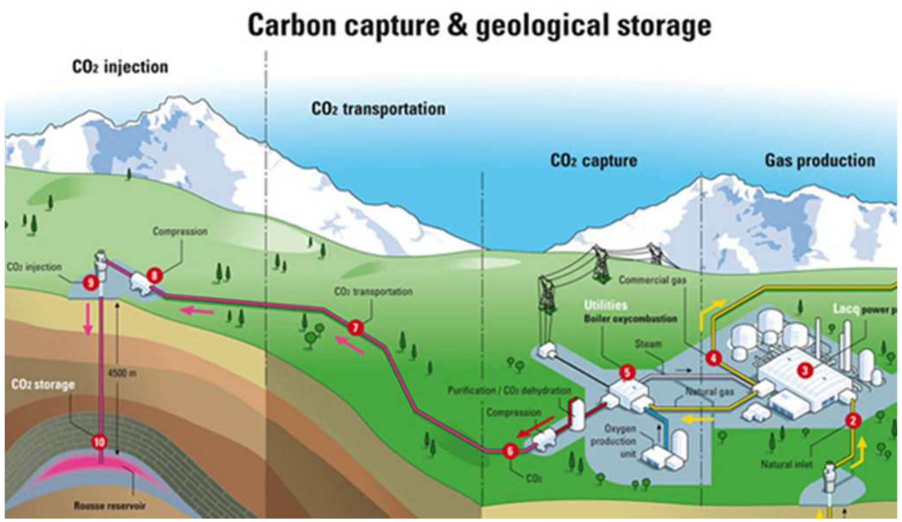
9th Euroconference
Trondheim, Norway

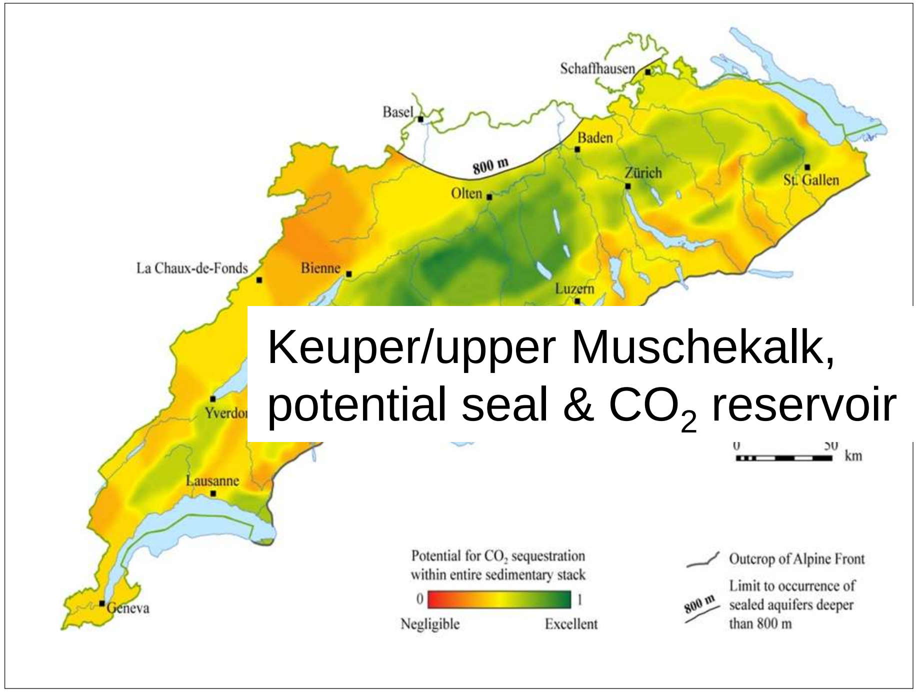
Physical and chemical properties of the Upper Muschelkalk aquifer in Northern Switzerland

B.S.G. Almqvist, L. Aschwanden, K. Ramseyer, A. Zappone, P. Benson
& L. Diamond

Acknowledgments:
Nagra
Ronny Pini (Stanford U.)
Dorian Marx (ETHZ)
Carbon management in energy generation (CARMA)

Motivation





Keuper/upper Muschekalk, potential seal & CO_2 reservoir

Chevalier et al. (2010) Swiss Journal of Geosciences, Vol. 203

Where is the unit porous and permeable?
(spatial distribution in the Swiss Molasse Basin)

How did the porosity and permeability form?
(sedimentary, diagenetic and tectonic history)

