Facies related thermo-physical characterization of the Upper Jurassic geothermal carbonate reservoirs of the Molasse Basin, Germany

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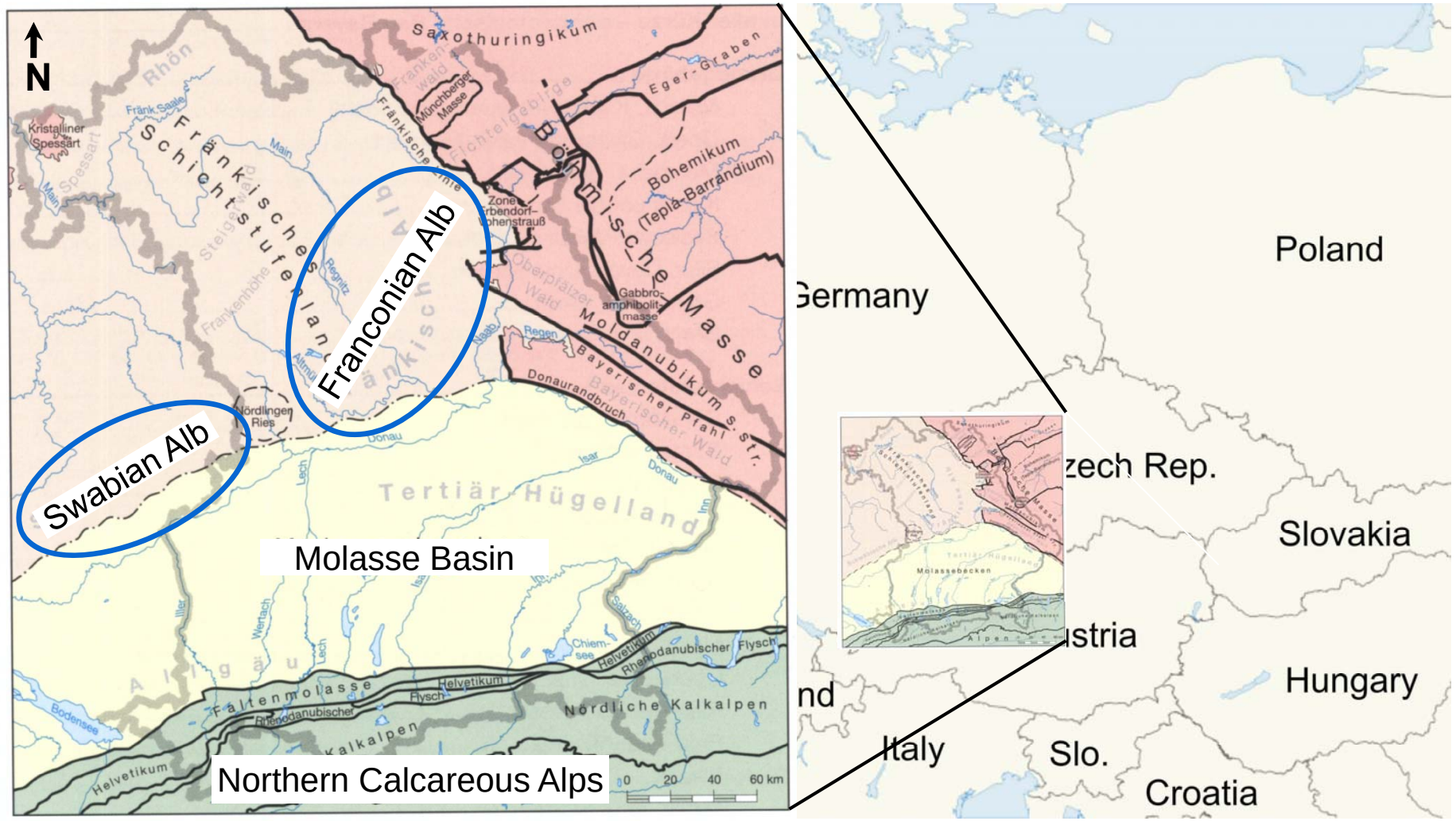
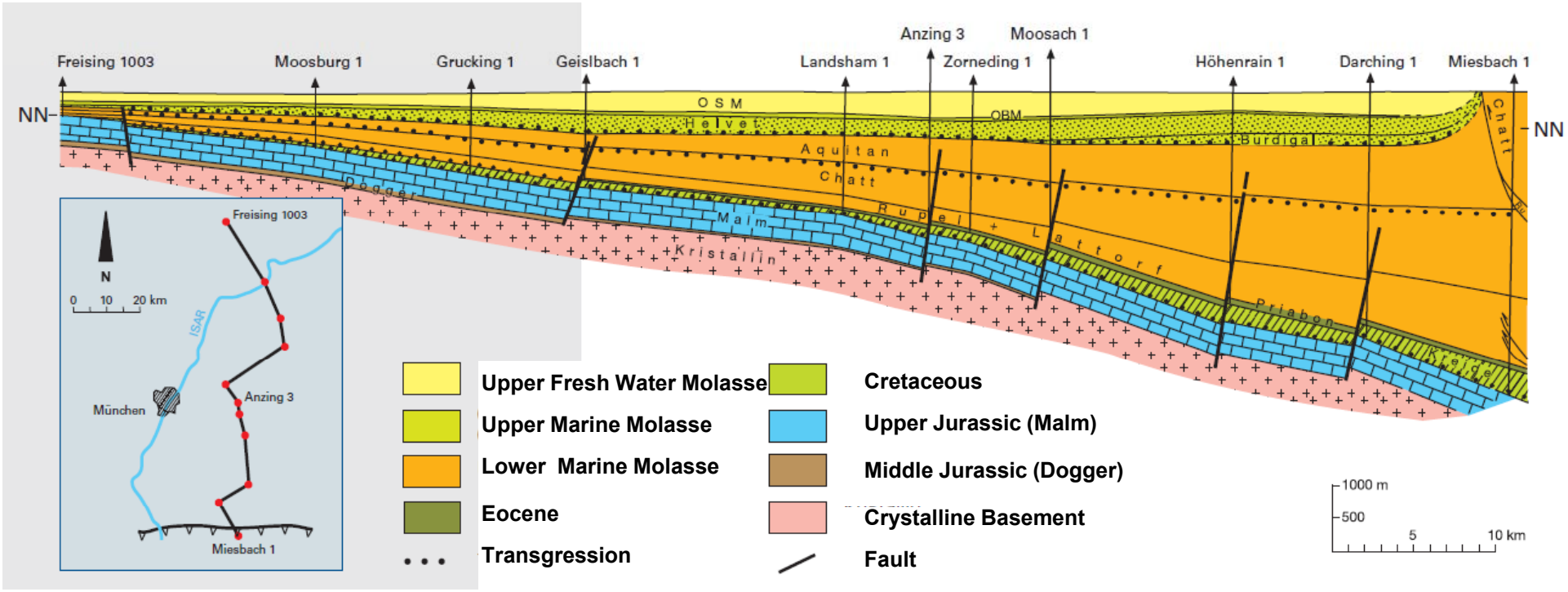
Study Area – SE Germany (Molasse Basin)



