

## Induced Polarization ( IP )

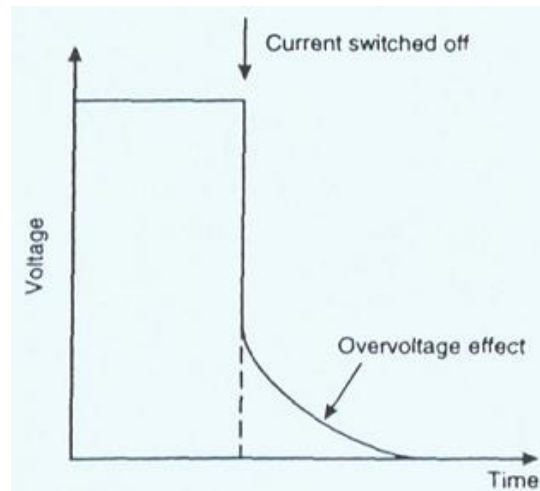
**IP** depends on a small amount of electric charge being stored in an ore when a current is passed through it, to be released and measured when the current is switched off.

The main application is in the search for **disseminated metallic ores** and to a lesser extent, ground water and geothermal exploration.

Measurements of IP using 2 current electrodes and 2 non-polarizable potential electrodes. When the current is switched off, the voltage between the potential electrodes takes a finite time to decay to zero because the ground temporarily stores charge ( **become Polarized** )

### Four systems of IP .

- 1- Time domain
- 2- Frequency domain < 10 HZ
- 3- Phase domain
- 4- Spectral IP  $10^{-3}$  to 4000 HZ



### Sources of IP Effects

#### 1) Normal IP

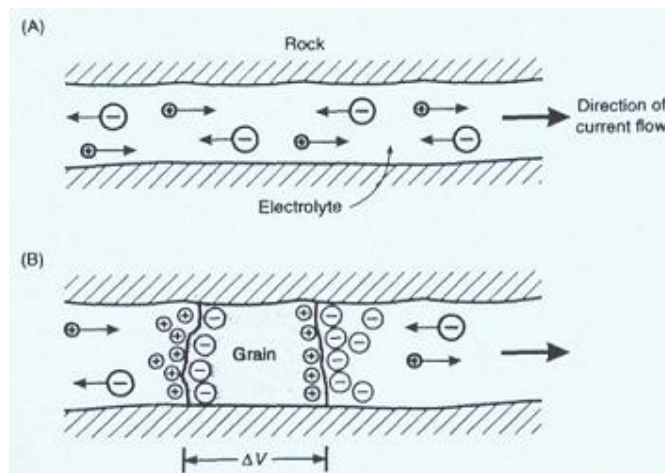
- Membrane Polarization

- Most Pronounced with clays
- Decreases with very high (> 10%) clay content due to few pores, low conductivity.

## 2) Electrode polarization

- Most metallic minerals have EP
- Decreases with increased porosity.
- Over-voltage effect

## 3) IP is A bulk effect.



**Grain (electrode) polarization. (A) Unrestricted electrolytic flow in an open channel. (B) Polarization of an electronically conductive grain, blocking a channel**

## 1. Time – domain measurements.

One measure of the IP effects is the ratio  $V_p / V_o$  which is known as chargeability which is expressed in terms of millivolts per volt or percent.

$V_p$  : overvoltage

$V_o$  : observed voltage

$$M = V_p / V_o \text{ ( mV/v or \% )}$$

Apparent chargeability

$$M_a = (1 / V_o) \int_{t_1}^{t_2} V_p(t) dt = A / V_o$$

$V_p(t)$  is the over-voltage at time  $t$ .

10 – 20 %	sulphides	1000-3000 msec .
	Sand stones	100-200 msec.
	Shale	50-100
	Water	0

## 2) Frequency- Domain measurements.

Frequency effect  $FE = (P_{a0} - P_{a1}) / P_{a1}$  ( unitless )

$P_{a0}$  : apparent resistivity at low frequencies

$P_{a1}$  : apparent resistivity at high frequencies

$$P_{a0} > P_{a1}$$

Percentage frequency effect  $PFE = 100(P_{a0} - P_{a1}) / P_{a1} = 100 FE$

The frequency effect in the frequency domain is equivalent to the chargeability in the time domain for a weakly polarisable medium where  $FE < 1$ .

$$\text{Metal Factor } MF = A (\rho_{a0} - \rho_{a1}) / (\rho_{a0} \rho_{a1})$$

$$= A (\delta_{a1} - \delta_{a0}) \quad \text{siemens / m}$$

$\rho_{a0}$  &  $\rho_{a1}$  apparent resistivity.

$\delta_{a0}$  and  $\delta_{a1}$  are apparent conductivities ( $1/\rho_a$ ) at low and higher frequencies respectively where

$$\rho_{a0} > \rho_{a1} \quad \text{and} \quad \delta_{a0} < \delta_{a1} \quad A = 2 \pi \times 10^5$$

$$\begin{aligned} MF &= A \times FE / \rho_{a0} = A \times FE / \rho_{a0} \\ &= FE / \rho_{a0} = A \times FE \times \delta_{a0} \end{aligned}$$

The above methods do not give a good indication of the relative amount of the metallic mineralization within the source of the IP. It is necessary to go with spectral IP.