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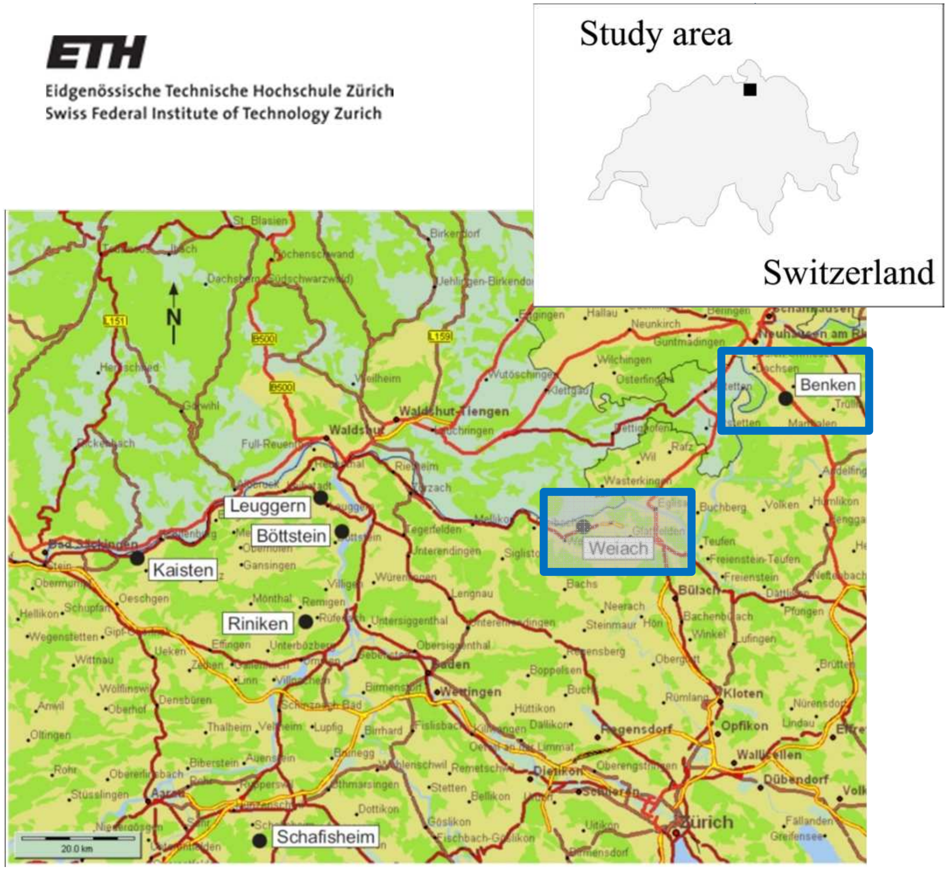
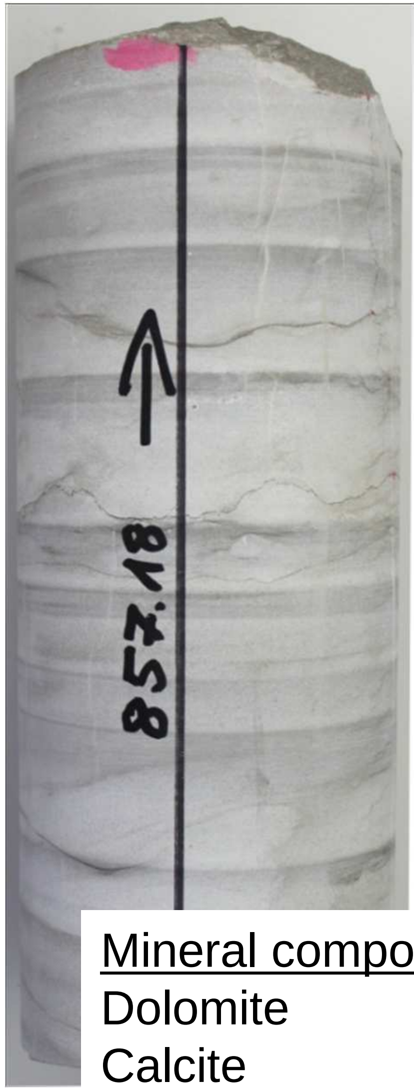
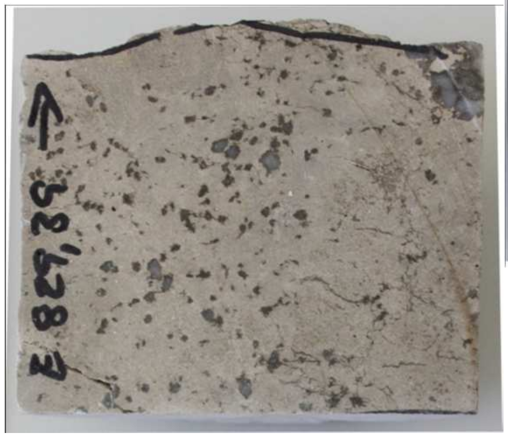
Swiss Federal Institute of Technology Zurich





Benken (822m)

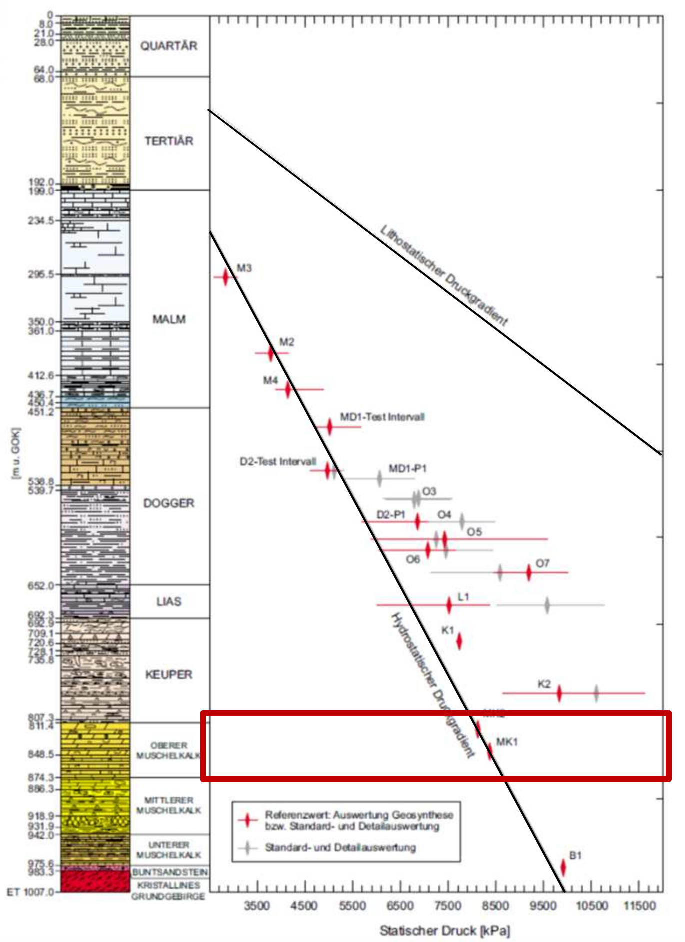


Weiach (829m)

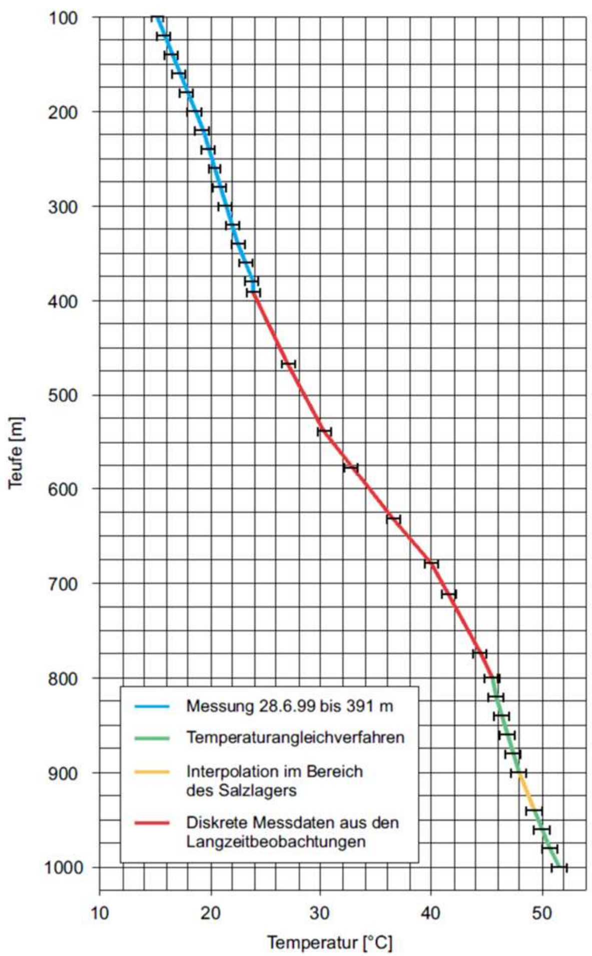
<u>Mineral composition</u>:
Dolomite
Calcite
Anhydrite
Quartz
Kaolinite
Iron sulphides

