Logistics

- paulina.seibel@gmx.de
- Sign up today @ 19:00 - own report
- 16.06 Geophysics BBQ @Lauswiesen (bei der Brücke B27)
- 14.05 Pint of Science Cafe Haag → evening 18:30

VL7

Electrical properties of the subsurface

Seismics: We deal with elastic properties (Young's modulus....) which are emcaps in seismic wave velocities.

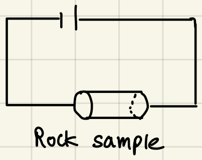
Electrics: Explores the subsurface in terms of electr. conductivity/resistivity.

For now: We only focus on time-independent processes ($\overset{\text{direct current}}{\text{DC}}$ current not $\overset{\text{fast phase shifts}}{\text{AC}}$)

Basic Relationships

Ohm's law in an electrical circuit: $\boxed{U = R \cdot I}$

U: Potential difference [V]
I: Current [A]
R: Recistance [Ω] ⟷ Cunductance $c = \frac{1}{R}$ [S]

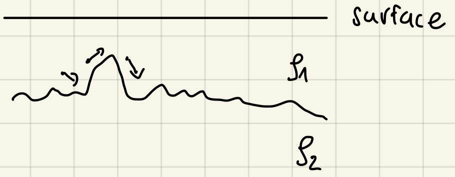


Resistence depends on geometry (A, l)

Spezifischer Widerstand

resistivity is a material property only $\frac{l}{A}\rho = R \iff \boxed{\rho = \frac{A}{L} R}$ [Ωm]

For Geo/Env. application it's required to expand Ohms law for a continous (spacially extended) medium:

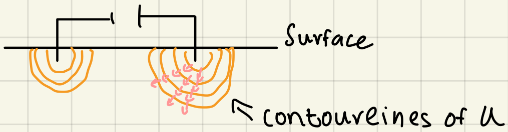


$\boxed{\vec{j} = \sigma \vec{E}}$ Vectorized Ohms law

$\vec{j}(x,y,z)$: current density
$\sigma = \frac{1}{\rho}$: conductivity
$\vec{E}(x,y,z)$: Electric field $[\frac{V}{m}]$

With $\boxed{\vec{E} = -\nabla U}$
$U = U(x,y,z)$ "scalar field"
"numbers"

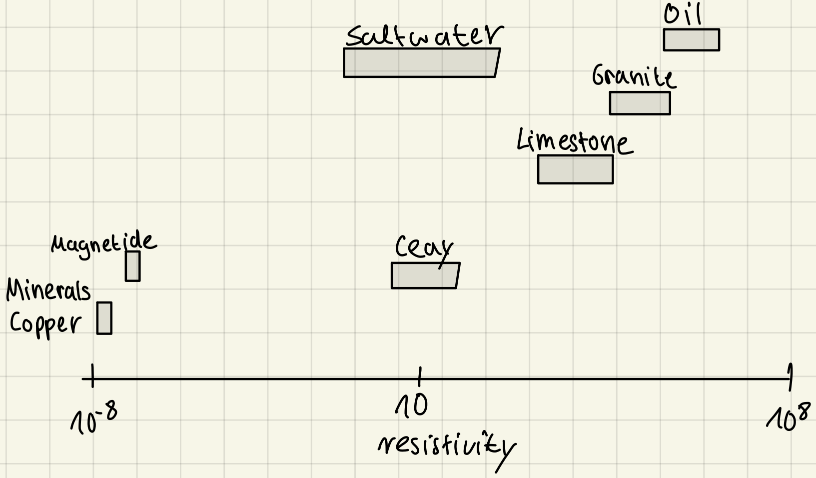
"Vector field" → number + direction



$$\boxed{\begin{array}{l}\vec{E} = -\nabla U \rightarrow \vec{E} \perp \text{contour lines} \\ \rightarrow \vec{J} \parallel \vec{E}\end{array}}$$

σ can be a tensor → cunductivity depends on direction

Range of resistivities of Earth mat.



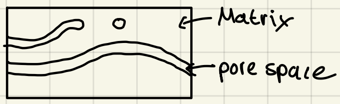
Large, large, large range!

Factors influenceing conduction

here: Ionic conduction

1. Conductivity of pore fluid: number of dissolved ions (Na^+, Cl^-, ...)

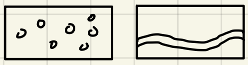
2. Porosity of rocks



more pore space → better conductivity

3. Saturation: is the pore filled?

4. Connectedness



Archie's law (most cited paper)

Formation factor: $\boxed{F = \frac{\rho_0}{\rho_f}}$ ← fully saturated rock ← resistivity pore fluid

Empirically: $\boxed{F = \frac{\rho_0}{\rho_f} = \Phi^{-m}}$

Φ: porosity
m: most rocks > 1 } no units

- → m is "indicative" of degree of cementation.
- → low values of m indicate good connectedness
- → All of this is only valid for the fully saturated case. All pore space filled with brine.

$$\rho_0 = \rho_f \Phi^{-m}$$

What happens if pore space is "invaded" by a different component such as oil?

If water/brine solution is displaced

$\boxed{I = \frac{\rho_r}{\rho_0}}$ ← partially saturated

resistivity index

$\boxed{I = S_w^{-n}}$ ← empirical constant ← fractional water saturation

· change saturation a bit
→ resistivity changes a lot

Combined Law: $\boxed{\rho_r = \rho_f \Phi^{-m} S_w^{-n}}$

Determine exponents in lab for a given hostrock

1. We understood that resistivity is great way to characterize the subsurface because of its large range and dependency to pore fluids.

2. However, to measure any ρ / σ we need electrical currents