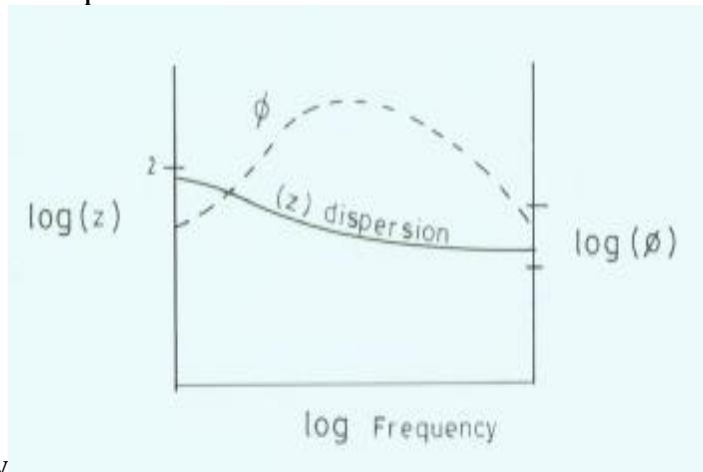
### 3. Spectral IP and Complex Resistivity.

Is the measurement of the dielectric properties of materials

$\Theta$  is the phase lag between the applied current and the polarization voltage measured.

$$|z(\omega)| = P_0 [ 1 - M ( 1 - 1 / ( 1 + (i\omega\tau)^c ) ) ]$$

$Z(\omega)$  : complex



resistivity

$P_0$  : D.c. resistivity

$M$  : IP chargeability

$\omega$  : Angular frequency.

$\tau$  : Time constant. (relaxation time) is the behaviour between the lower

and upper frequency limits.

i :  $\sqrt{-1}$

c : frequency exponent

**Critical Frequency ( $F_c$ )** : Which is the specific frequency at which the maximum phase shift is measured. This frequency is completely independent of resistivity.

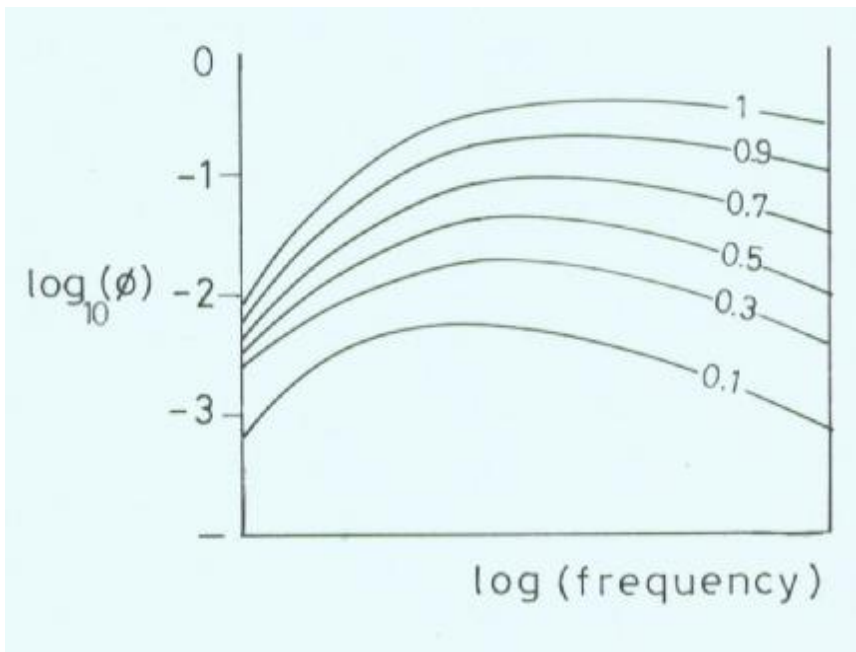
Phase angle and the critical frequency increase with increasing chargeability.

$$F_c = [ 2 \pi \tau ( 1 - M )^{1/2c} ]^{-1}$$

$\tau$  Time constant

M IP chargeability .

**This is call cole – cole relaxation**



## **IP Survey Design**

- 1- Profiling : Later contrasts in electrical properties such as lithologic contacts. (wenner + Dipole – Dipole) .
- 2- Sounding : to map the depths and thickness of stratigraphic units (Schlumberger + wenner).
- 3- Profiling – Sounding : in contaminant plume mapping , where subsurface electrical properties are expected to vary vertically and horizontally (wenner + Dipole – Dipole) .

## **Limitations of IP**

- 1- IP is more susceptible to sources of cultural interference (metal fences, pipe lines , power lines) than electrical resistivity.
- 2- IP equipment requires more power than resistivity alone . This translates into heavier field instruments
- 3- The cost of IP much greater than resistivity – alone system.
- 4- IP requires experience.
- 5- Complexity in data interpretation.
- 6- Intensive field work requires more than 3 crew members.
- 7- IP requires a fairly large area far removed from power lines , fences, pipelines .

## **Advantages of IP**

- 1- IP data can be collected during an electrical resistivity survey
- 2- IP data and resistivity together improves the resolution of the analysis of Resistivity data in three ways:
  - a. some of the ambiguities in resistivity data can be reduced by IP analysis.
  - b. IP can be used to distinguish geologic layers which do not respond well to an electrical resistivity .
  - c. Measurements of chargeability can be used to discriminate equally electrically conductive target such as saline, electrolytic or metallic-ion contaminant plumes from clay Layers.