

FKPE

7. Workshop

**Bohrlochgeophysik und Gesteinsphysik
Geozentrum, Hannover, 23. - 24. Okt. 2003**



Relationship between electrical and hydraulic properties of reservoir rocks

DFG SPP 1135: Dynamics of sedimentary basins

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*** IG DL, Göttingen**

- **Outline**

- **Drillings:** Schleswig, Fehmarn, Oldenburg, Glückstadt, Lingen

- **Petrophysics:**

 - density,

 - porosity

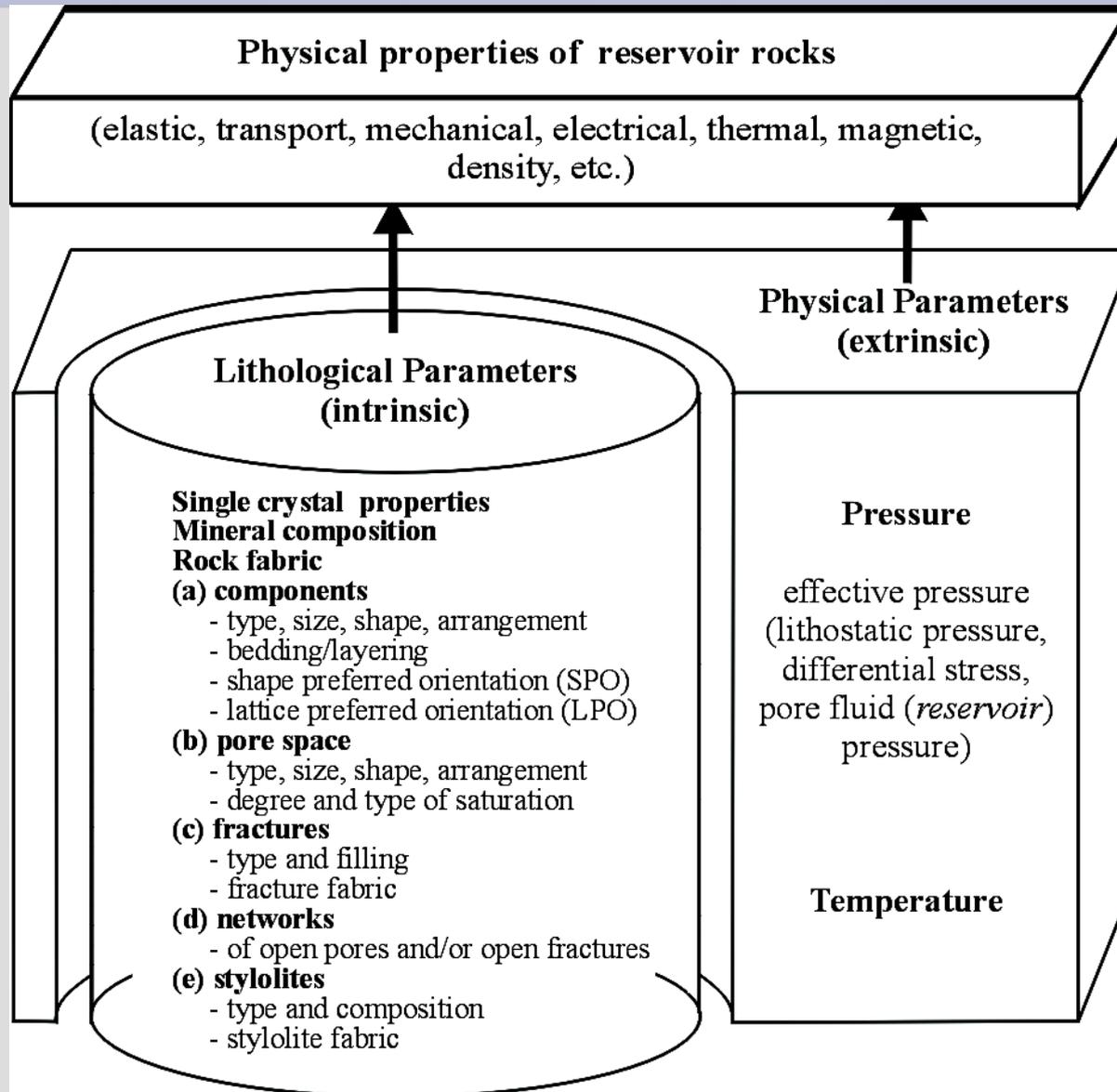
 - pressure dependence of the permeability,

