

Induced Polarization (IP)

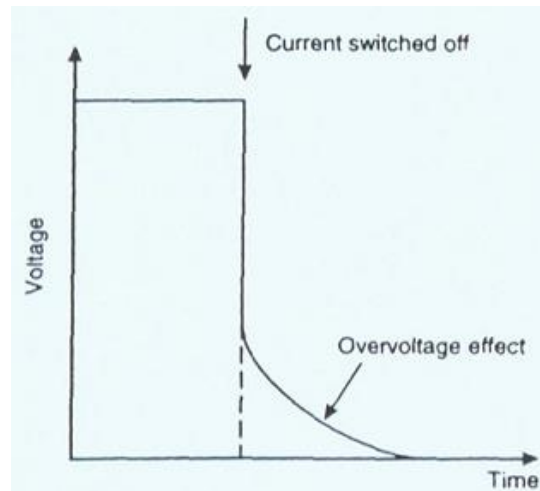
IP depends on a small amount of electric charge being stored in an ore when a current is passed through it, to be released and measured when the current is switched off.

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

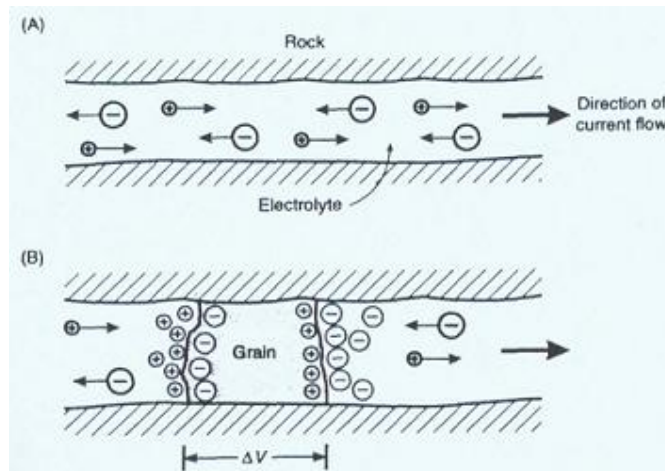
- Membrane Polarization

- 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 chargeability which expressed in terms of millivolts per volt or percent.

V_p : overvoltage

V_o : observed voltage

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

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 $FE = (P_{ao} - P_{a1}) / P_{a1}$ (unitless)

P_{ao} : apparent resistivity at low frequencies

P_{a1} : appatent resistivity at high frequencies

$$P_{ao} > P_{a1}$$

Percentage frequency affect $PFE = 100(P_{ao} - P_{a1}) / P_{a1} = 100 FE$

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

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

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

ρ_{a0} & ρ_{a1} apparent resistivity.

δ_{a0} and δ_{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.

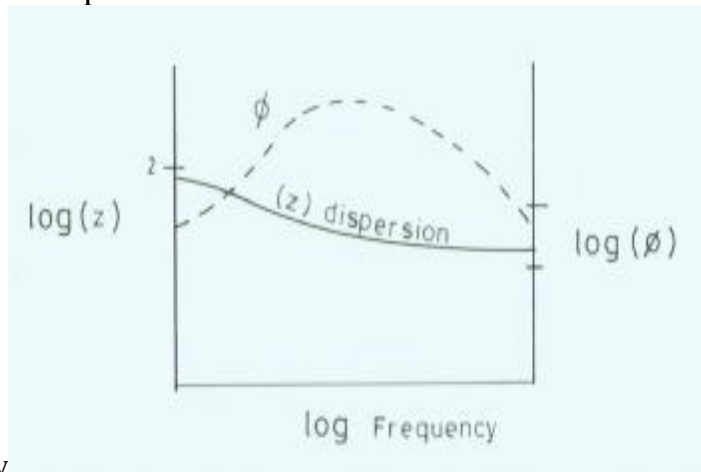
3. Spectral IP and Complex Resistivity.

Is the measurement of the dielectric properties of materials

Θ is the phase lag between the applied current and the polarization voltage measured.

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

$Z(w)$: complex



resistivity

P_0 : D.c. resistivity

M : IP chargeability

W : Angular frequency.

τ : Time constant. (relaxation time) is the behavior 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.

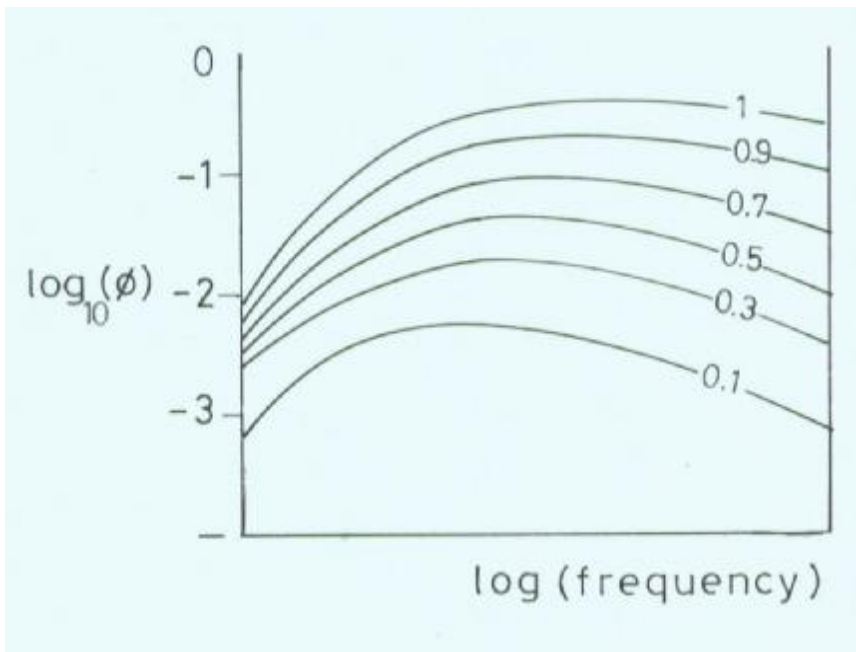
Phase angle and the critical frequency increase with increasing chargeability.

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

τ 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.