Introduction to Geophysics

R. Drews

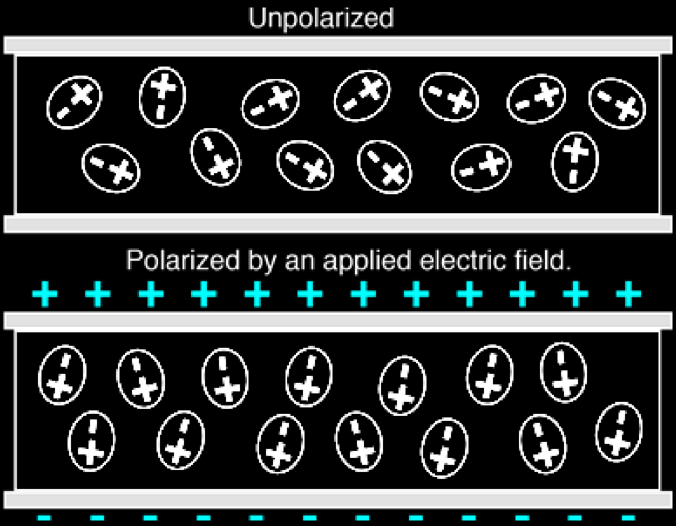
Induced Polarization

Learning Goals

- Polarization.
- Polarization in the subsurface.
- Principles of an RC circuit.
- Definition of chargeability.

What is electric polarization?

Electric Polarization



Polarization (cf. magnetic susceptibility)

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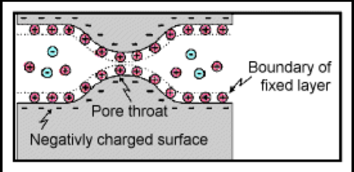
Electric polarization originates from effective charge separation in an (external) electric field. It opposes the external field an leads to an overall weakening of the total field.

$$\vec{P} = \chi \varepsilon \vec{E} \tag{1}$$

$$\vec{D} = \varepsilon \vec{E} + \vec{P} \tag{2}$$

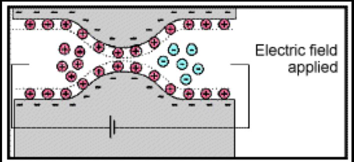
Polarization in sub-surface: Membrane Polarization



[EOS, UBC 2022]

- Electric double layer forms in water-filled pore space.

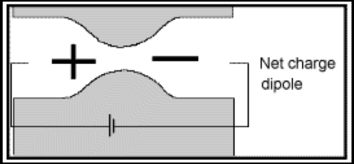
Polarization in sub-surface: Membrane Polarization



[EOS, UBC 2022]

- Constrictions in pores leads to charge accumulation

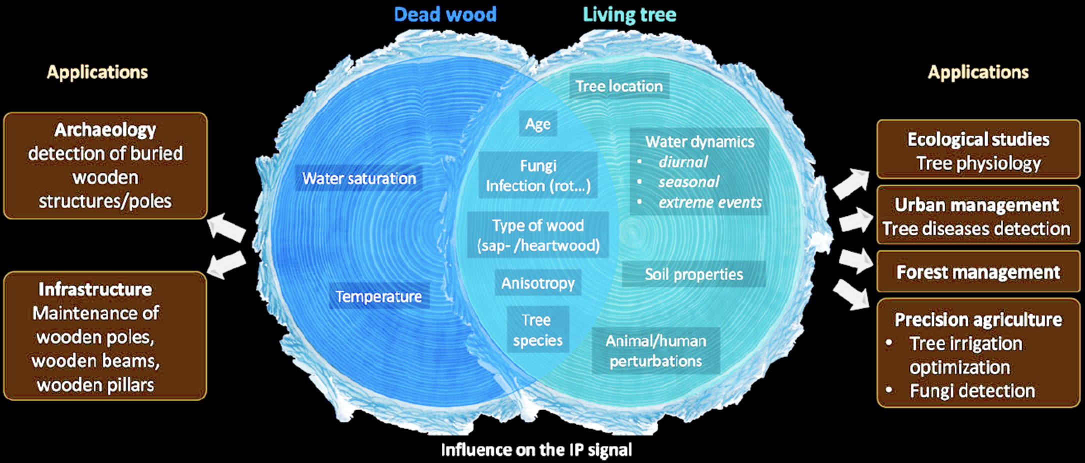
Polarization in sub-surface: Membrane Polarization



[EOS, UBC 2022]

- Constrictions in pores leads to charge accumulation
- This can result in a macroscopic polarization

Plants & Roots



[Kessouri et al., 2019, Near Surf. Geophys.]