 - complex electrical conductivity and its pressure dependence

 - relation to transport properties

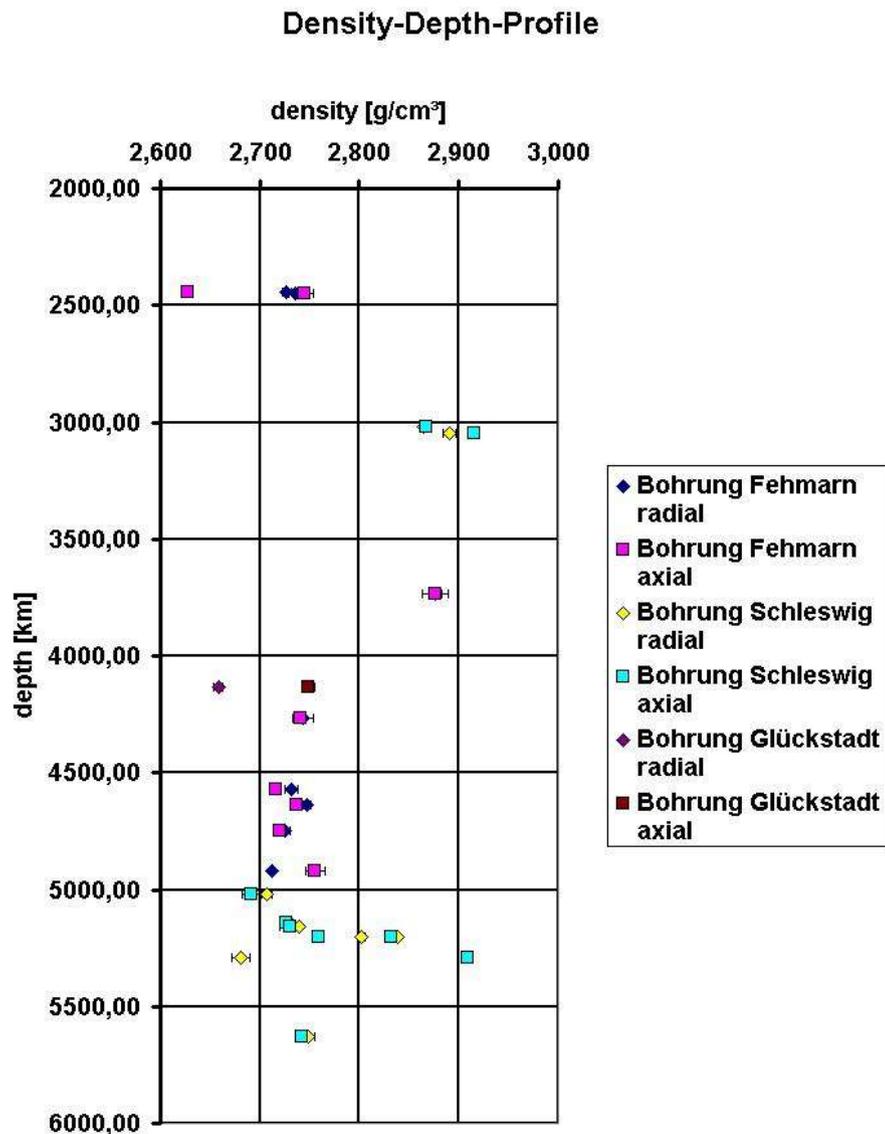
- **Conclusion & cooperations**

Petrophysical properties of reservoir rocks



Petrophysics Density

Rotliegendes: conglomerate: clay, sandstone, coarse silt

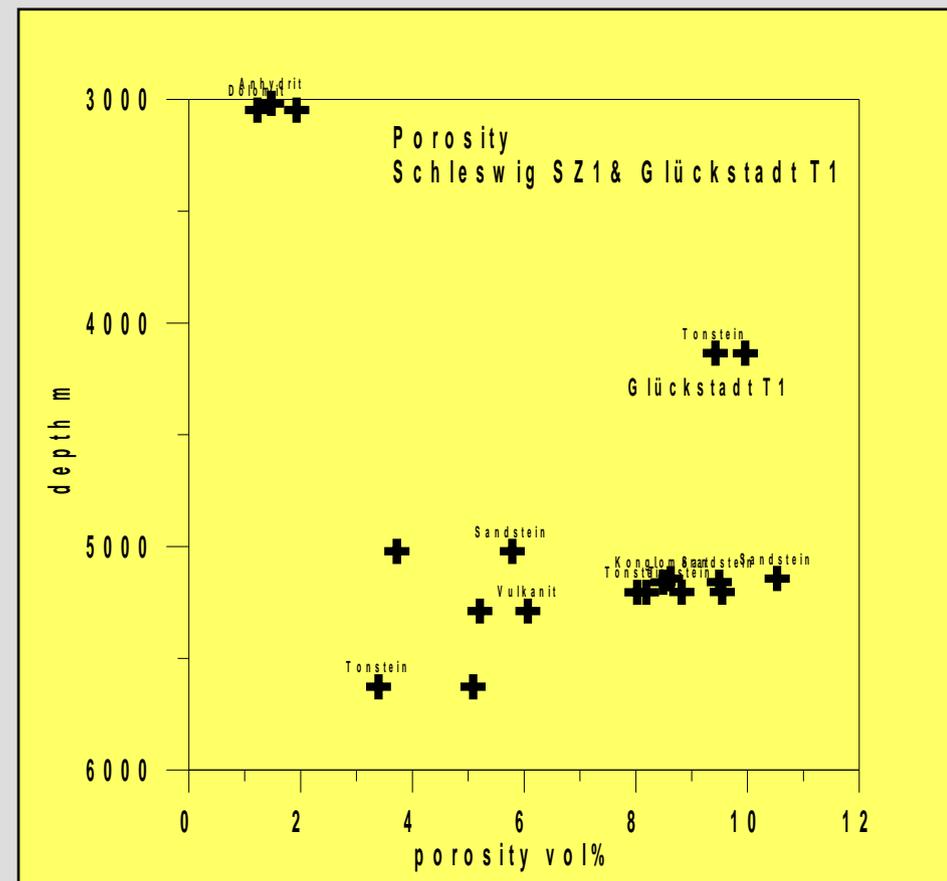
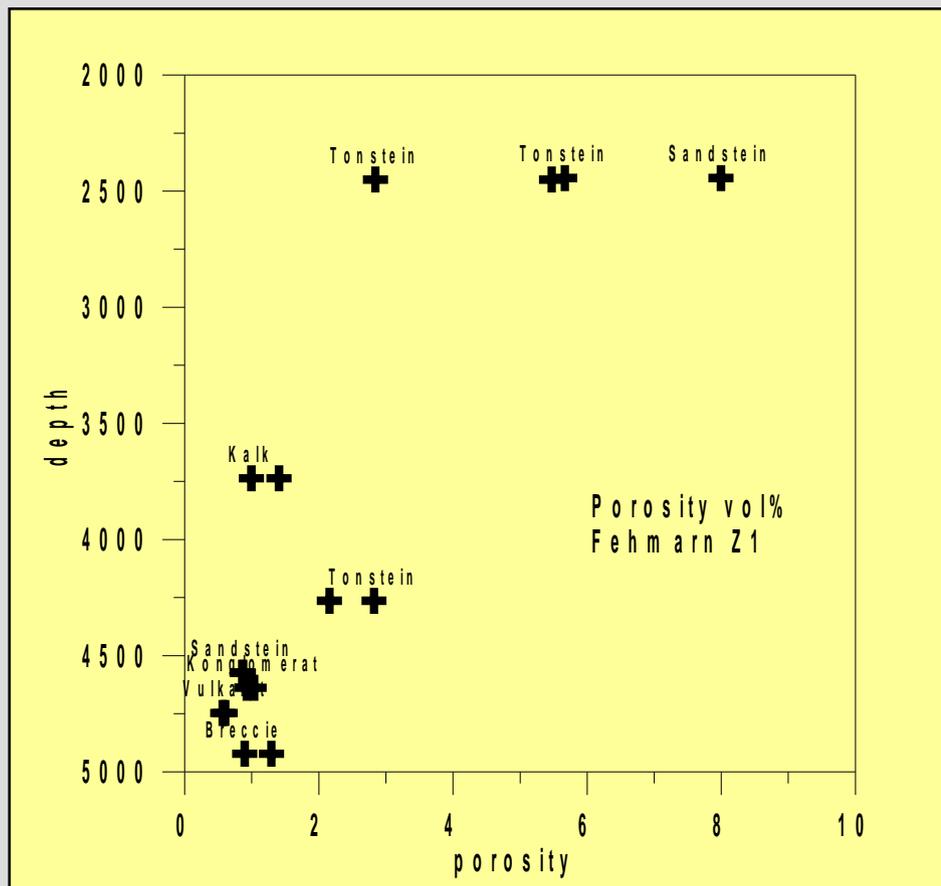