Pressure and temperature effects (Benken)

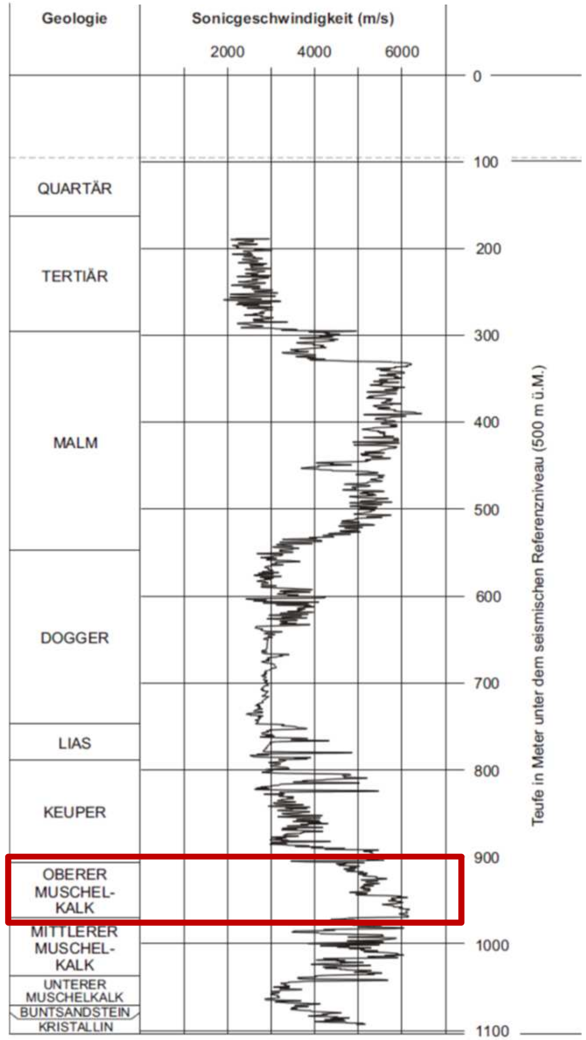
Pore pressure



Geothermal gradient

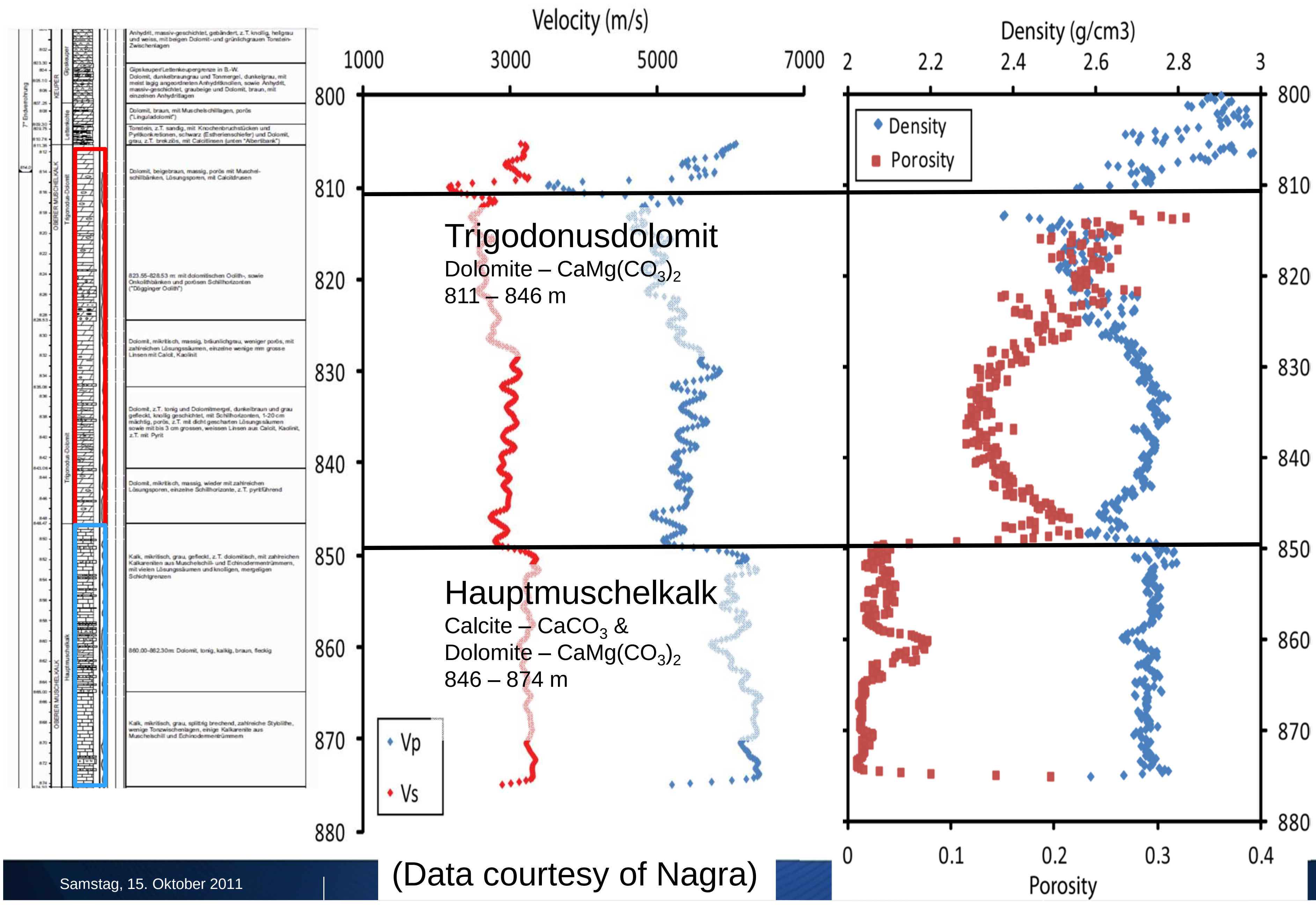


Sonic velocity (m/s)



