Introduction to Geophysics

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Resistivity Methods

Houskeeping

- Geophysics at seminar 20.05.2022
- Questions regarding exercises

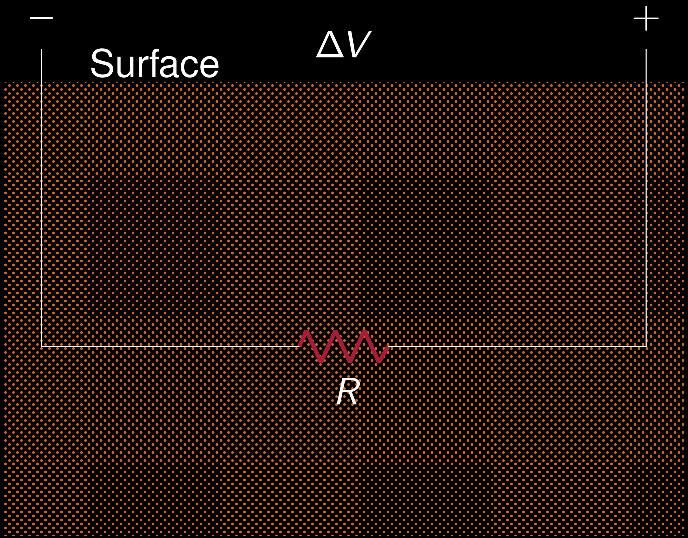
Learning Goals

- Resistivity..
- Currents..
- Electric Fields..

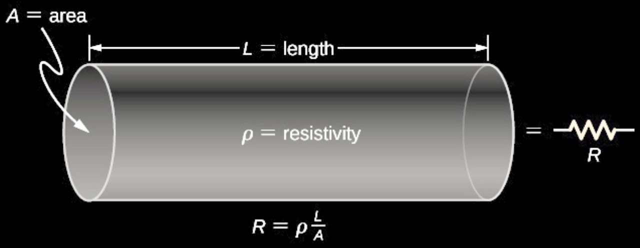
Resistivity Method Principles

Characterize the sub-surface in it's ability to conduct electrical currents. A material that has a high electrical resistivity will conduct electrical currents poorly and vice versa.

Primary parameter of the resistivity method

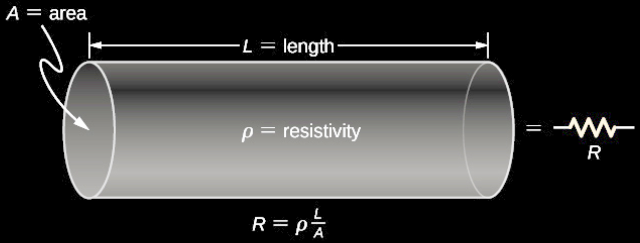


Resistivity vs. Resistance



- Resistivity (spez. elektr. Widerstand) is a material property
- Resistance (elektr. Widerstand) includes material and geometry of the resistor

Resistivity vs. Resistance



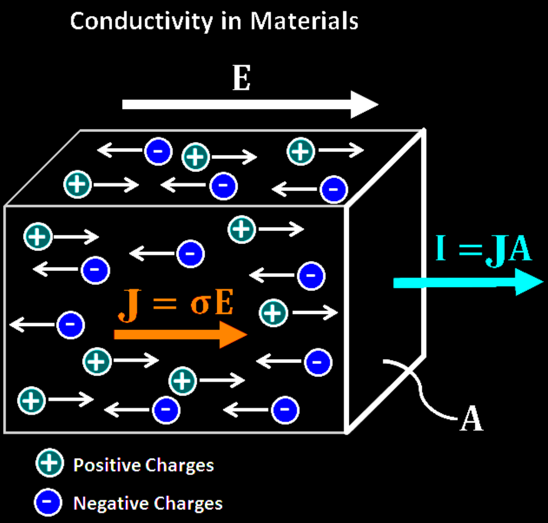
- Resistance [Ohm, Ω]
- Resistivity [Ωm]

Resistivity (ρ) vs. Conductivity (σ)

$$\rho = \frac{1}{\sigma}$$

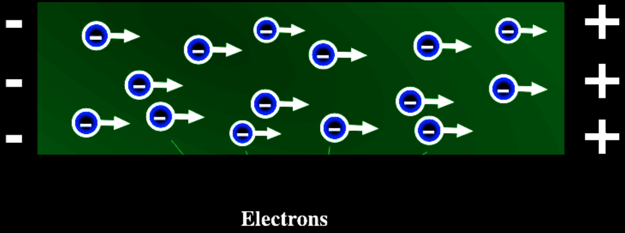
- Resistivity [Ωm]
- Conductivity [$(\Omega m)^{-1}$, i.e. Siemens]