Plants & Roots

Geophysical Research Letters

Research Letter | Full Access

Modeling Plant Roots Spectral Induced Polarization Signature

Kuzma Tsukanov, Nimrod Schwartz

First published: 06 February 2021 | https://doi.org/10.1029/2020GL090184 | Citations: 2

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Journal of Applied Geophysics
Volume 135, December 2016, Pages 387-396

Mapping tree root system in dikes using induced polarization: Focus on the influence of soil water content

Benjamin Mary [a, b], Ginette Saracco [b, d], Laurent Peyras [a], Michel Vennetier [a, d], Patrice Mériaux [a], Christian Camerlynck [c]

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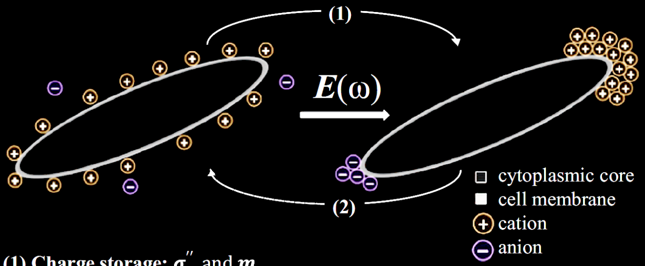
Microbial activity in soils



(1) Charge storage: σ'' and m_n

Tangential migration of counterions within cell EDL once current is applied

(2) Ion back-diffusion: $\tau = \frac{d^2}{8D_s}[s]$ (Schwarz, 1962)

Diffusion-controlled relaxation, back to equilibrium state, within the cell EDL

[Kessouri et al., 2019, Near Surf. Geophys.]

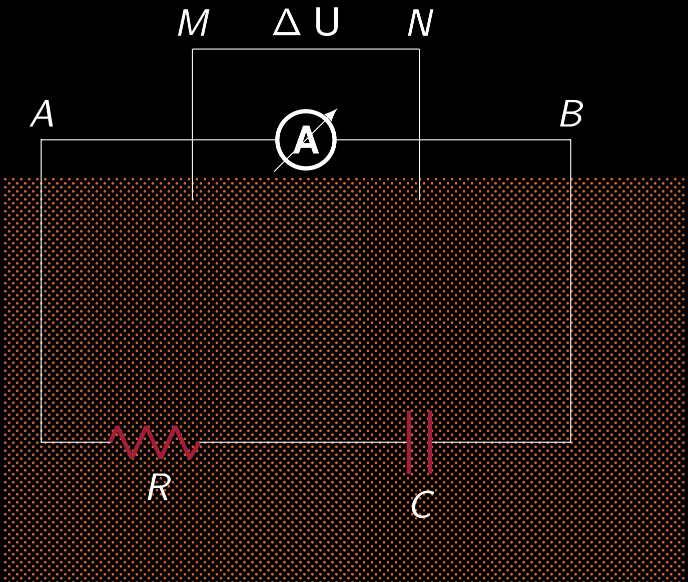
Electric Polarization

How does polarization in the sub-surface appear within a resistivity setup?

Electric Polarization

How does polarization in the sub-surface appear within a resistivity setup?
$\rightarrow$ This is equivalent to an RC-Circuit.

RC Circuits



Electric Polarization

How does the current behave in an RC circuit connected to a DC battery? Start with Kirchoffs law that The sum of the potential differences around any closed loop is zero.

RC - Circuit: Charging

$$V - V_R - V_C = 0$$

What is the voltage drop across a capacitor?

Electric Polarization

$$V_C = \frac{q}{C}$$

It depends on the charge accumulation q(t) and the material constants (C) including the geometry.

RC - Circuit: Charging

$$V - V_R - V_C = 0$$

$$V - RI - \frac{q}{C} = 0$$

$$V - R\frac{dq}{dt} - \frac{1}{C}q = 0$$

Can be solved with separation of Variables.