Cross Section – Molasse Basin



Bavarian Geothermal Atlas, 2010

Swabian and Franconian Alb - Outcrops

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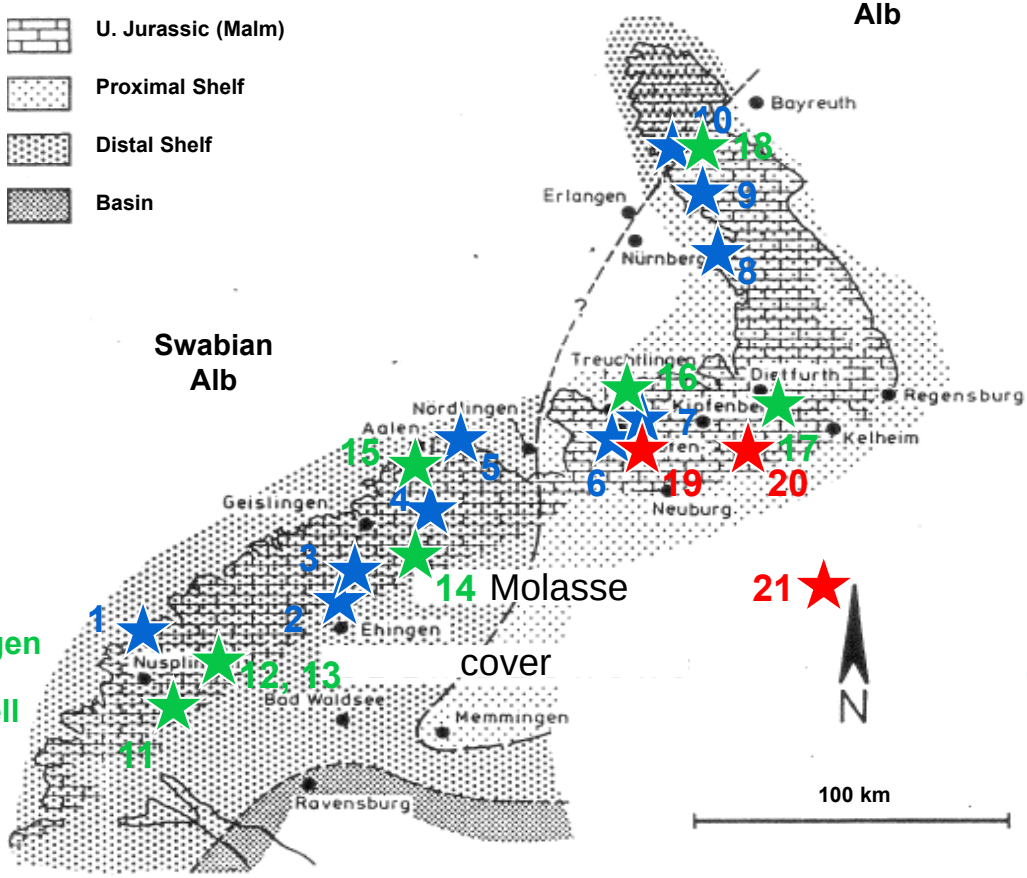
Boreholes:

- 19 ★ Solnhofen (110 m)
- 20 ★ Oberdolling (236 m)
- 21 ★ Moosburg SC4 (1585 m)

Field campaign 2011:

- 11 ★ Liptingen
- 12 ★ Straßberg
- 13 ★ Thiergarten
- 14 ★ Herrlingen
- 15 ★ Aalen-Wasseralfingen
- 16 ★ Eichstätt-Wasserzell
- 17 ★ Köttingwörth
- 18 ★ Simmeldorf