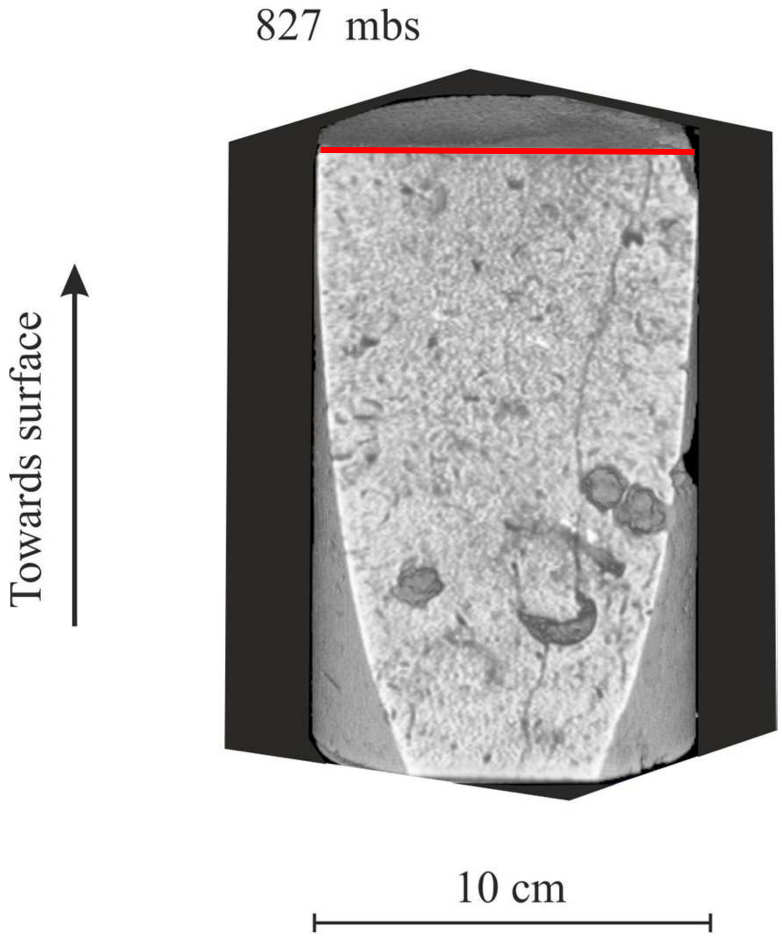
(Nagra, 1999)

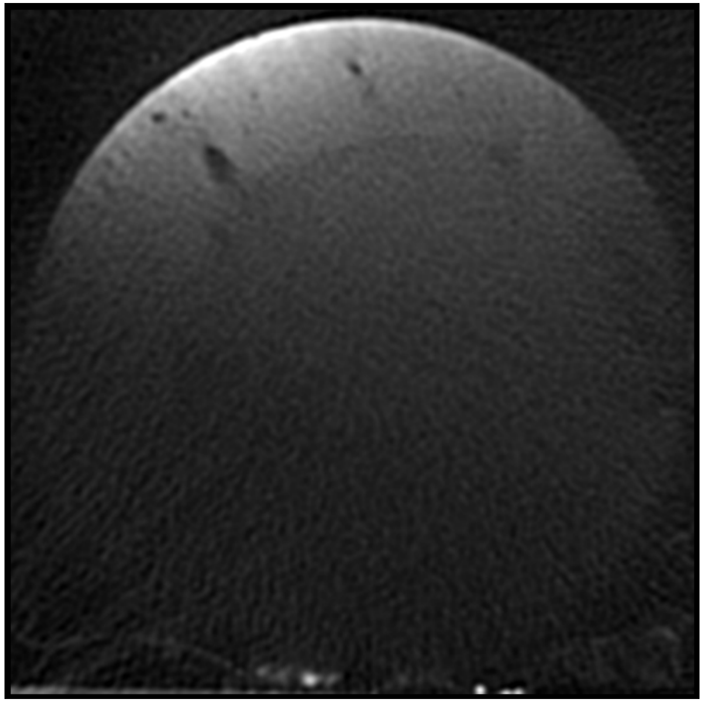
Upper Muschelkalk borehole logging record



(Data courtesy of Nagra)

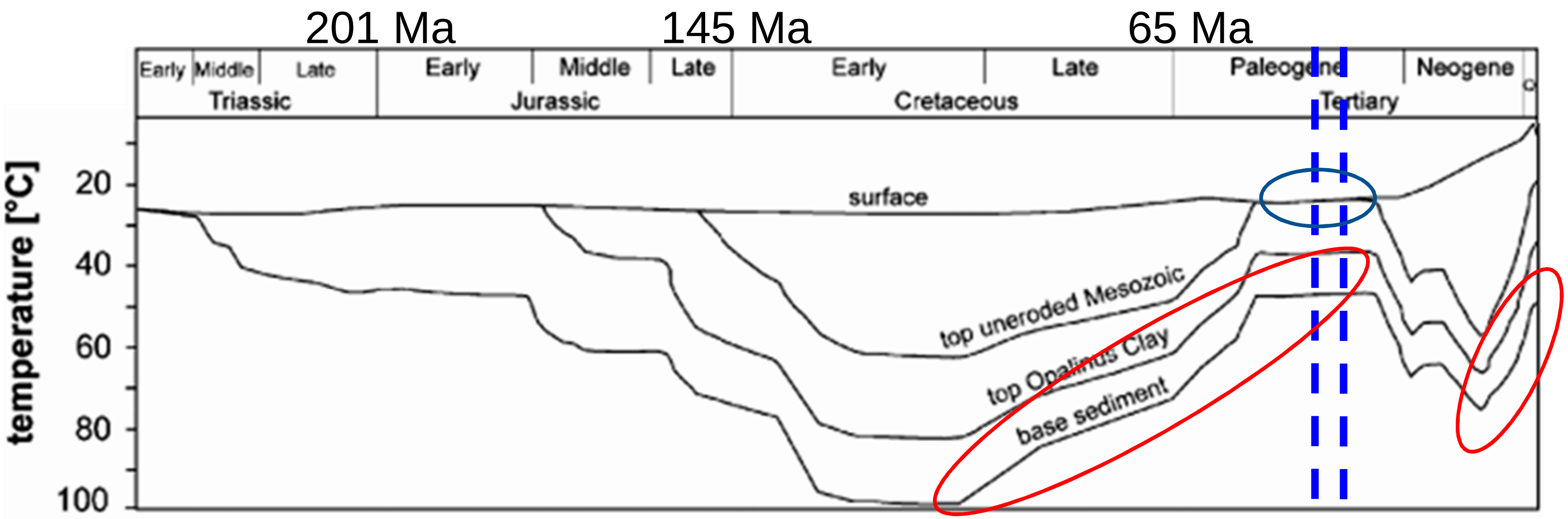
Macroporosity – hospital CT scan





Resolution = 0.6 mm

Origin of the macroporosity



Mazurek et al. (2006)

Fluid inclusion data indicates that quartz grows during uplift of basin

Oxygen isotope data of quartz indicates influence of meteoric water during crystal growth

