The Upper Jurassic In Southern Germany – A Carbonate Aquifer For Geothermal Exploration

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   2. Primary facies – Diagenesis
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ERDWERK at a glance …

- Founded in 2002 by Dr. Achim Schubert
- Leading consultant for design and project management of geothermal projects in South Germany
- Currently active in Germany, Belgium, Switzerland, UK, Costa-Rica and Tanzania.
- Over 110,000 m planned and drilled
Southern German Molasse Basin

Source: ©BGR

Source: udo-leuschner.de
Geology of the Molasse Basin

N-S Schematic Cross Section

Adapted from ‘Geologische Karte von Bayern 1:500000’, Bayerisches Geologisches Landesamt, 1996
Paleogeographic situation

MEYER & SCHMIDT-KALER 1996
Geothermal Development in Bavaria

Deep geothermal wells (excluding balneology):
- Green circle: Active well sites, realised by ERDWERK (10/15)
- Red circle: Wells realised by ERDWERK
- Yellow square: Other realised wells

Max. pumping rate [l/s] and wellhead temperature [°C]
"-": no information; source: http://www.geotis.de; 04/14

- Blue circle: Planned well sites (approximate location)

Molasses Basin

[Map of Bavaria showing geothermal well sites with temperatures and pumping rates]
The Malm has the characteristics of many different aquifer types
History of Exploration Strategy

Faults vs. Facies
Key Factors for Productive Geothermal Wells

- Structural Geology – Faults/Fractures
- Primary Facies & Diagenesis – Matrix Porosity
- Karstifikation - Corrosion
Key Factors for Productive Geothermal Wells

Structural Geology – Normal Faulting
Key Factors for Productive Geothermal Wells

Primary Facies - Diagenesis

- High water-energy carbonates favour dolomitization
- Controlled by the degree of purity of the carbonates
- Size and shape of the dolomite crystals are controlled by the amount of insolvable residues inside the primary carbonate
- Size and shape of the dolomite crystals are controlling the porosity and permeability of the matrix

Koch 1997
Combination of Facies and Hydrostratigraphical Model
Analogous Studies Malm Relief
Facies Interpretation Using Imagelogs

**Bedded Facies**
- **Type A** - thin bedded facies
- **Type B** - thick bedded facies

**Massive Facies**
- **Type C** – massive facies - limestone
- **Type D** massive facies – bioherm
- **Type E** – massive facies - dolomite

Essentially for the facies model
Facies Interpretation Using Imagelogs

Facies Model of the Malm in the Molasse Subsurface (after Mayer 1994)
Facies Interpretation Using Imagelogs

Imagelog classification

- Bedded Facies
  - Mud/Wakestone
  - Pack/Grainstone
  - Dolomite
Locally dolomitization of Bioherm Facies

Coral in a well-core of the Upper Jurassic Malmian

Sponge Bioclasts

Coral Bioclasts

Dolomitization Processes in Massive Facies

Facies Interpretation in Seismic Data
Facies Interpretation in Seismic Data

Light blue: Top Massfacies
Facies Interpretation in Seismic Data

Facies Interpretation supported by seismic attributes

Attribut Isofrequency 15 Hz, spectral decomposition
Example of a Relief Map of the Top Massive Facies
Karstification

Large-scale Karstification

Sinkholes – Collapse structures
Conclusion

The productivity of geothermal wells in the carbonate reservoir of the Malm not a question about a structural OR facies orientated exploration strategy, but is controlled by a complex interplay of different geological factors like primary facies, diagenesis, structural geology and especially karstification.

To further reduce the exploration risk, a deeper insight of the seismic data is nessecery. Profound knowledge of geology and hydrogeology of the Malm from drilled wells is the basic rerequisite for this.
Thank you!
Karstification