Selg & Wagenplast (1990)

Field campaign 2010:

1. ★ Plettenberg
2. ★ Vohenbronnen
3. ★ Gerhausen
4. ★ Mergelstetten
5. ★ Hülen
6. ★ Solnhofen
7. ★ Kinding
8. ★ Vilshofen
9. ★ Drügendorf
10. ★ Gräfenberg

Upper Jurassic: Malm α – ζ_5

Concept – Scales of Investigation

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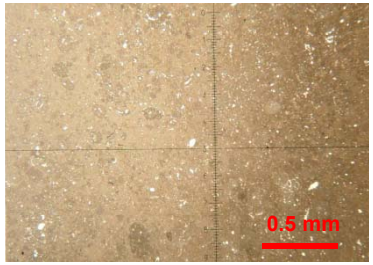
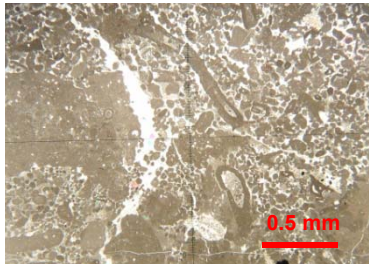
Outcrop

Core Samples

Thin Sections





Macro Scale → **Meso Scale** → **Micro Scale**

Outcrop Analogue Studies

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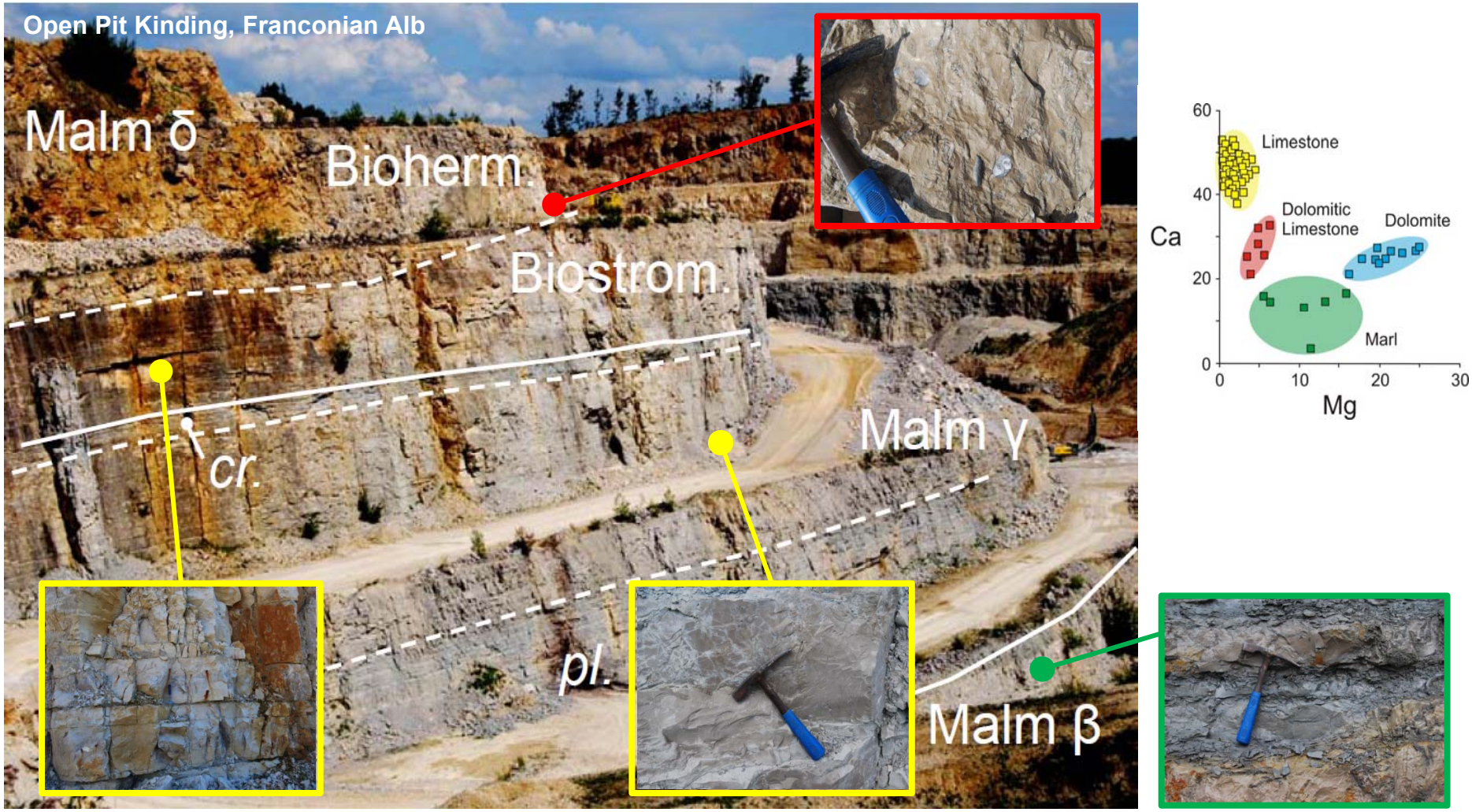