RC - Circuit: Charging

$$\frac{dq}{dt} = \frac{UC-q}{RC}$$

$$\rightarrow \frac{1}{UC-q}dq = \frac{1}{RC}dt$$

$$\rightarrow q(t) = CV(1 - e^{-\frac{t}{RC}})$$

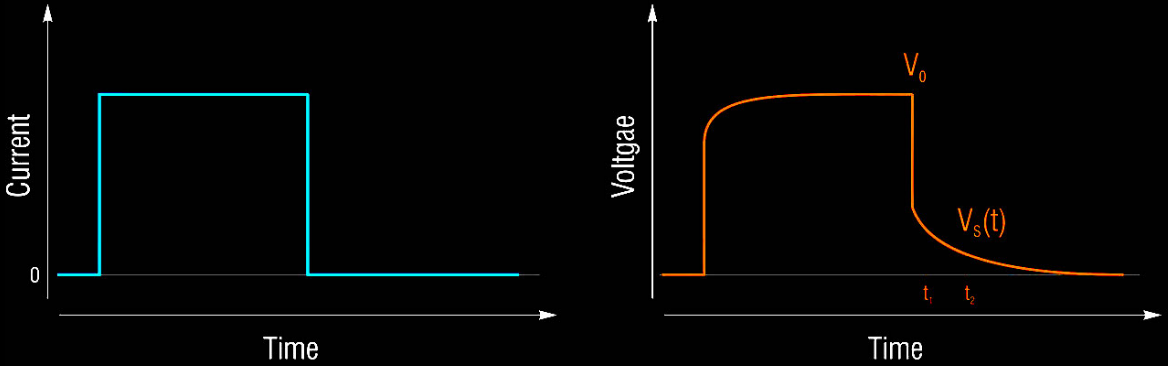
$$I(t) = \frac{dq(t)}{dt} = \frac{V}{R}e^{-\frac{t}{RC}} = I_0 e^{-\frac{t}{RC}} \tag{3}$$

RC - Circuit: Decharging

For decharging $V = 0$ (battery disconnected):

$$I(t) = -\frac{Q}{RC} e^{-\frac{t}{RC}} \tag{4}$$

(Exercises.)



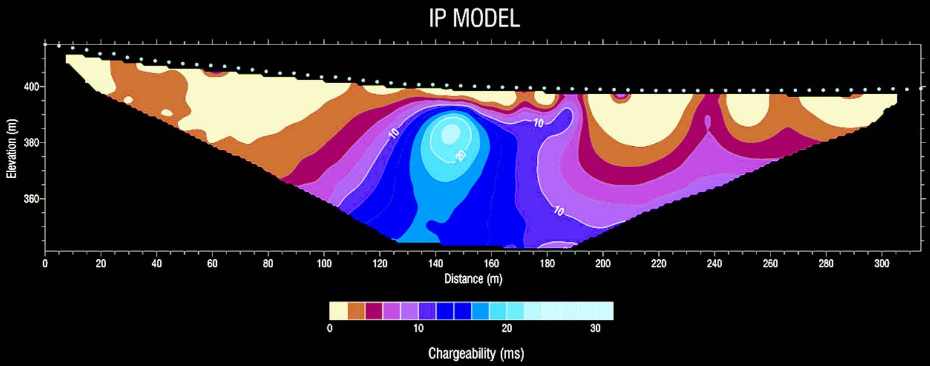
[Source: Everest Geophysics (Spain)]

Chargeability

The chargeability M [ms] is the quantitiy measured in time-domain, induced polarization:

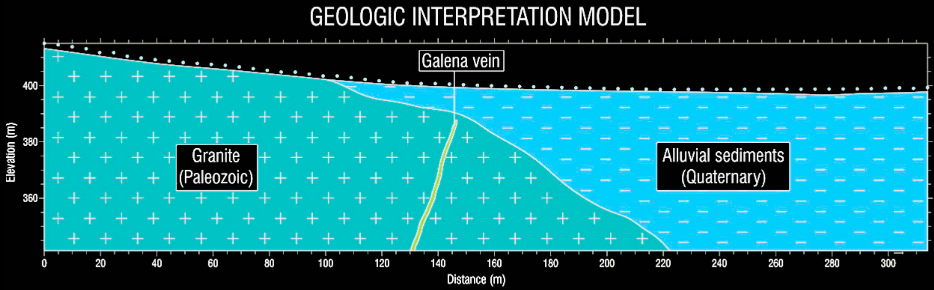
$$M = \frac{1}{V_0} \int_{t_1}^{t_2} V(t)$$

