Outcrop analogue studies for reservoir characterization and prediction of deep geothermal systems in the Molasse Basin, Germany

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# **Motivation**



# Scientific

Reservoir characterization with determining thermo-physical parameters including permeability and thermal conductivity data which are rarely available measured at the same sample.

3D prognosis of reservoir properties by applying facies models to the deeper subsurface can be implemented as an exploration tool.

# Engineering

Geothermal reservior properties serve to distinguish between enhanced (petrothermal) and hydrothermal systems and can be used for optimized drilling design.

# Economic

Outcrop analogue studies offer effective opportunities to gain data to be transferred to greater depths and higher temperatures which lead to a better understanding of production capacities of geothermal reservoirs.

# Concept



**Thin Sections** 

# OutcropCore SamplesImage: Sample Sam



Macro Scale Meso Scale Micro Scale



# **Cross Section – Molasse Basin**







Bayerischer Geothermieatlas, 2010

# Facies Regions – Swabian & Franconian Alb





**Outcrop Analogue Studies - Concept** 







# Outcrop Analogue Study – Sampling 🕑









**Oriented Drill cores (whereever possible)** 

**Representative samples** 

Thermophysical parameter determination done with Thermal Conductivity Scanner and Mini-Gas-Permeameter

# Thermo-physical Matrix Parameters (Franconian Facies)







# Thermo-physical Matrix Parameters (Swabian Facies)







# **Karst Phenomena**







Thick bedded/platy limestone:

### Karstification along faults and major joints

Reefal/fossile-rich limestone: Primary and secondary porosity Karstification on a larger scale

# **Outcrop Study – Franconian Alb**



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Assessing: Joint/fault opening width, roughness of joint, joint surfaces, kind of fillings, joint texture, distribution of joints

*Lithology:* micritic limestone and marly limestone

Bedding: 84/04

Joint structure: heavily jointed

Main joint directions: 120° – 130°

Opening width: 1 mm – 1.5 cm

*Joint fillings:* partly filled with clay or calcite, some iron and manganese precipitation

### Kartstification: weak





Dip Direction 10° classes

Structural data combined with stress field data will give inside on the fracture system in the reservoir formation

In addition pump test data of the target formation will be analysed to evaluate the in-situ hydraulic performance Facies Model – Upper Jurassic (Malm)



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# **3D Structural Facies Model**





# Conclusions



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

Facies concepts are applied as exploration tool producing conservative results, because secondary porosities, karstification, stress field will lead to higher reservoir capacities.

To create realistic predictions and 3D reservoir models structural geology and pump test data of the according formations have to be included in the reservoir assessment.

The key feature for reliable reservoir prognosis, reservoir stimulation, and efficient reservoir utilization is to combine facies, thermo-physical, and structural geology data into integrated 3D reservoir models.



# **THANK YOU VERY MUCH FOR YOUR ATTENTION**



Wackerstein, Franconian Alb

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