Facies-related Correlation

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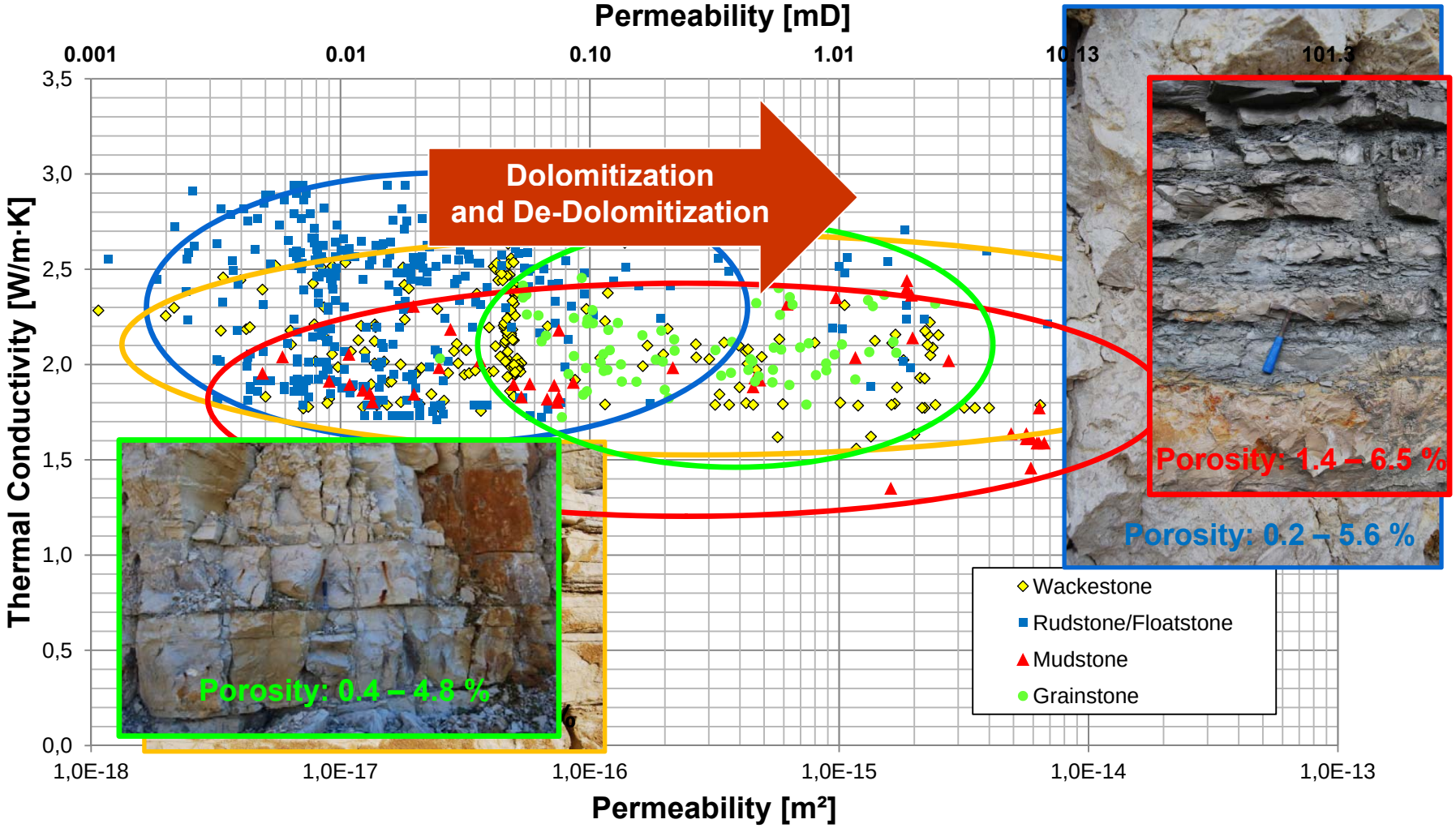
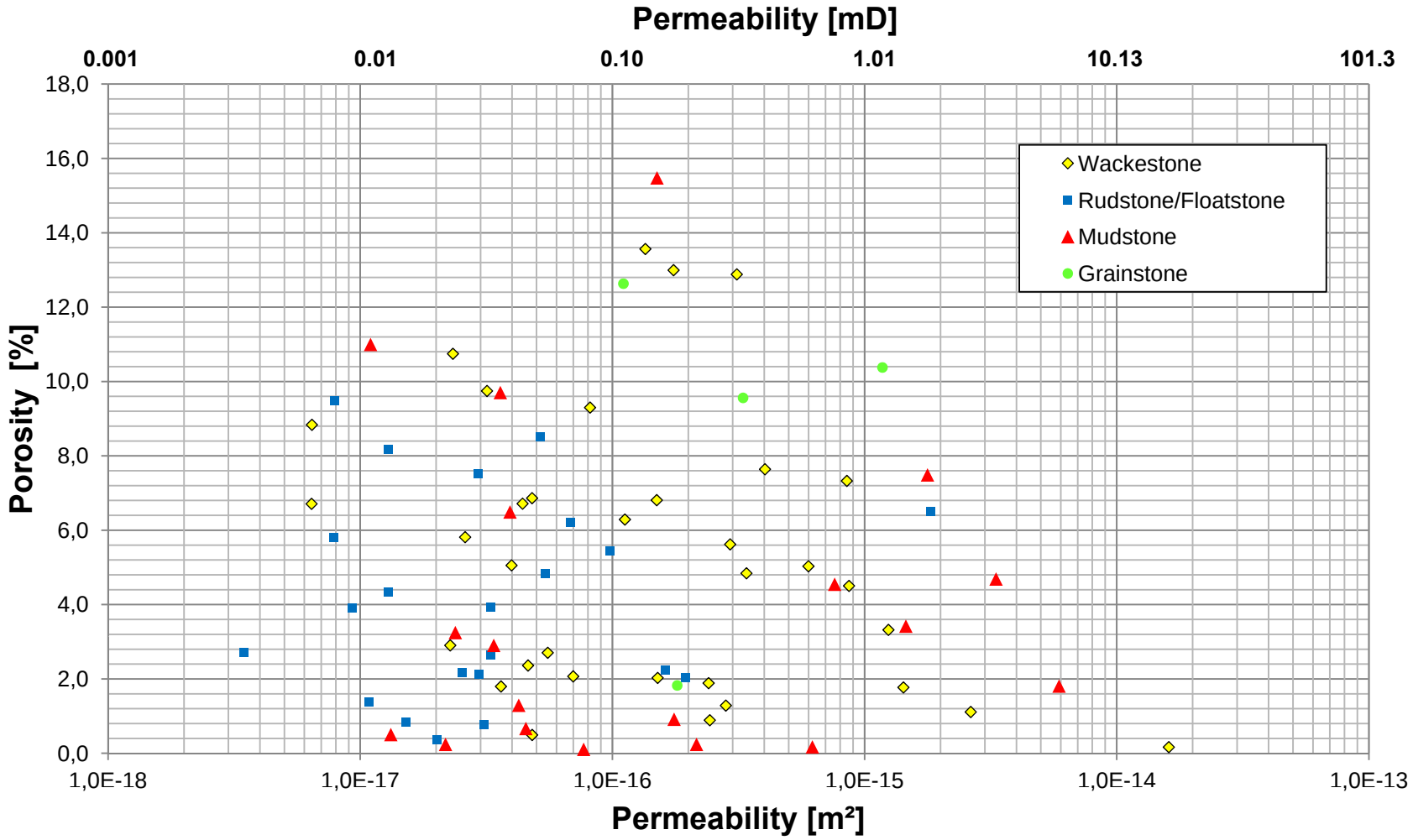