- Matrix density
- Porosity
- Mineralogical composition

Petrophysics Porosity

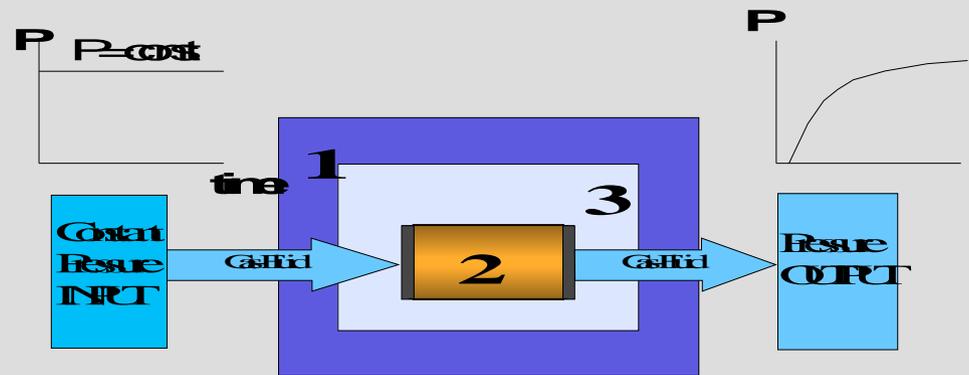
Fehmarn Z1; Schleswig Z1; Glückstadt T1

1. Archimedian,
2. Volumetric



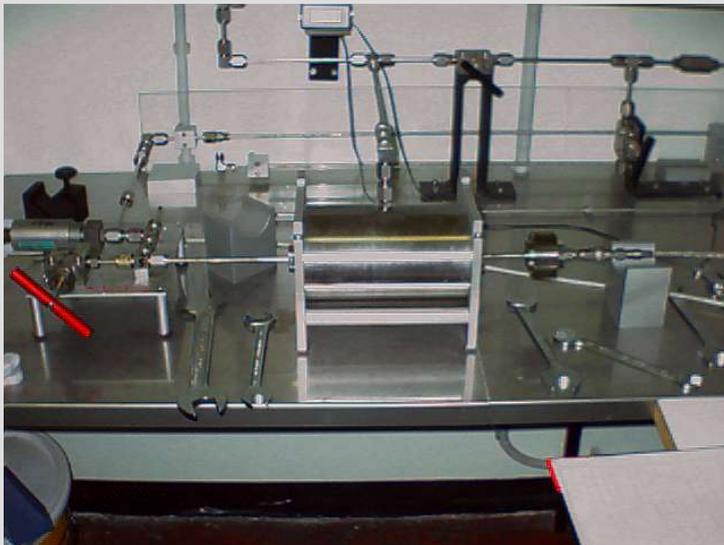
Petrophysics Permeability

Pressure Dependence; instationary technique



1. kontry
2. prøvning
3. gass

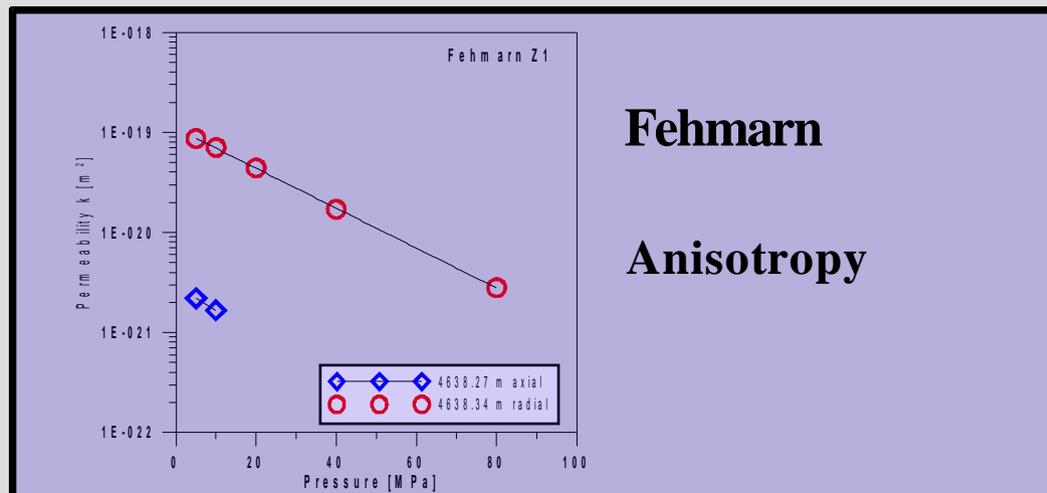
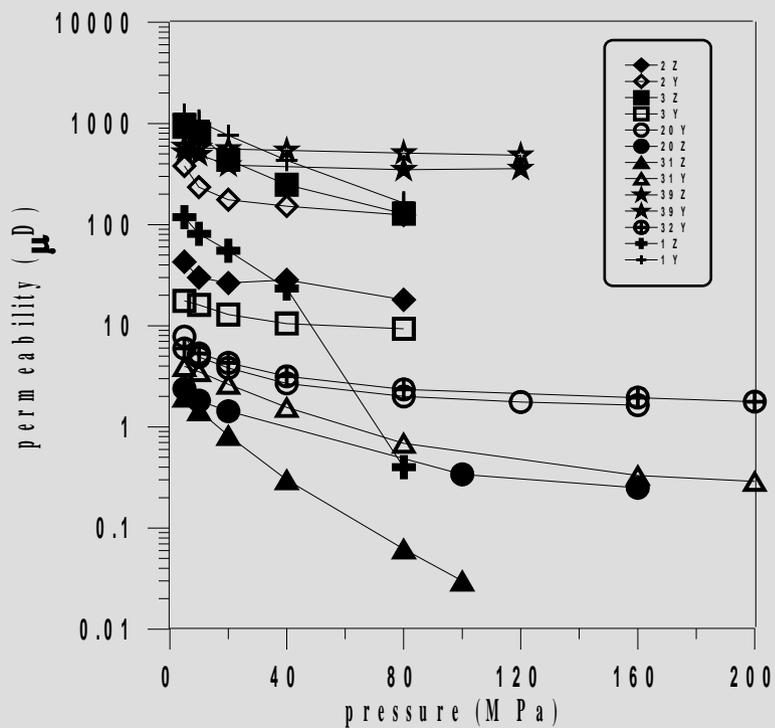
sample diameter:	10 - 45 mm ;