→ infiltration Eocene/Oligocene

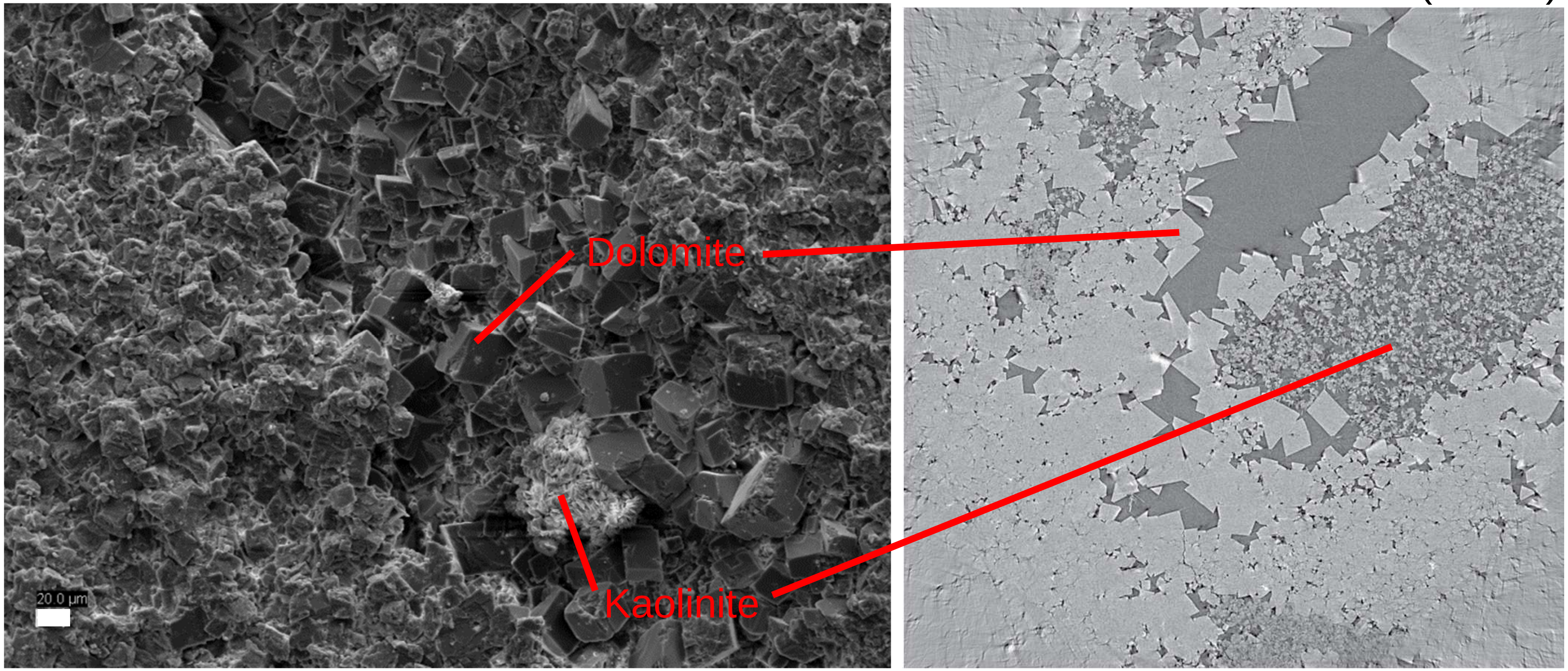
Signal from Eocene/Oligocene boundary via hydrogen isotope data of kaolinite

Timing of dissolution of anhydrite nodules and creation of macroporosity most likely during late stage uplift in the Upper Cretaceous

Imaging the microporosity

SEM (825 m)

microCT (825 m)