Porosity – Permeability Relation



Porosity – Permeability Relation

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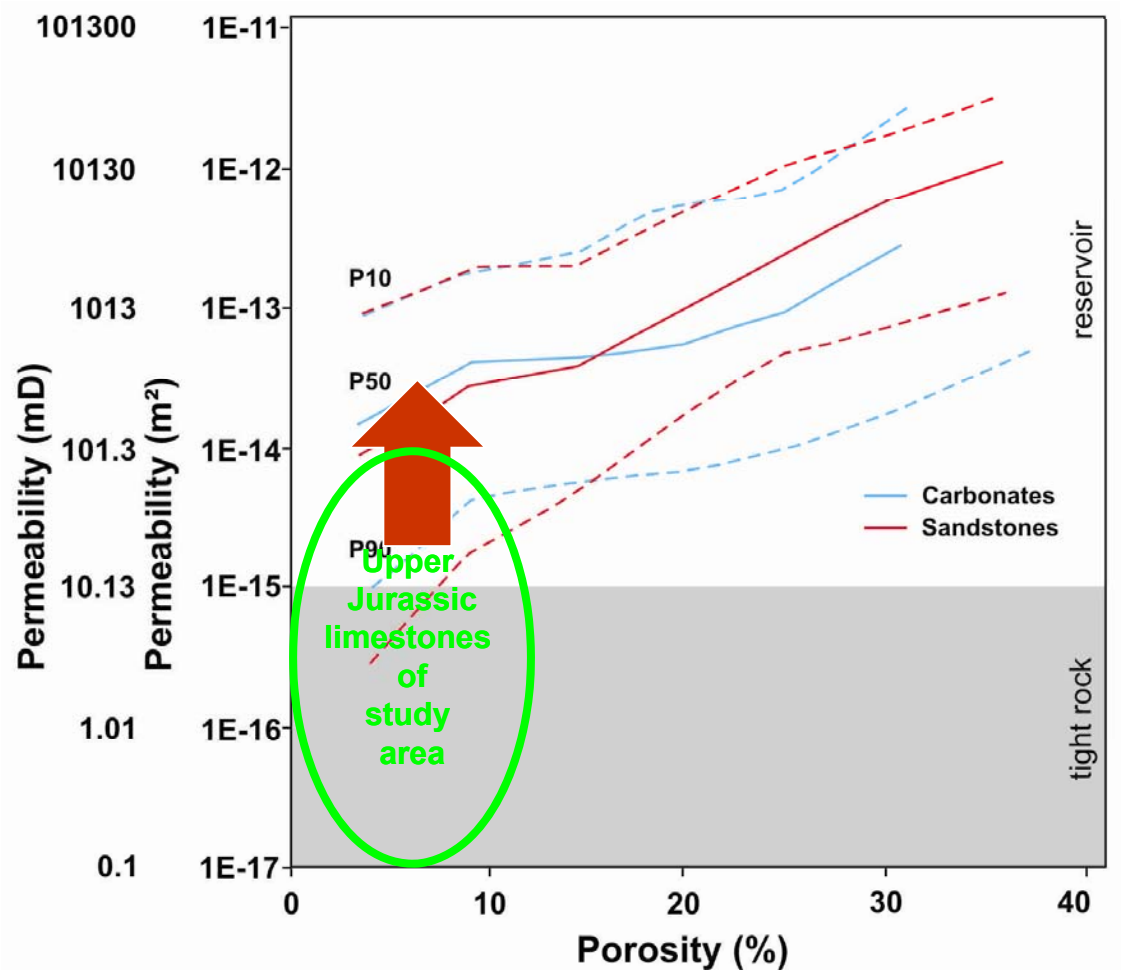
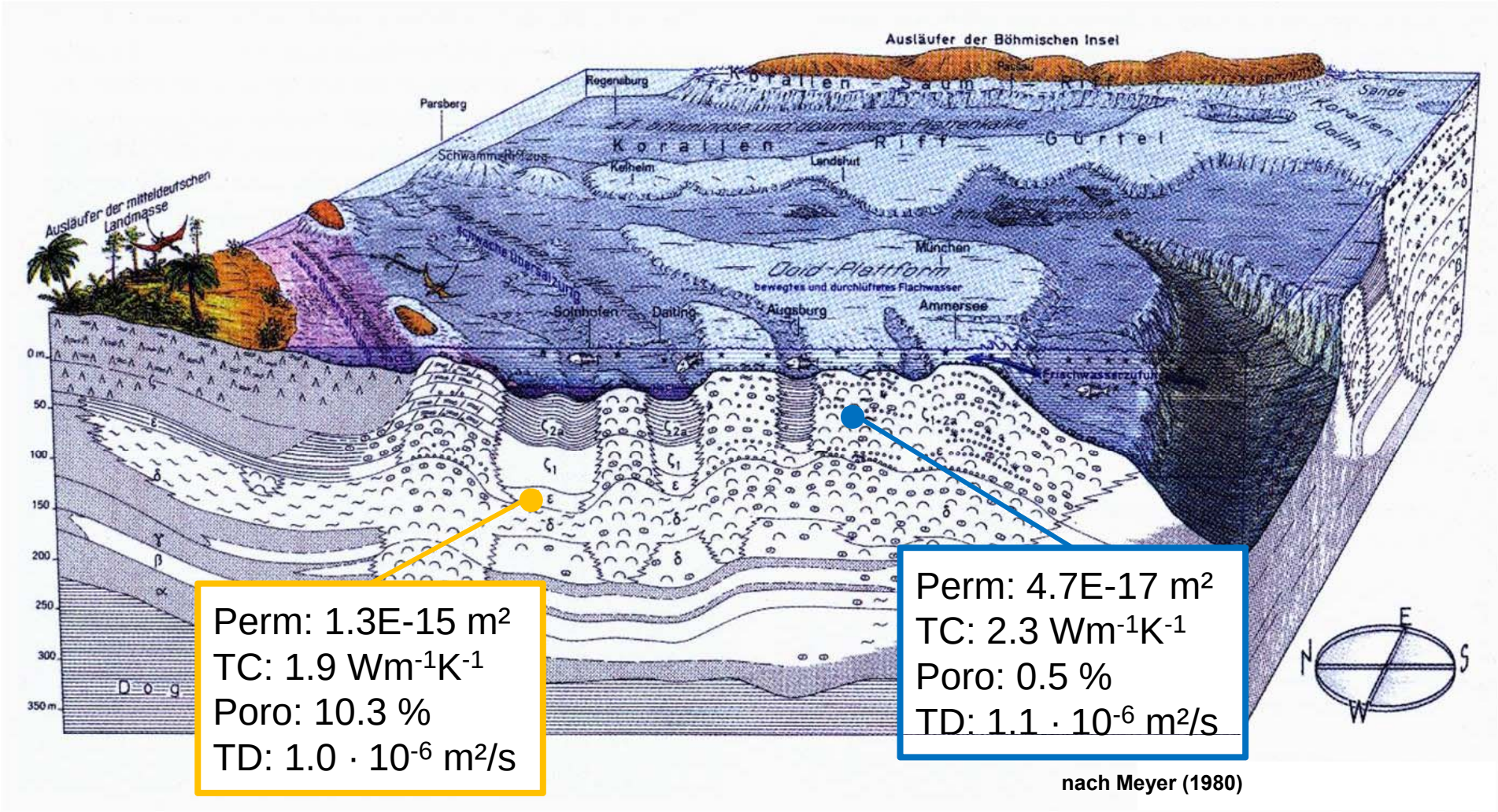


- **Lower permeability corresponding to lower porosity**
- **This is simply a fundamental characteristic of porous media (Nelson, 1994) and does not necessarily imply different pore geometry.**
- **Fractures are not considered, yet.**

Fractured/ karstified formations will increase reservoir permeabilty

Facies Model – Upper Jurassic (Malm)



nach Meyer (1980)

Depth-related Correction of Parameters

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The measured matrix parameters are obtained from dried cores under laboratory conditions (atm. pressure, 20°C temperature).

To simulate reservoir conditions temperature, pressure and water saturation occuring in the geothermal reservoir have to be considered.

Different transfer models for water saturated rocks under pressure and temperature conditions for relevant depth exist (e. g. Zoth & Hänel, 1988; Vosteen & Schellschmidt, 2003; Popov et al., 2003; Sass et al., 1971, Clauser, 2006) and can be validated by High Pressure/High Temperature Triaxial tests. Also CT-measurements are under way.