sample length:	10 - 60 mm
confining pressure:	up to 350 MPa
flow media:	gas (argon), fluids (water, oil)
permeability range:	mD - nD ($10^{-15} - 10^{-21} \text{ m}^2$)



Petrophysics results

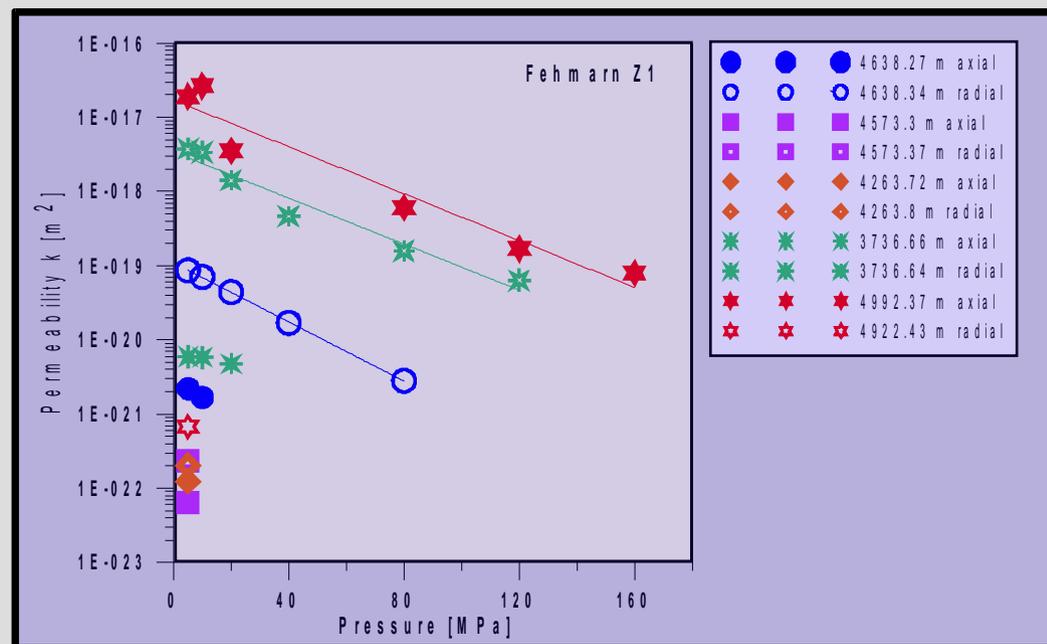
Pressure Dependence of the Permeability Anisotropy

Lingen limestone



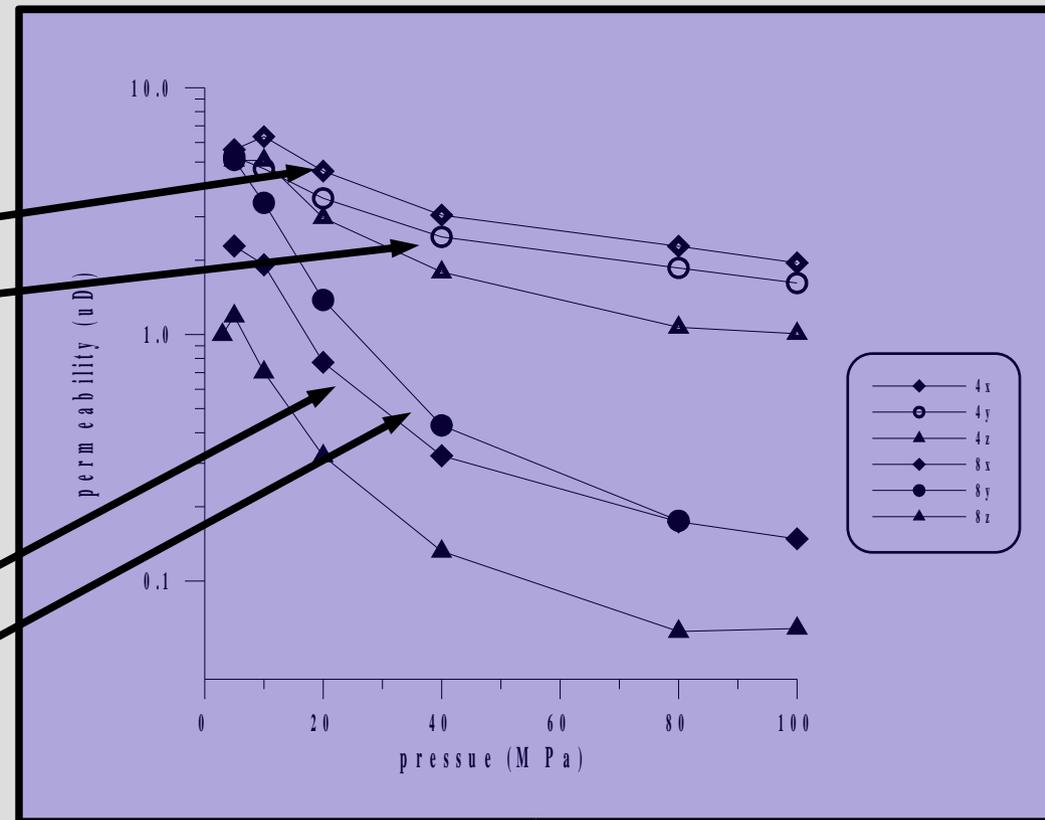
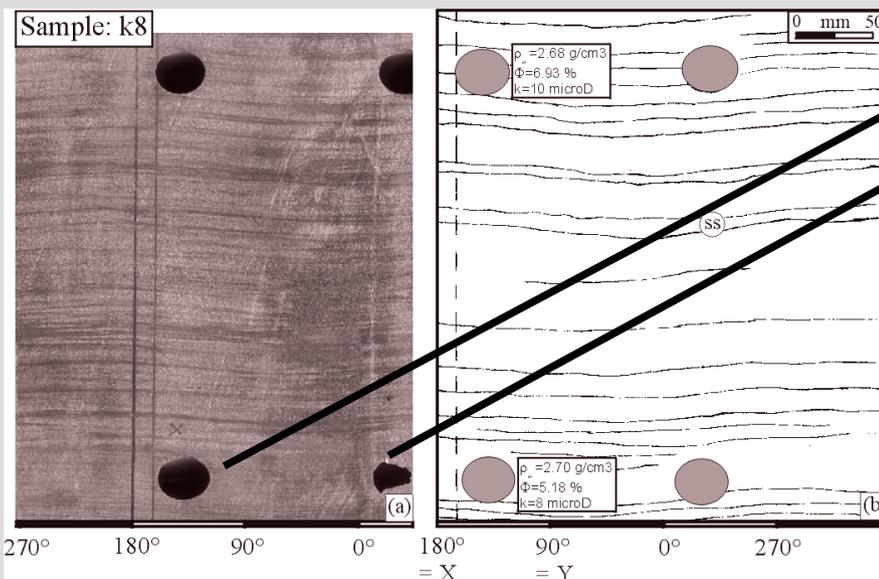
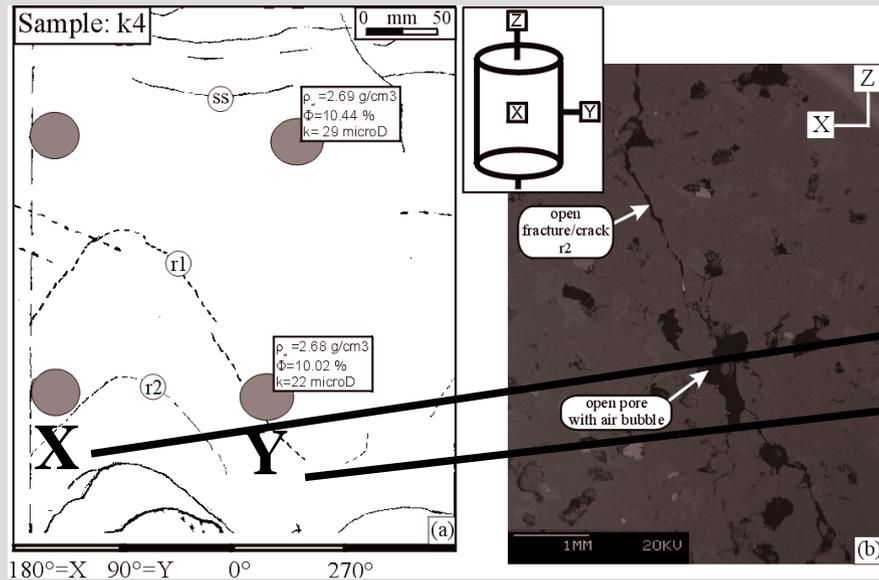
Fehmarn

