \rho i$$

The potential gradient $-\frac{\delta V}{\delta r}$ associated with the current is given by:

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

By integration we get:

$$V = \rho I / 2\pi\ r$$

The potential at distance (r) (e.g., at point (P) in figure (3,(b)) , is obtained byintegrating the previous equation and is :

$$V_M^A = \rho I / 2\pi r$$

This is the basic equation which enables the calculation of the potential distributionin a homogeneous conducting semi-infinite medium.

The potential difference (ΔV) between the potential electrodes M and N ,Figure(3,(b)) which caused by current (+I) at the source entry point (A) is:

$$\Delta V_{MN}^A = \frac{\rho I}{2\pi}\left(\frac{1}{AM} - \frac{1}{AN}\right)$$

In the same manner, the potential difference (ΔV) between the points M and N ,caused by (-I) current at the (sink) or exit point (B) is :

$$\Delta V_{MN}^B = \frac{-\rho I}{2\pi}\left(\frac{1}{BM} - \frac{1}{BN}\right)$$

The total potential difference between M and N is therefore, given by the sum of the right-hand sides of the previous two equations, and is:

$$\Delta V_{MN}^{AB} = (\Delta V_{MN}^A + \Delta V_{MN}^B)$$

Or

$$\Delta V_{MN}^{AB} = \frac{\rho I}{2\pi}\left(\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}\right)$$

$\left(\frac{1}{AM} - \frac{1}{AN} - \frac{1}{BM} + \frac{1}{BN}\right)$ is called the geometrical factor (G).

Then the potential difference between M and N could be written as:

$$\Delta V_{MN}^{AB} = \frac{\rho I G}{2\pi}$$

A more simple way to write the previous equation is:

$$\Delta V\, 2\pi = \rho I G$$

Or:

$$\rho = 2\pi \frac{\Delta V}{I} * \frac{1}{G}$$

(ρ) Will be constant in homogenous and isotropic Medias even if the electrode array or the geometrical factor (G) is changed.

It's common in the geoelectrical – hydrogeological studies to use the Ohm resistivity meter as a field instrument and Schlumberger configuration as a ground electrodes array, (Figure (4)).

<u>The Vertical Electrical Sounding (VES) by using Schlumberger array</u>

In the generalized Schlumberger array the distance between the potential electrodes (MN) is small as compared to the distance between current electrodes (AB) , where : AB ≥ 5MN, (Kunetz,1966).The (VES) points apparent resistivity (ρ_a) field readings were obtained as the half current electrodes separation (AB/2) which for example increased in steps starting from 1 to 200 m gradually, while the half distance between potential electrodes MN/2 was gradually increased in steps starting from 0.2 m to a 40 m, according to the geometrical factor (G) of Schlumberger configuration in order to obtain a measurable potential difference.the apparent resistivity is measured at every step of changing electrode spacing. The current gain (output current) of the resistivity meter is increased gradually from 1 to 1000 mAmp. , to yield a sufficient current penetration to the required depths according to the subsurface lithology. The Schlumberger array, (Figure (4)), is used by keeping the potential electrodes at a closer distance. The apparent resistivity (ρ_a) is determined by using the Equation:

$$\boldsymbol{\rho_a = \pi \left\{ \frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right\} * \frac{\Delta V}{I}}$$

Where (AB/2) is the half distance of current electrodes, (MN/2) is the half distance of potential electrodes and (ΔV/I) is the potential difference over the appliedcurrent.

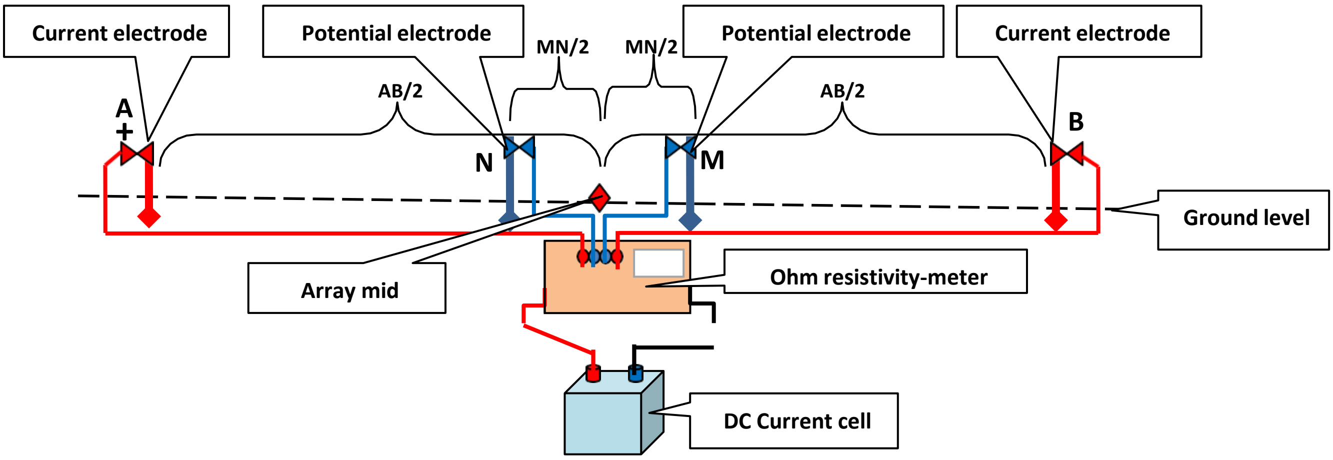

Figure (4): The electrode array for Schlumberger configuration at field resistivitysurvey, (AL-Khafaji 2014).

Apparent resistivity (ρ_a) with AB\2, MN\2 field readings is arranged in a table likethe one of figure (5).

References

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