Vertical pressure: 500 MPa
Horizontal pressure: 60 MPa
Temperature: up to 170°C
Permeability range: 10^{-9} – 10^{-16}m²

Parameters under Reservoir Conditions

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Consideration of 5000 m depth, 150°C temperature, water saturated

Thermal Capacity [J/kgK]:

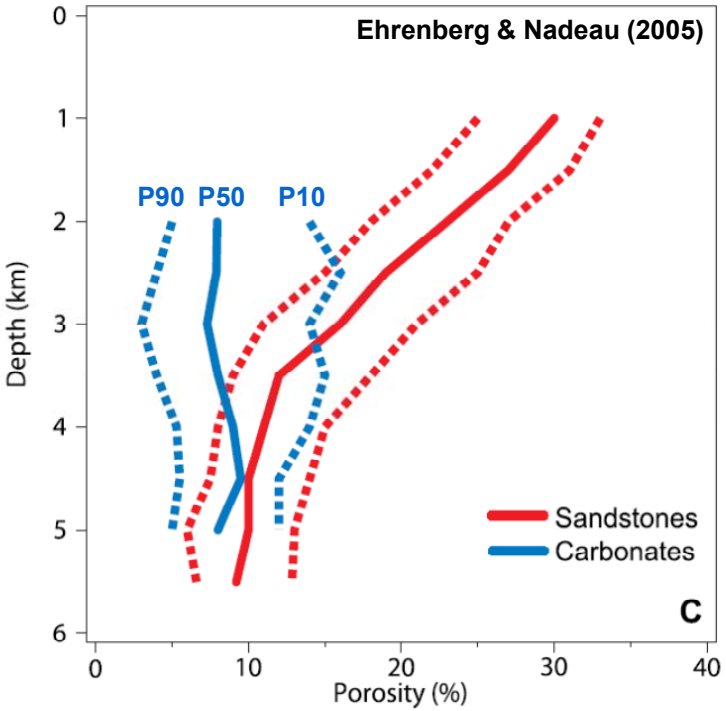
- Vosteen & Schellschmidt (2003)
  - 750 (20°C) ➔ 890 (150°C)

Thermal Conductivity [W/mK]:

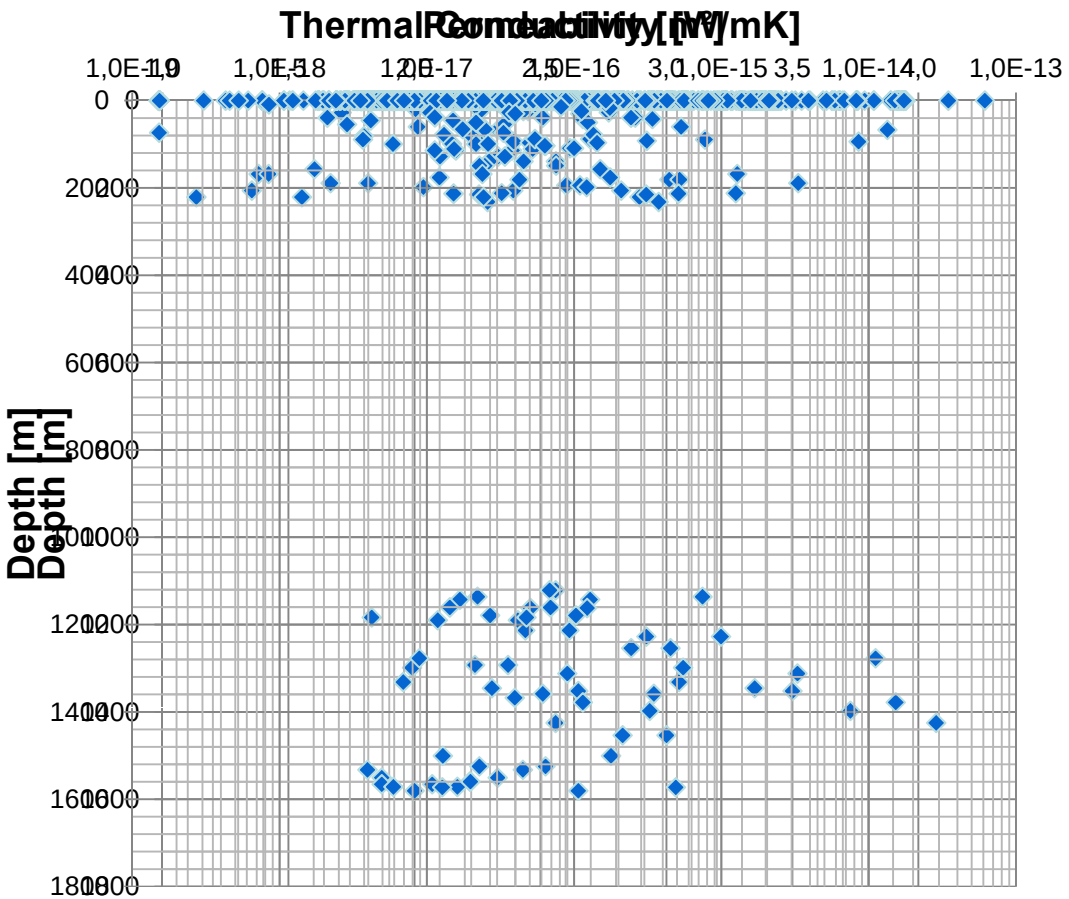
- Zoth & Hänel (1988)
  - 2.68 (20°C) ➔ 2.25 (150°C)
- Sass, Lachenbruch, Munroe, Green & Moses (1971)
  - 2.53 (0°C) ➔ 2.26 (150°C)
- Vosteen & Schellschmidt (2003)
  - 2.51 (0°C) ➔ 1.99 (150°C)