Examples



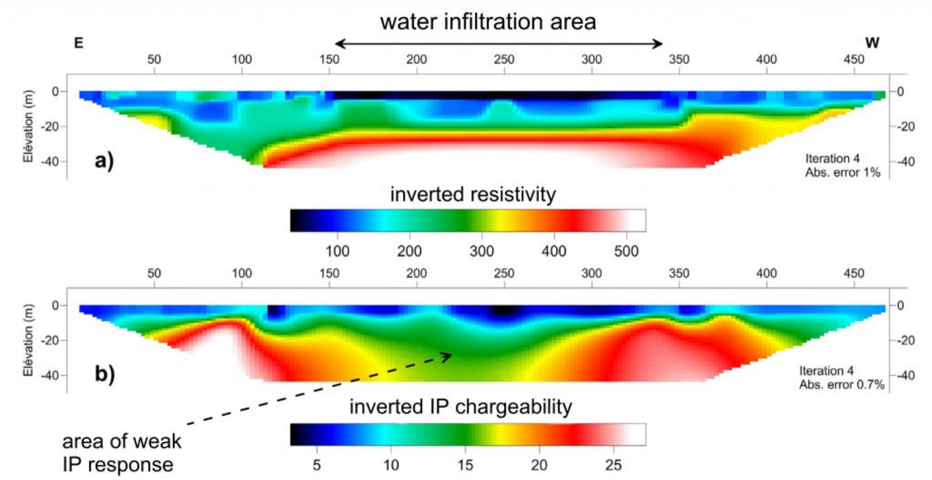
[Source: Everest Geophysics (Spain)]

Examples



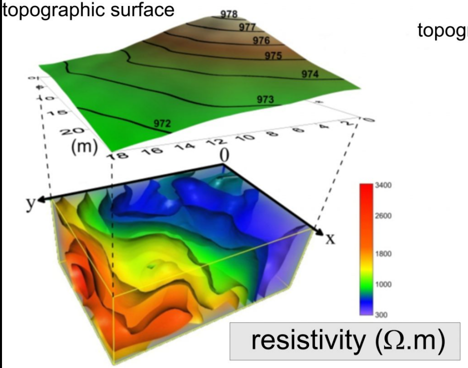
[Source: Everest Geophysics (Spain)]

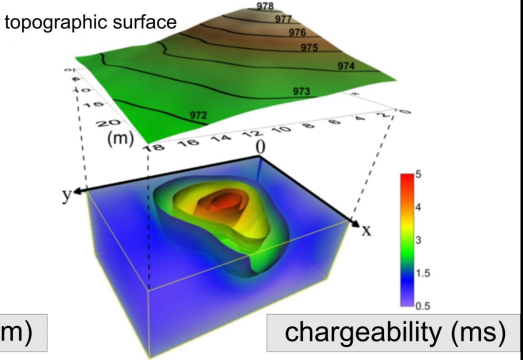
Examples



[CITREX At Guidel site (France) the high chargeability is linked with pyrite preserved in non-weathered granites. In the central zone, pyrite has been oxidized and the chargeability is lower.]

Ancient slag heap waste survey with resistivity and IP





[CITREX: On the mining site of

Examples

Share talk from C. Moser at EGU 2022

Learning Goals

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Primer Spectral induced polarization

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The idea of spectral induced polarization is to apply a time variable potential / input current:

$$V(t) = V_0 e^{i\omega t}$$

(Clarify complex notation if this is unclear.)

$$V(t) - V_R(t) - V_C(t) = 0$$

$$V_C(t) = \frac{q(t)}{C}$$

$$V_R(t) = RI$$

$$I(t) = \frac{dq}{dt}$$

Primer Spectral Induced Polarization

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$$V(t) = V_0 e^{i\omega t} \tag{5}$$

$$V_c = \frac{q}{C} \tag{6}$$

$$\frac{d}{dt} V_C = I_C \frac{1}{C} \tag{7}$$

$$\rightarrow \underbrace{\frac{1}{i\omega C}}_{Impedance} I_C = V(t) \tag{8}$$

Primer Spectral Induced Polarization

$$V(t) = I(t)R + \frac{C}{j\omega}I(t) \tag{9}$$

$$= (R + \frac{1}{iC\omega})I(t) \tag{10}$$

$$= \underbrace{(R - i\frac{1}{C\omega})}_{\text{I(t) and V(t) are phase shifted.}} I(t) \tag{11}$$