Scale bar = 20 µm

Viewfield = 750 µm
Pixel Resolution = 0.38 µm

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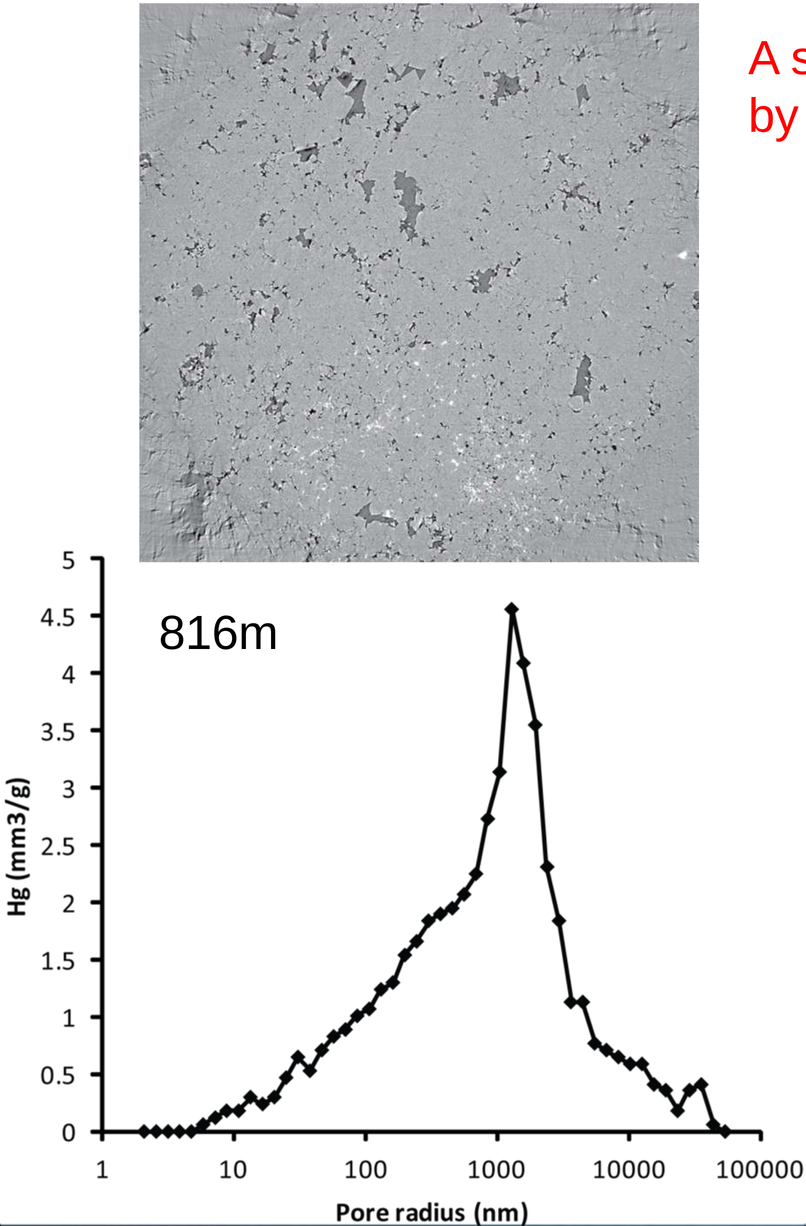
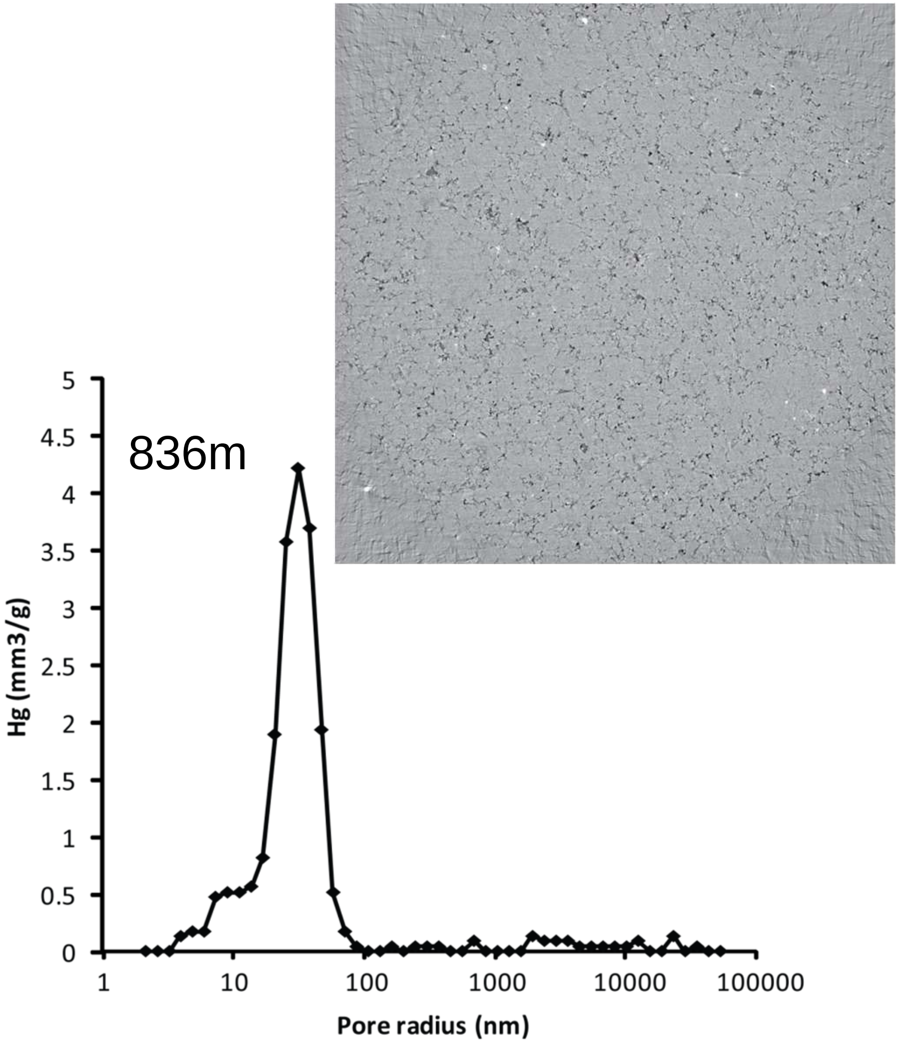
The microporosity: mercury porosimetry

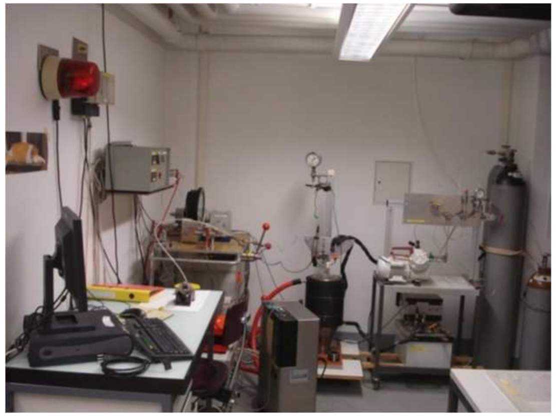
A significant portion of the microporosity is left out by the microCT measurements (<0.3 µm)