Porosity [%]:

➔Temperature is more important than depth for controlling average reservoir porosity (Schmoker, 1984; Bjørkum et al.,1998)



Depth Dependance of Reservoir Properties



Validation with Reservoir Data

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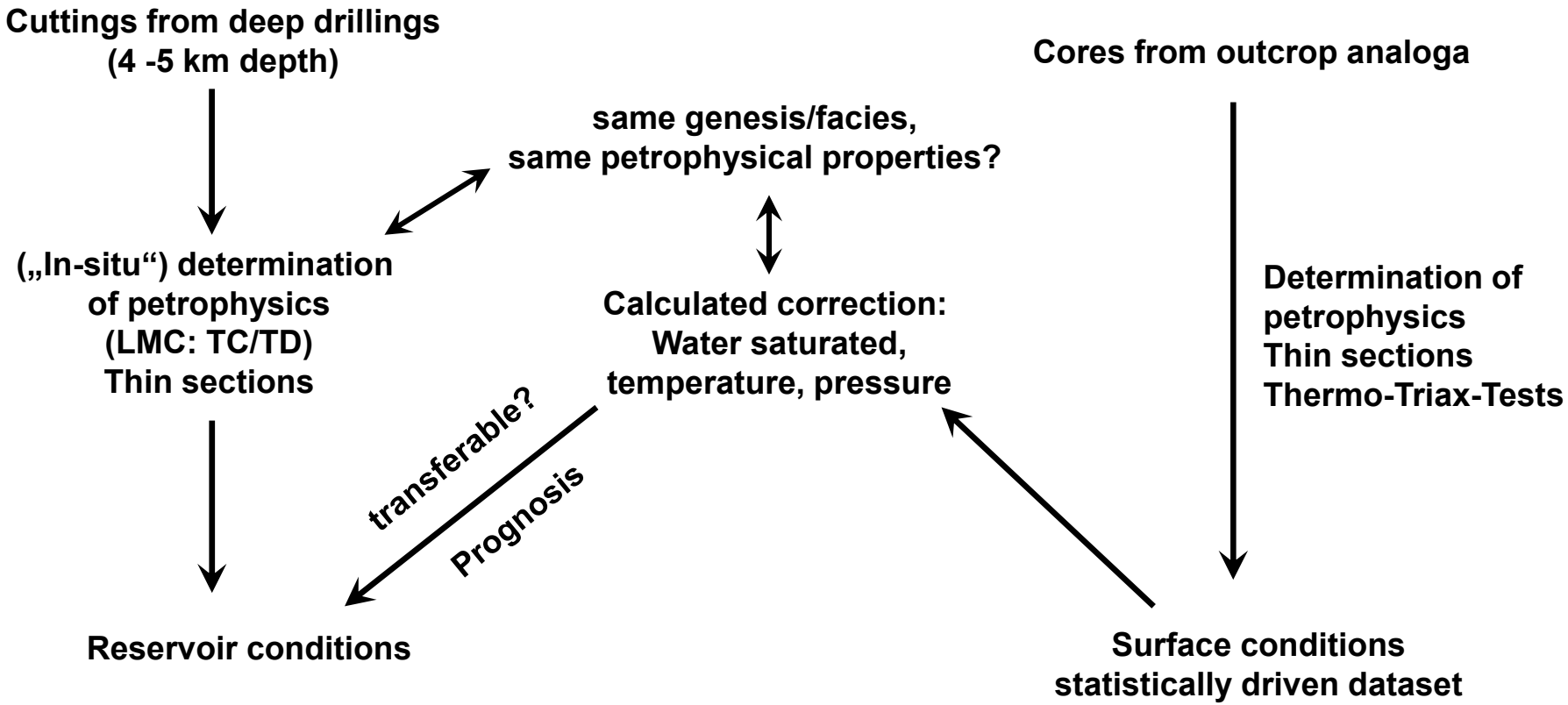

After drilling: pumping test analyses !

Conclusions

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Outcrop analogue studies provide a sufficient data base to determine thermo-physical reservoir characteristics of the matrix of geothermal reservoir formations and producing conservative results.

By adding information on secondary porosities, karstification, and stress field higher reservoir capacities can be inferred.
Facies concepts can be applied as exploration tool.

Based on the investigation of the matrix parameters the sustainable heat transport into the geothermal reservoir can be assessed and the long term capacities for different utilization scenarios can be calculated more precisely.
Investigations on the lateral extension and facies heterogeneity will give insight on the transmissibility of different target horizons.

To create reliable predictions and 3D reservoir models structural geology and pumping test data as well as validated transfer models have to be included in the assessment for numerical simulations of geothermal carbonate reservoirs.

The facies related characterization and prediction of reservoir formations is a powerful tool for the design, operation, extension and quality management of geothermal reservoirs.

THANK YOU VERY MUCH FOR YOUR ATTENTION

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