MECHANISM OF ELECTRICAL CONDUCTION

Mechanism of electrical conduction in Materials the conduction of electricity through materials can be accomplished by three means :

a) The flow of electrons Ex. In Metal
b) The flow of ions Ex. Salt water .
c) Polarization in which ions or electrons move only a short distance under the influence of an electric field and then stop.

1 Metals :

Conduction by the flow of electrons depends upon the availability of free electrons. If there is a large number of free electrons available, then the material is called a metal, the number of free electrons in a metal is roughly equal to the number of atoms.

The number of conduction electrons is proportional to a factor

$$\mathbf{n \approx \varepsilon^{E/KT} \qquad E \ \infty\ 1/n \qquad T \ \infty\ n}$$

ε : Dielectric constant
K: Boltzman's constant
T: Absolute Temperature.
E Activation Energy.

Metals may be considered a special class of electron semi conductor for which E approaches zero .

Among earth materials native gold and copper are true metals. Most sulfide ore minerals are electron semi conductors with such a low activation energy.

b) The flow of ions, is best exemplified by conduction through water, especially water with appreciable salinity. So that there is an abundance of free ions.

Most earth materials conduct electricity by the motion of ions contained in the water within the pore spaces .

ELECTRICAL PROPERTIES OF ROCKS :

ý Resistivity (or conductivity), which governs the amount of current that passes when a potential difference is created.

ý Electrochemical activity or polarizability, the response of certain minerals to electrolytes in the ground, the bases for SP and IP.

ý Dielectric constant or permittivity. A measure of the capacity of a material to store charge when an electric field is applied . It measure the polarizability of a material in an electric field $= 1 + 4\pi X$
X : electrical susceptibility .

Electrical methods utilize direct current or Low frequency alternating current to investigate electrical properties of the subsurface. Electromagnetic methods use alternating electromagnetic field of high frequencies.

Two properties are of primary concern in the Application of electrical methods.

(1) The ability of Rocks to conduct an electrical current.

(2) The polarization which occurs when an electrical current is passed through them (IP).

Resistivity

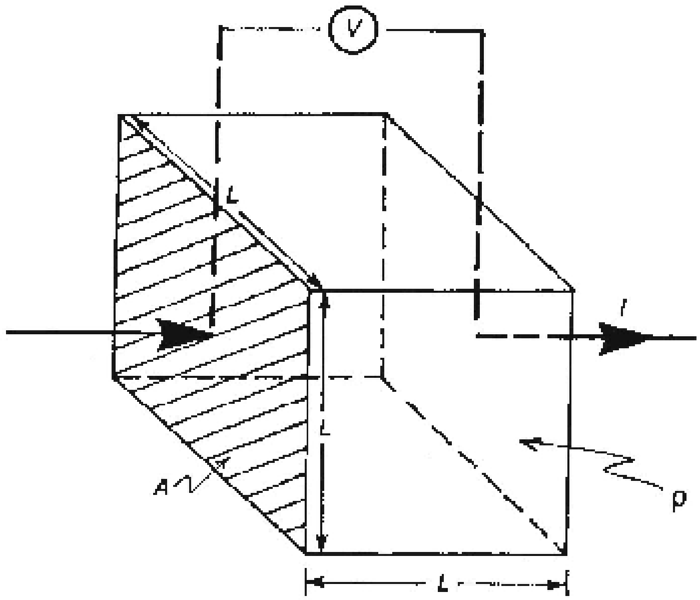
For a uniform wire or cube, resistance is proportional to length and inversely proportional to cross-sectional area. Resistivity is related to resistance but it not identical to it. The resistance R depends an length, Area and properties of the material which we term resistivity (ohm.m) . $R = \rho \frac{L}{A}$

Constant of proportionality is called <u>Resistivity :</u>

<u>Resistivity is the fundamental physical property of the metal in the wire</u>

$$\rho = \frac{VA}{IL}$$

Resistivity is measured in ohm-m



Conductivity is defined as 1/ρ and is measured in Siemens per meter (S/m), equivalent to $ohm^{-1}m^{-1}$.

EX. 1 Copper has ρ =1.7 X 10^{-8} ohm.m. What is the resistance of 20 m of copper with a cross-sectional radius of 0.005m .

EX. Quartz has ρ = 1 X 10^{16} ohm.m. What is the resistance at a quartz wire at the same dimension.

Anisotropy : is a characteristic of stratified rocks which is generally more conducive in the bedding plane. The anisotropy might be find in a schist (micro anisotropic) or in a large scale as in layered sequence of shale (macro anisotropic) .

هو النسبة بين الحد الأقصى للمقاومية إلى الحد الأدنى ويصل ما بين 1-1و1 هذا يعني انه لو طبق التيار في اتجاه واحد فان هذا المعامل يقوم بتغير الصفات الخواص الكهربائية للاتجاه الآخر .

Coefficient of anisotropy $\lambda = \rho t / \rho l$

ρl : Longitudinal Resistivety .

ρt : Transverse Resistivity.

The effective Resistivity depends on whether the current is flowing parallel to the layering or perpendicular to it .

Factors which control the Resistivity

(1) Geologic Age
(2) Salinity.
(3) Free-ion content of the connate water.
(4) Interconnection of the pore spaces (Permeability).
(5) Temperature.
(6) Porosity.
(7) Pressure
(8) Depth

Archie's Law

Empirical relationship defining bulk resistivity of a saturated porous rock. In sedimentary rocks, resistivity of pore fluid is probably single most important factor controlling resistivity of whole rock.

Archie (1942) developed empirical formula for effective resistivity of rock:

$$\rho_0 = a\rho_w\phi^{-m}$$

ρ_0 = ***bulk rock resistivity***
ρ_w = *pore-water resistivity*
a = empirical constant ($0.6 < a < 1$)
m = *cementation factor* (1.3 poor, unconsolidated) < m < 2.2 (good, cemented or crystalline)
φ = *fractional porosity* (vol liq. / vol rock)

Formation Factor*:*

$$F = \frac{\rho_0}{\rho_w} = a\phi^{-m}$$

Effects of Partial Saturation:

$$\rho_t = S_w^{-n} a\rho_w\phi^{-m}$$

Sw is the volumetric saturation.
n is the *saturation coefficient* ($1.5 < n < 2.5$).

- Archie's Law ignores the effect of pore geometry, but is a reasonable approximation in many sedimentary rocks

Resistivity survey instruments:

a- High tension battery pack (source of current).
b- Four metal stakes.
c- Milliammeter.
d- Voltmeter.
e- Four reels of insulated cable.

AC is preferred over DC as source of current. The advantage of using AC is that unwanted potential can be avoided.