Anisotropy



Permeability: Pressure dependence; Anisotropy

Sandstones from a tight gas reservoir, NW Germany



Petrophysics

Electrical Properties and their relation

T
A
R
G
E
T

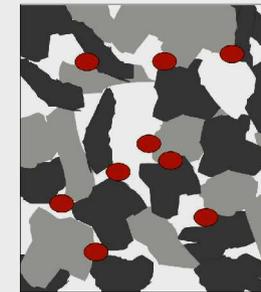
PHYSICAL PROPERTY

	Density	Magnetic Susceptibility	Electrical Resistivity	Dielectric Permittivity	Seismic Velocity
Porosity (pore, fracture)	strong	none	strong	strong	strong
Permeability	strong	none	strong	strong	strong
Water content	strong	none	strong	strong	strong
Oil content	strong	none	strong	strong	strong
Water quality	strong	none	strong	strong	strong
Clay content	strong	none	strong	strong	strong
Magnetic mineral content	strong	strong	strong	strong	strong
Metallic mineral content	strong	strong	strong	strong	strong
Metallic object	strong	strong	strong	strong	strong
Mechanical properties	strong	strong	strong	strong	strong
Subsurface structure	strong	strong	strong	strong	strong

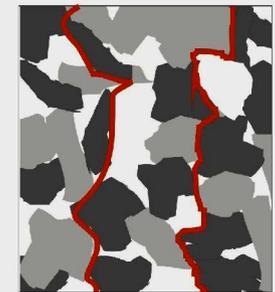


Degree of relationship

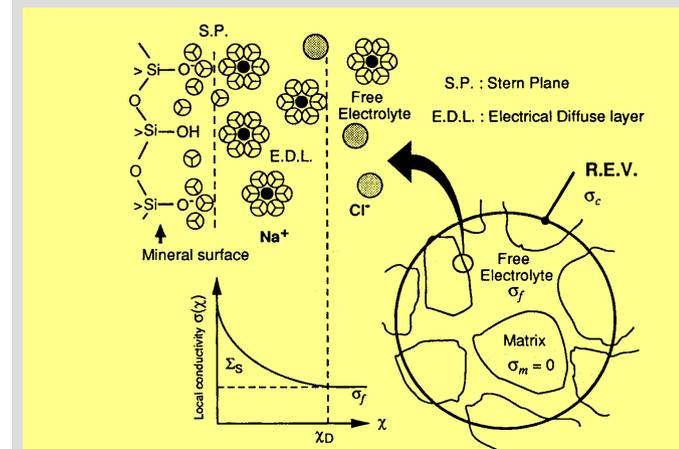
Degree of interconnection



R konstant
ε steigt



R fällt
ε steigt



Electrolyte, Double layer

Electrolytic charge transport - Model

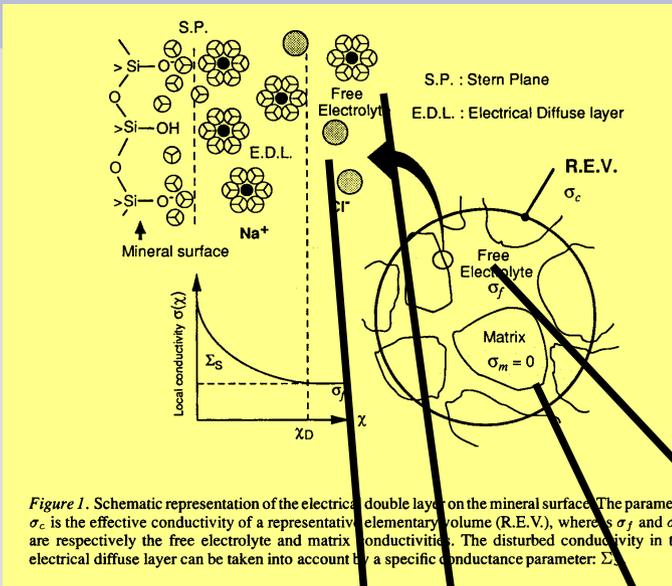
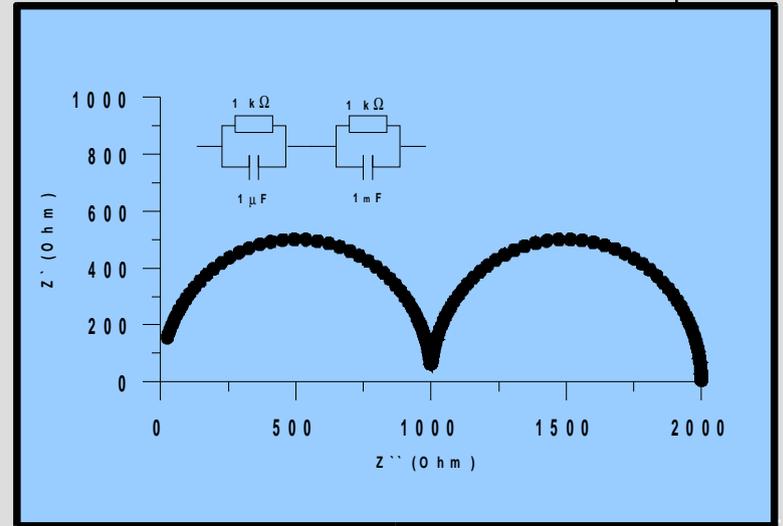
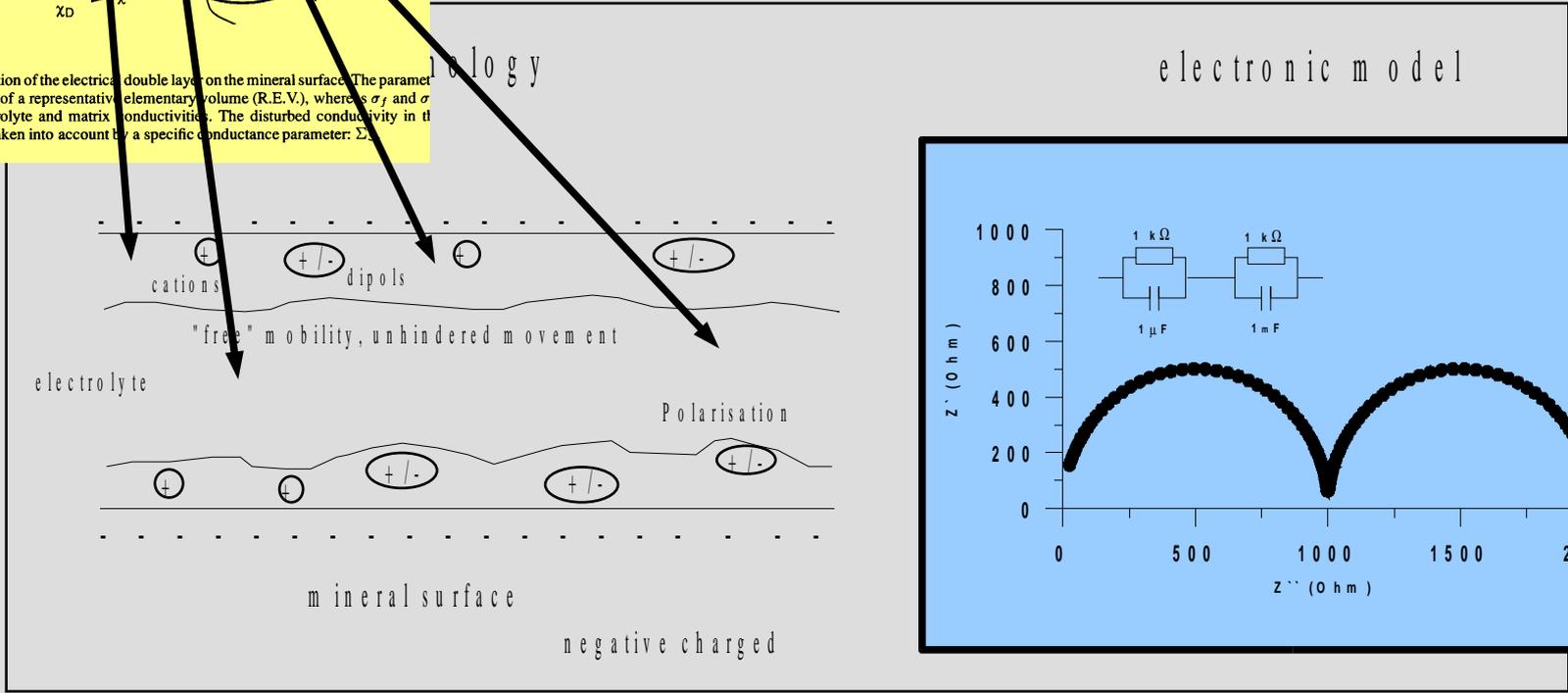


Figure 1. Schematic representation of the electrical double layer on the mineral surface. The parameter σ_c is the effective conductivity of a representative elementary volume (R.E.V.), where σ_f and σ_m are respectively the free electrolyte and matrix conductivities. The disturbed conductivity in the electrical diffuse layer can be taken into account by a specific conductance parameter: Σ_s .



Complex Electrical Conductivity: 5 Hz – 1 MHz

Pressure Dependence

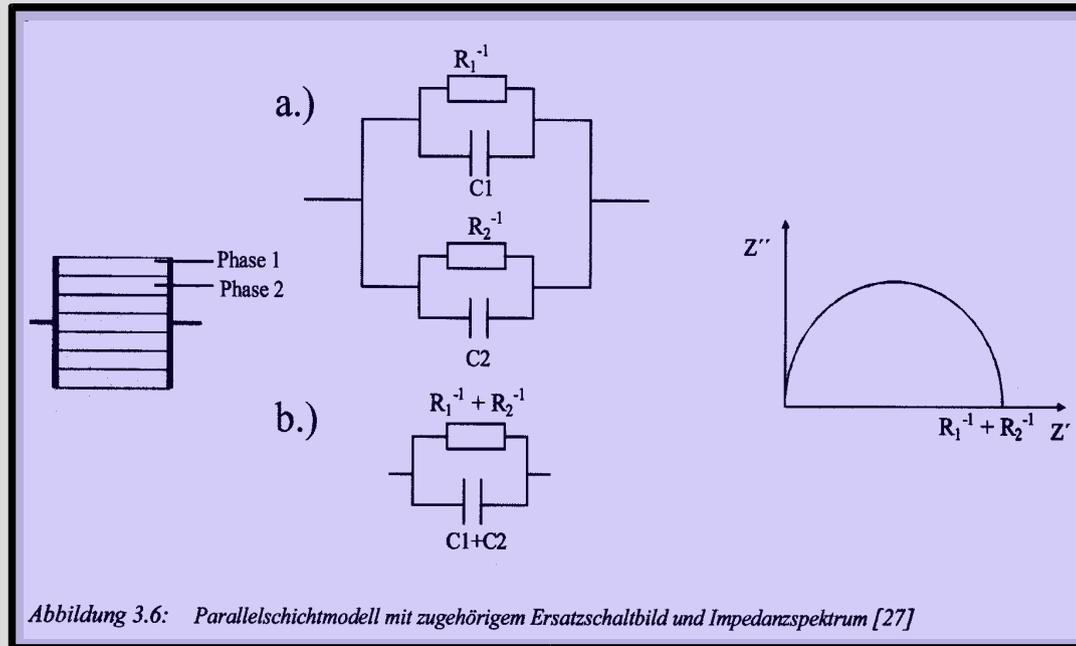
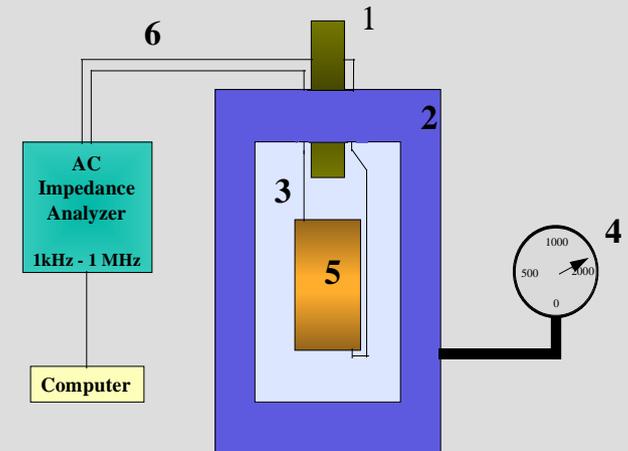


Abbildung 3.6: Parallelschichtmodell mit zugehörigem Ersatzschaltbild und Impedanzspektrum [27]