Ionic vs. metallic conduction



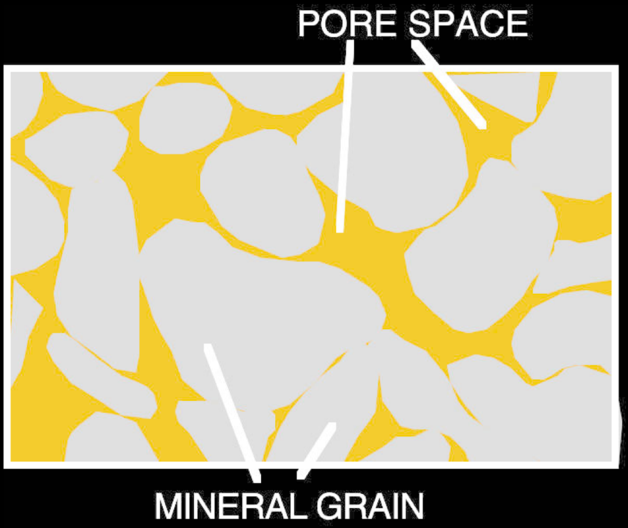
[GeoSci XYZ]

Ionic vs. metallic



- Metallic conduction uses declocalized electrons in the conduction band of metalls
- Ionic conduction uses charged Ions in electrolyt

Ionic conduction in porous sediments



Ionic conduction in porous sediments

- Increases with increasing pore space (ϕ)
- Increases with increasing water saturation
- Increases with decreasing water resistivity (ρ)

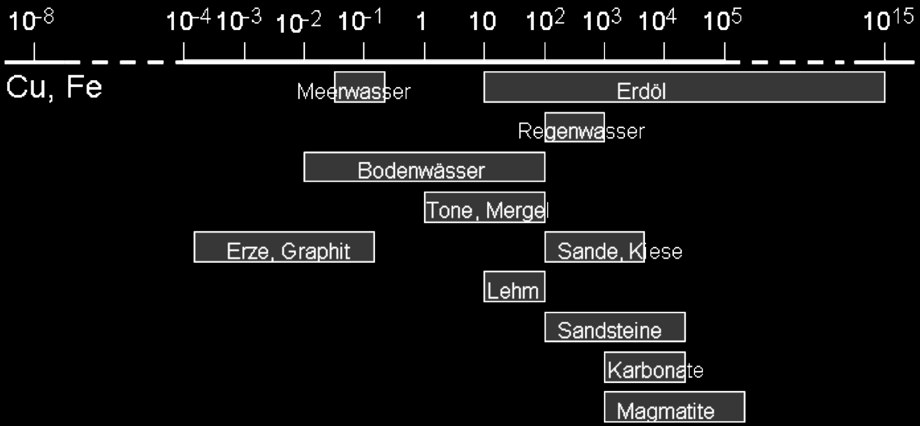
Ionic conduction in porous sediments

- Increases with increasing pore space (ϕ)
- Increases with increasing water saturation
- Increases with decreasing water resistivity (ρ)

$$\rho_t = a\rho_w\phi^{-m}s_w^{-n} \tag{1}$$

(Archie's Law)

Resisitivity in Ωm



Current flow through the sub-surface

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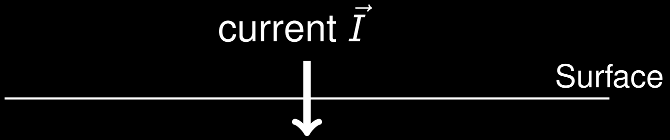
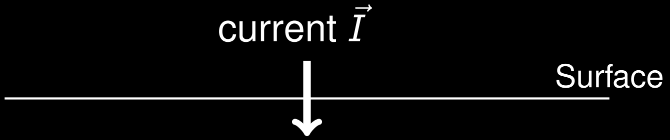
Consider a homogeneous conducting halfspace, with constant resistivity ρ, under an insulating medium. Let there be a point electrode at the surface injecting a steady current I. The current flows to a distributed sink at infinity. Find the electrostatic potential, the electric field, and consequently the pattern of current flow in the sub-surface.
[cf. Telford Chapter 8, online resources resistivity 1 and resistivity 2.]