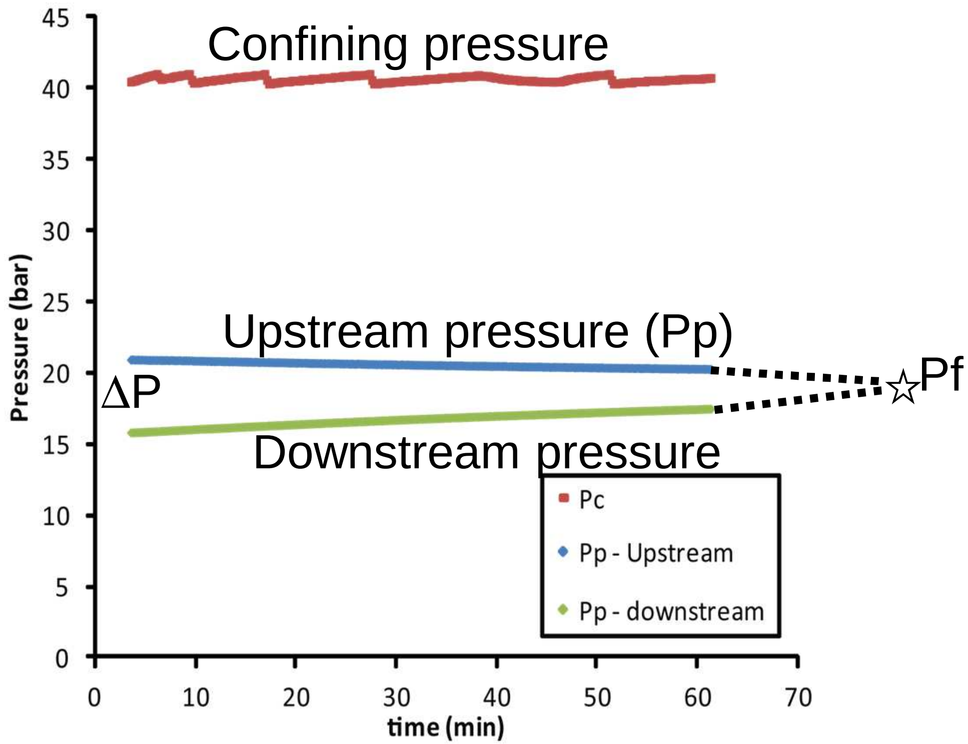


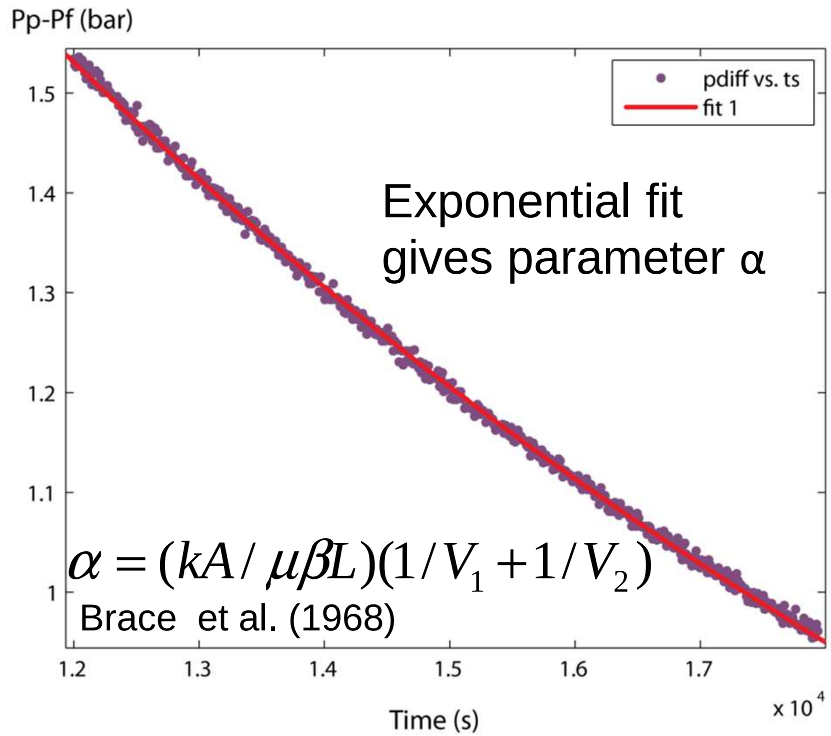


Permeability measurements

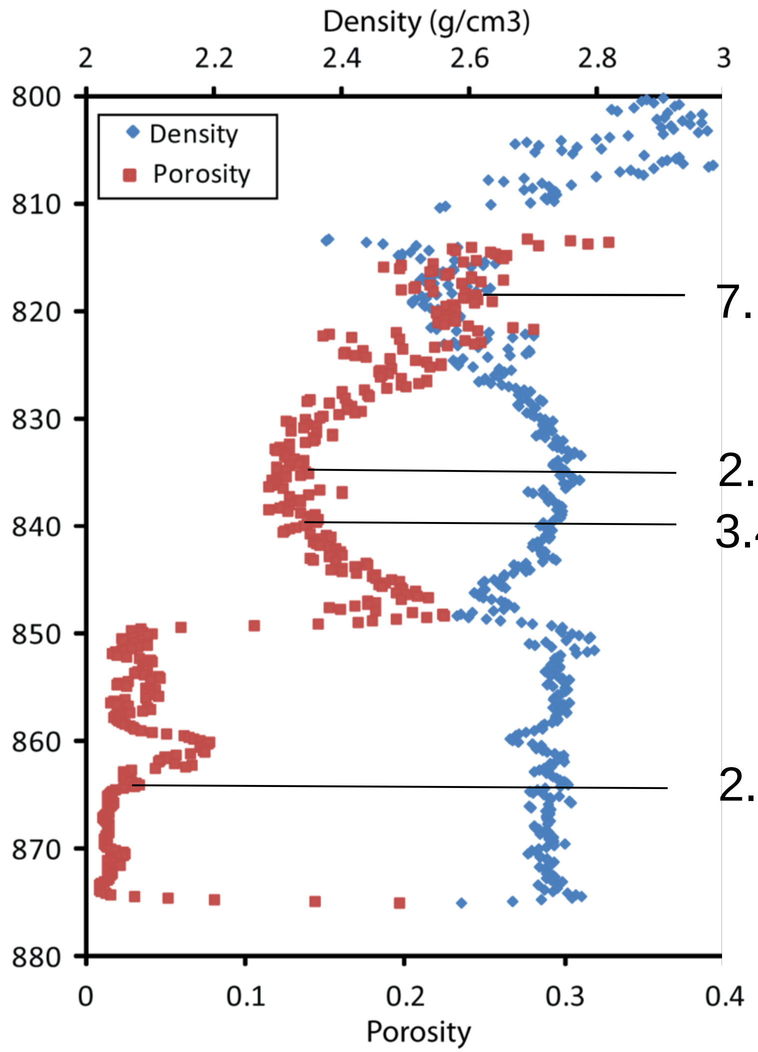
Transient step technique
Confining pressure (300 bar) and temperature (up to 200 °C)
Pore fluid (gaseous, supercritical state, liquid)
1 inch diameter cores, 3-5 cm long







Permeability measurements



7.16e-15 m2 (817 m)

2.65e-18 m2 (836 m)