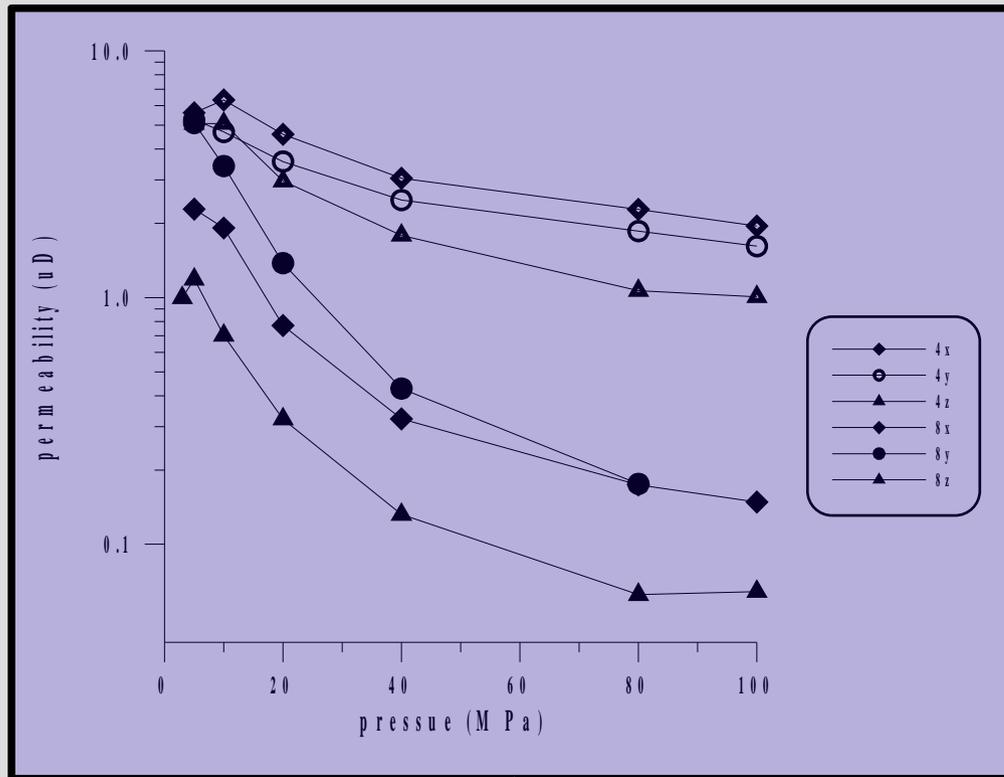


- 1 piston
- 2 autoclave
- 3 pressure transducer
- 4 manometer
- 5 sample

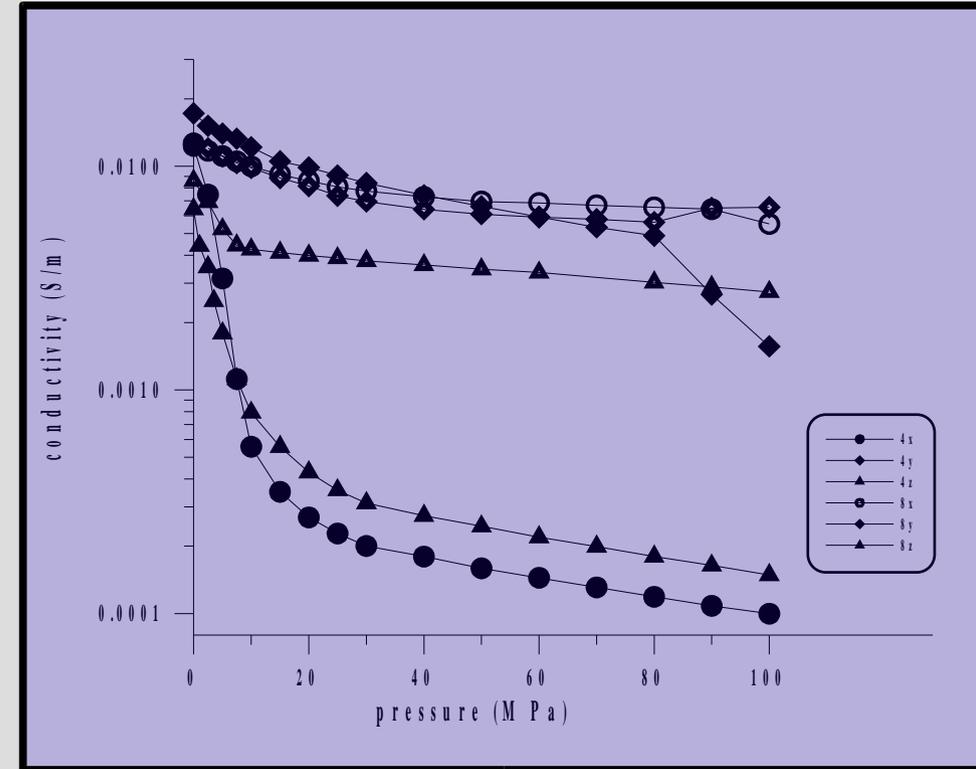


Pressure dependence

Permeability

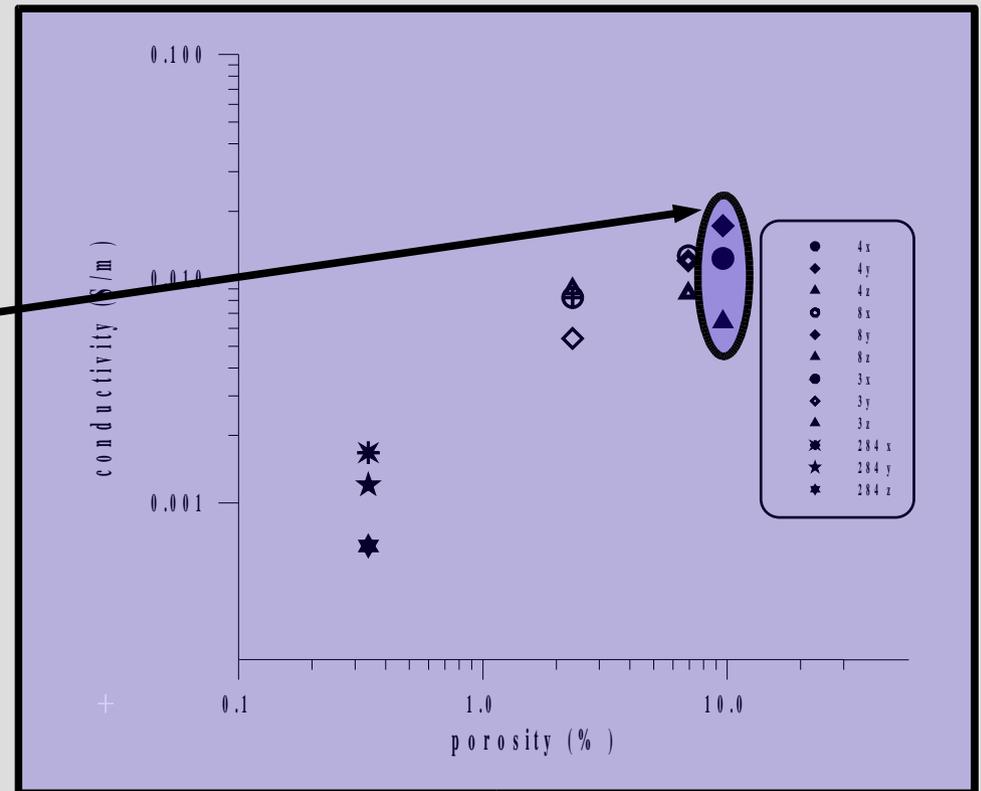
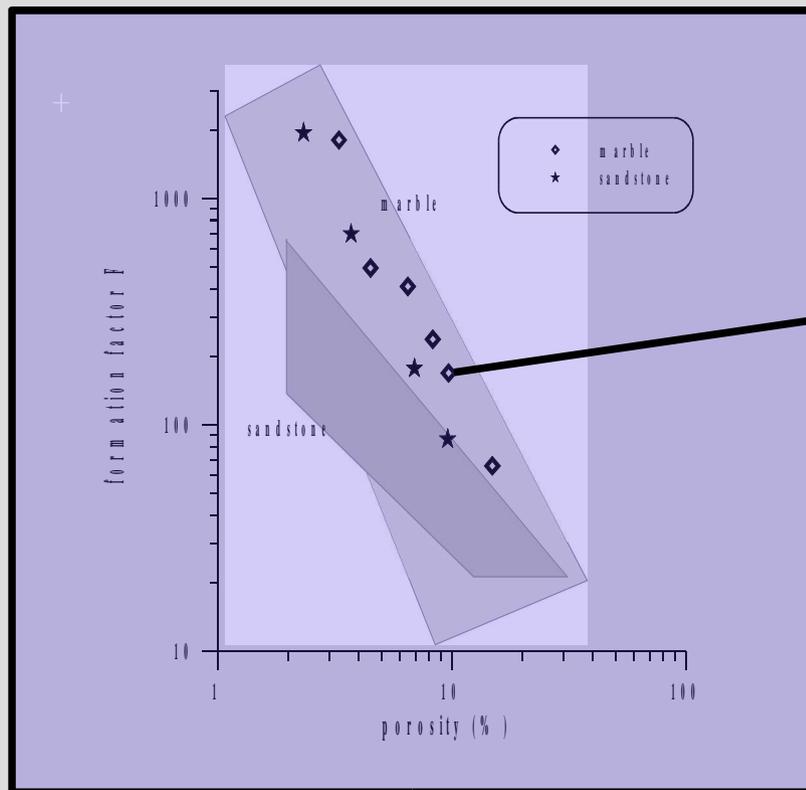