Primary parameter of the resistivity method



Current flow through the sub-surface

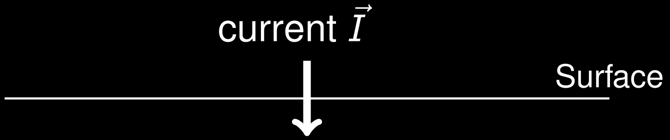


$$\boxed{\vec{j} = \sigma \vec{E}}$$

$\vec{E}$ is the electrical field ($V m^{-1}$)
$\vec{j}$ is the current density (Am^{-2})

Currents flow parallel to the electrical field.

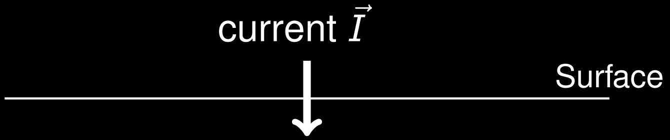
Current flow through the sub-surface



$$\vec{j} = \sigma \vec{E} = \sigma \nabla \phi$$

The electrical field is perpendicular to the electric potential (Volts).

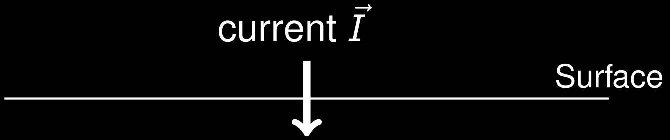
Current flow through the sub-surface



$$\nabla \cdot \vec{j} = 0$$

In the half space there are no sources and sinks for the current density. Understand this from what we learned about the magnetic dipole field which is also divergence free.

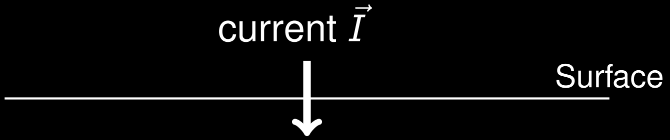
Current flow through the sub-surface



$$\nabla \cdot \vec{j} = \sigma \nabla \cdot \vec{E} = \sigma \nabla^2 \phi = 0$$

This is the Laplace equation.

Current flow through the sub-surface



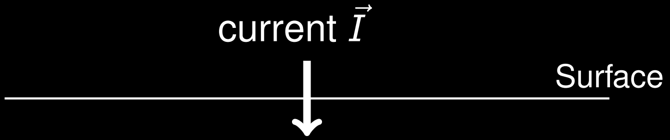
$$\nabla \cdot \vec{j} = \sigma \nabla \cdot \vec{E} = \sigma \nabla^2 \phi = 0$$

$$\rightarrow \phi = \frac{A}{r}$$

(Exercises)

The current flows radially outwards.

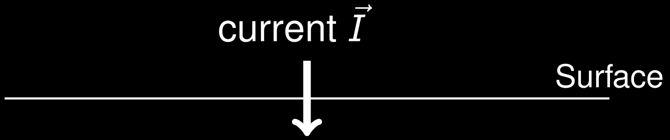
Current flow through the sub-surface



$$\begin{aligned} I &= 2\pi r^2 j \\ &= -2\pi r^2 \sigma \nabla \phi \\ &= 2\pi \sigma A \end{aligned}$$

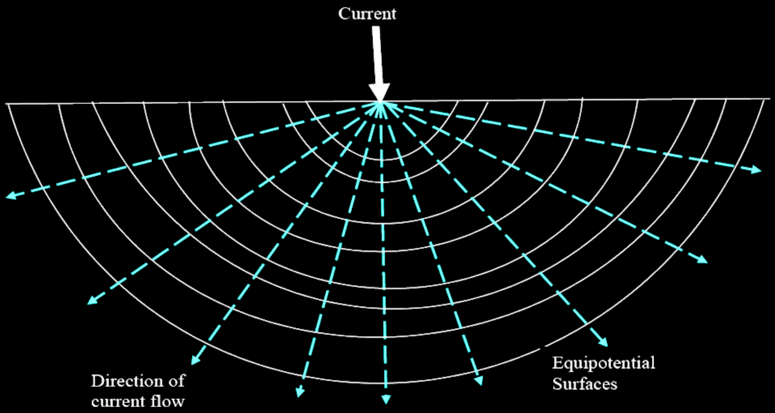
$$A = -\frac{I\rho}{4\pi}$$

Current flow through the sub-surface



$$\boxed{\phi = \frac{I\rho}{2\pi}\frac{1}{r}}$$

Current flow through the sub-surface



[Aizebeokhai et al., 2010]