3.45e-18 m2

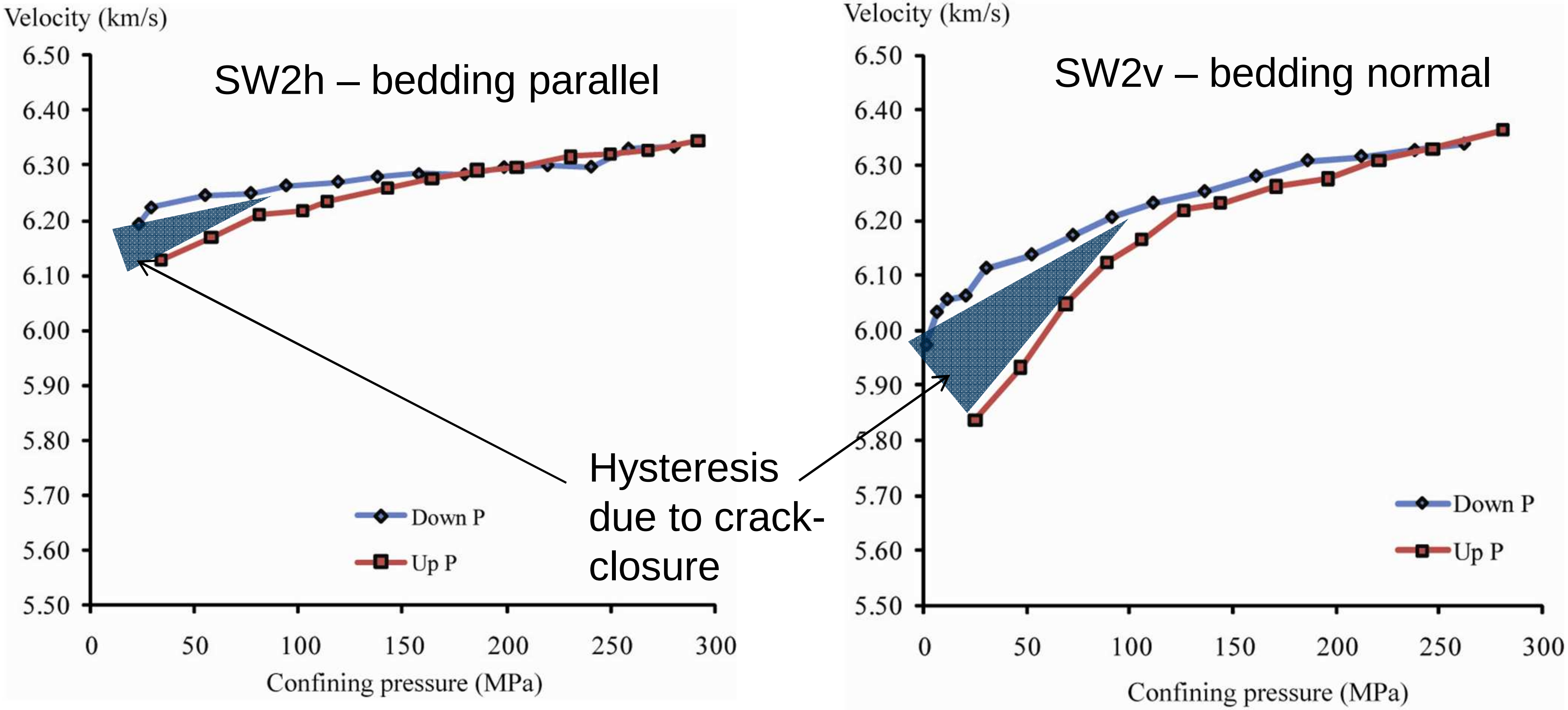
2.55e-19 m2

Effective pressure: 120 – 140 bars
Temperature: 45 °C
Argon as pore fluid

Samples chosen for permeability measurements show no large cracks (microporosity influence)

Measurements continue...

Anisotropy of laboratory sonic velocity and permeability



Porosity = 3.9 %
k = 1.14e-16 m^2 (130 bar Pe)

Porosity = 3.5 %
k = 7.16e-18 m^2 (130 bar Pe)

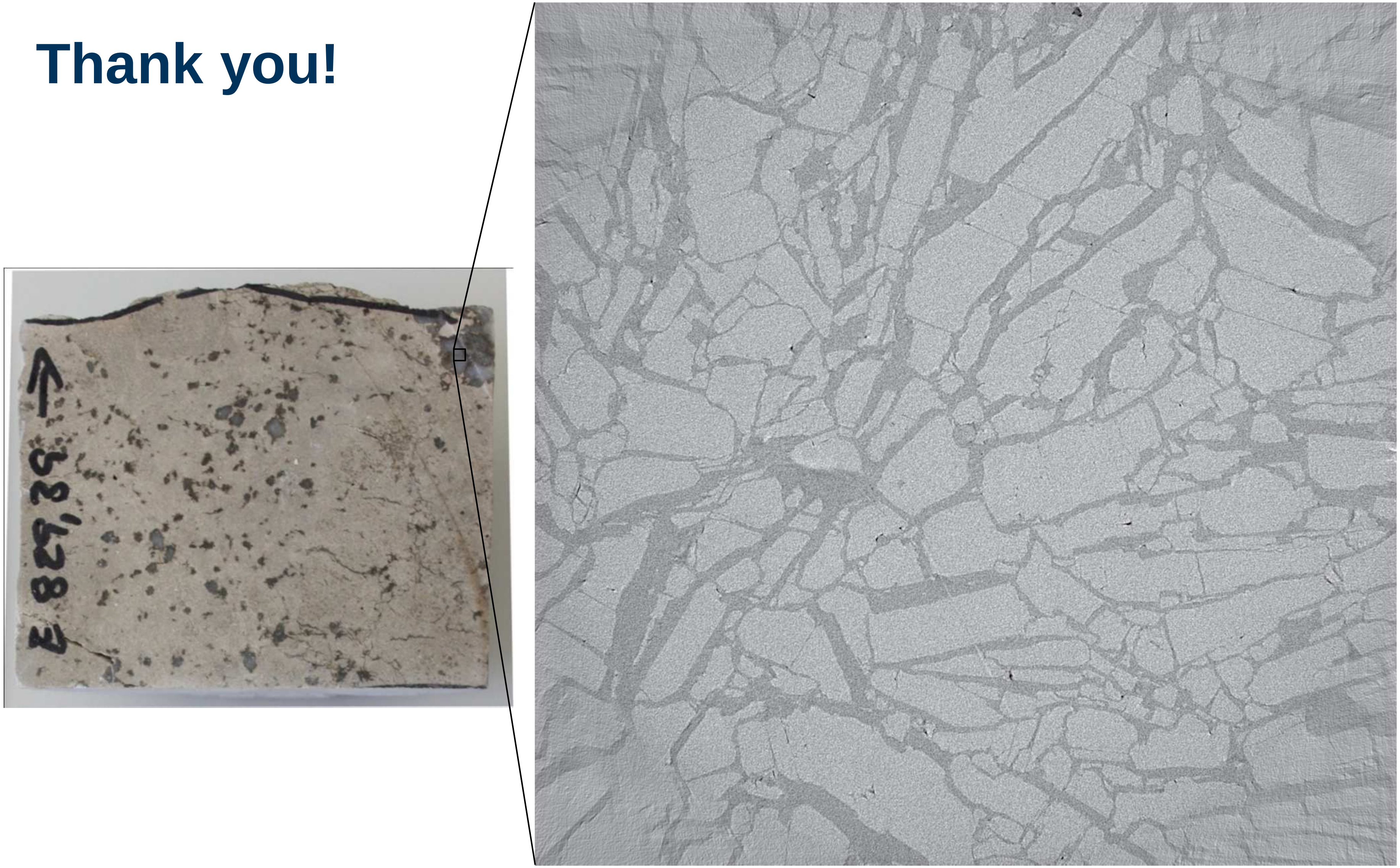
Conclusions

- Porosity and permeability in the upper Muschelkalk are heterogeneously distributed, over a large range:

  (<1% to 25% porosity; >10e-15 m^2 to ~10e-19 m^2)
- Geochemical investigations indicate that important events in the development of porosity and permeability are related to diagenesis, as well as tectonic uplift and burial of the basin.
- The upper Muschelkalk is an aquifer, sometimes...
- What is the respective roles of the microporosity / macroscopic pores and cracks on the permeability?
- Upscaling:

  Lab <-> Borehole logging <-> Geophysical survey

Thank you!



Viewfield = 750 µm