Volume conductivity



Crossplot: Porosity – Volume conductivity

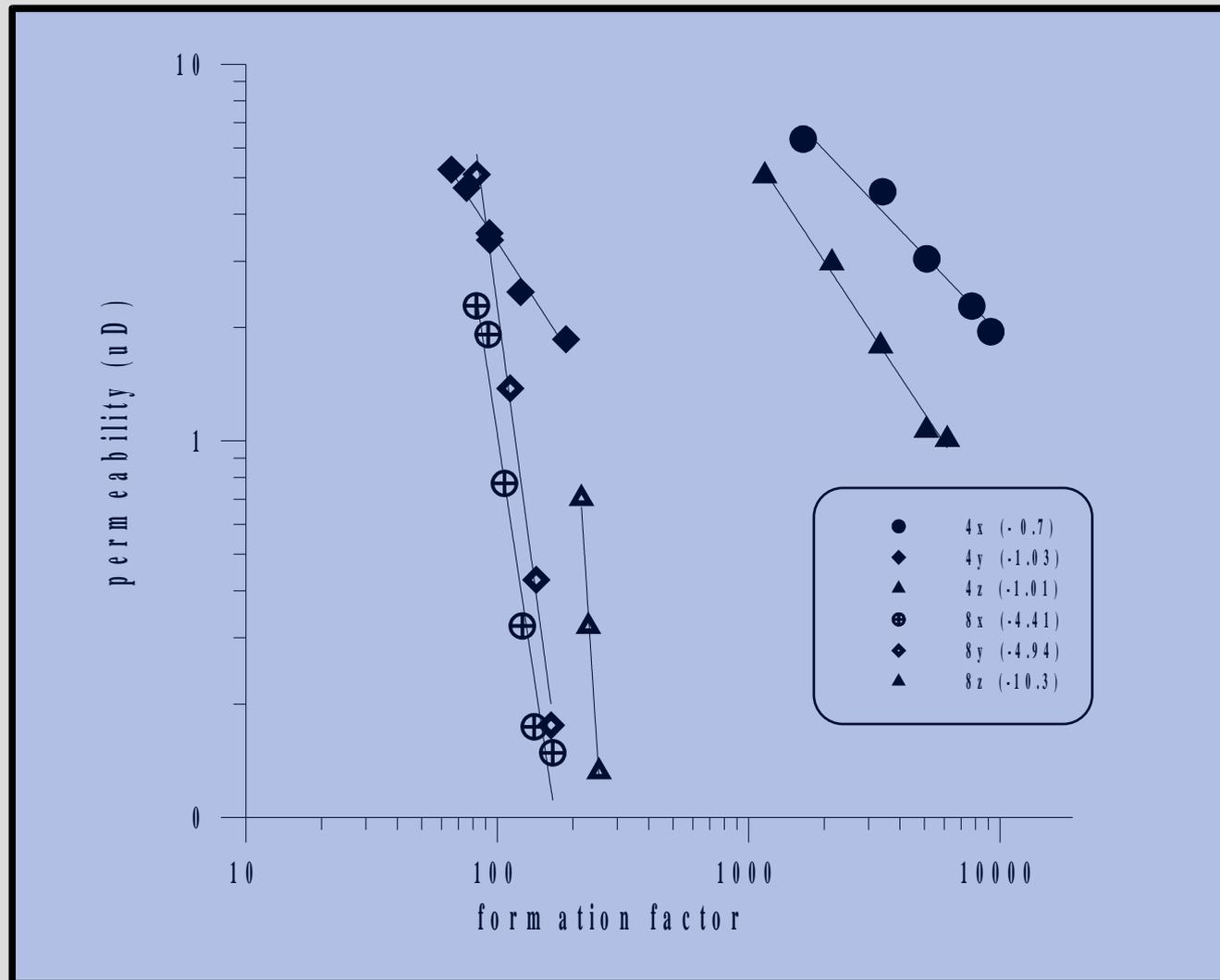
Anisotropy



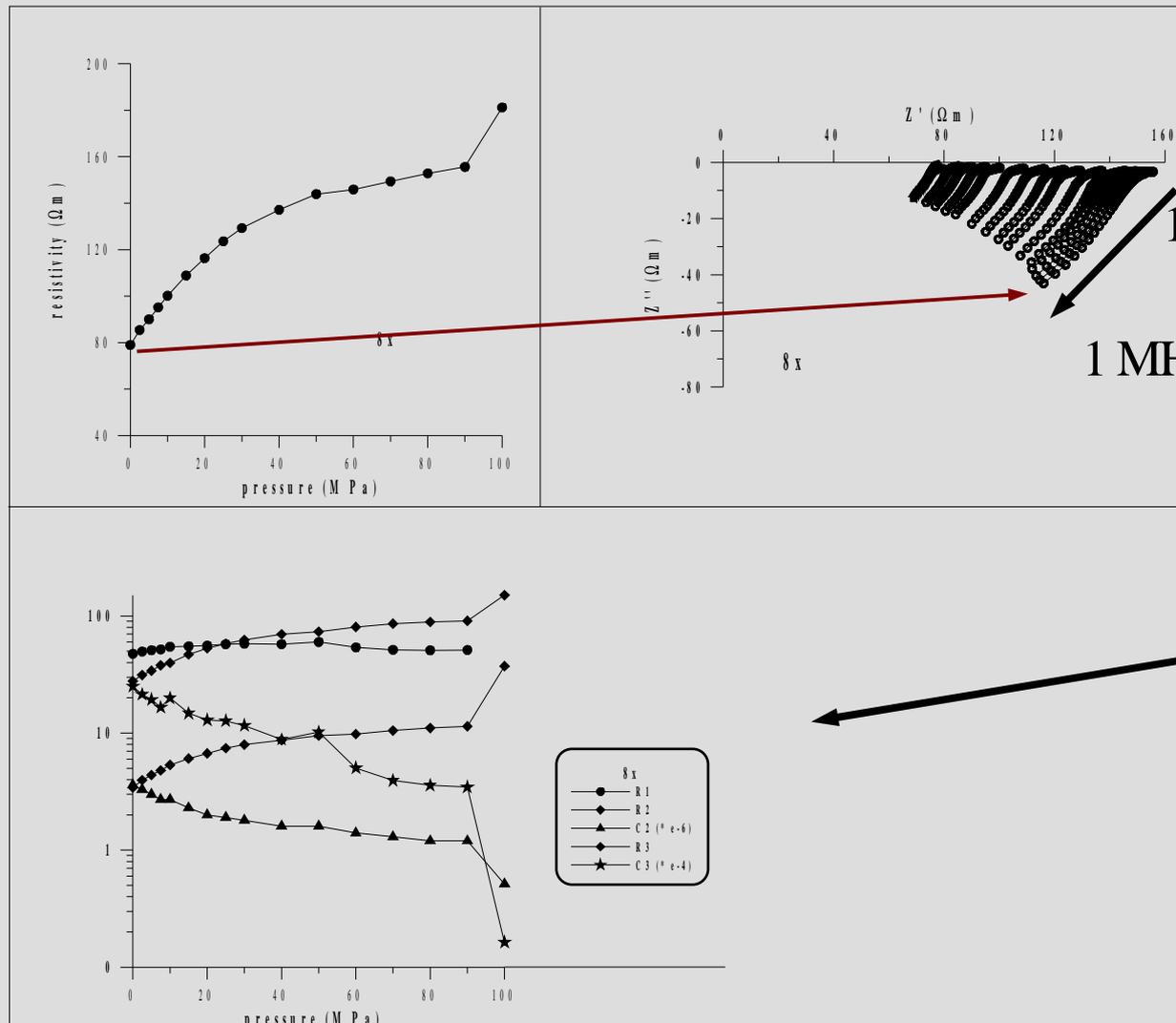
Anisotropy of electrical conductivity

Crossplot: Pressure dependence

Permeability – Volume conductivity



Complex response: Measured data – Model



Frequency

1 kHz

1 MHz

8x

Interpretation:

RC-equivalent circuit

(2 relaxation model)

- $(R_1 \parallel C_1)_{-}(R_2 \parallel C_2)$

- bulk conductivity

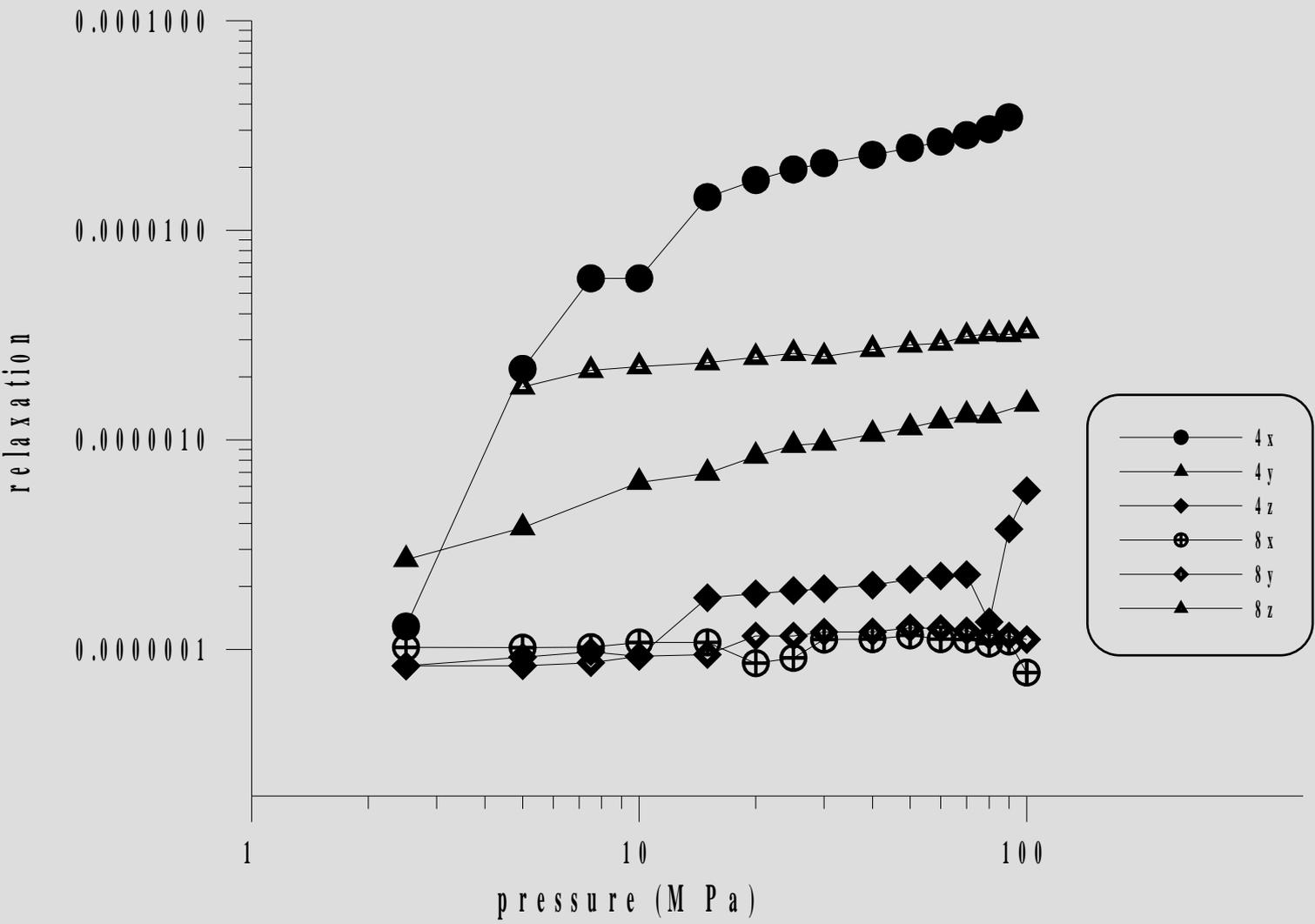
- surface conductivity

- Relaxation time

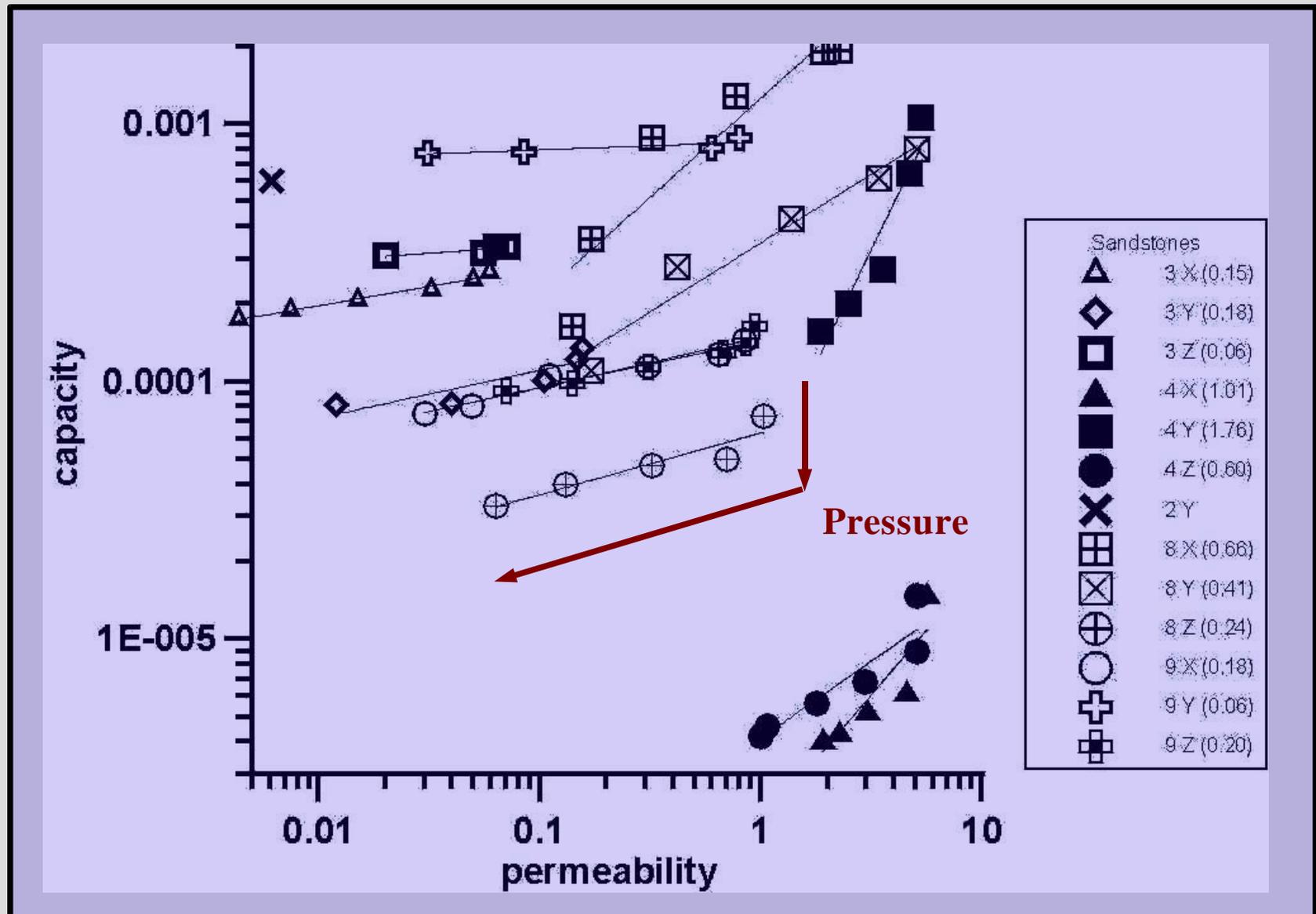
(time constant of polarisation)



Crossplot: pressure dependence of the relaxation time



Petrophysics AC-Impedance, Results



Conclusion & Cooperations

Conclusion

Electrical rock properties depend on:

- petrophysical parameters, porosity, permeability, aspect ratio
- Fabric, texture, grain size distribution, metamorphic overprint
- Anisotropy of layering
- Degree of interconnection of the pores

But,

the correlation between electrical and hydraulic properties still requires further experiments.

RWTH, Aachen:	Petrophysics, permeability, porosity, Data Base
Uni Münster:	Electrical conductivity, correlation lab-borehole data
GFZ:	BET surface, porosity
BGR:	Carbon enhanced conductivity
Uni Göttingen:	Correlation of lab data: V_p , V_s , permeability, el. Cond.