Investigation of the geological, technical and economical obstacles for large-scale utilization of geothermal energy from Danish sandstone reservoirs

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On behalf of participants of the GEOTHERM project

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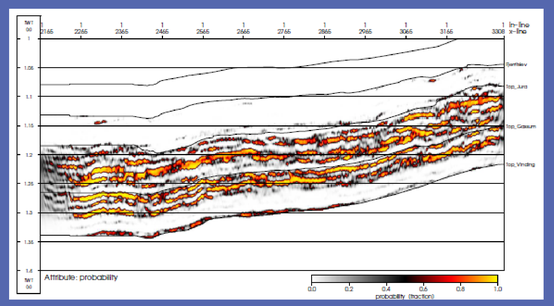
The Triassic–Jurassic sandstone reservoirs in the Danish subsurface at ca. 1–3 km depth contain an enormous geothermal resource that has so far been utilized in only three geothermal plants due to a number of geological, technical and commercial barriers. These barriers have been addressed in the GEOTHERM project (Geothermal energy from sedimentary reservoirs - Removing obstacles for large scale utilization) and recommendations for overcoming the obstacles have been made.

Quantitative seismic interpretation

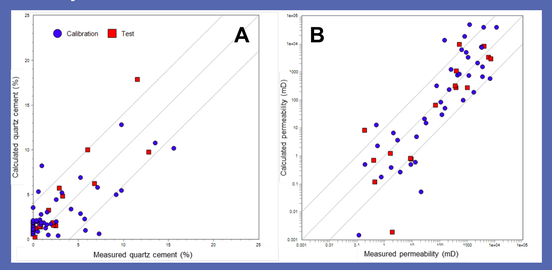
Quantitative seismic interpretation proved capable of giving a reliable reservoir characterization with regards to estimation of porosity and sand/clay distribution.



Probability of sandstone reservoir presence based on seismic reservoir characterization.

Diagenesis modelling

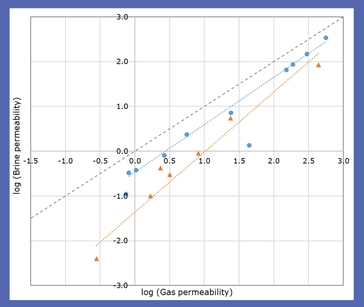
Diagenesis modelling gave good estimates of reservoir quality by utilizing the knowledge obtained about depositional environments, petrography, reservoir properties and burial history.



Comparison between measured and modelled values for calibration and test samples of A) quartz cement volume and B) reservoir permeability.

Fluid versus gas permeability

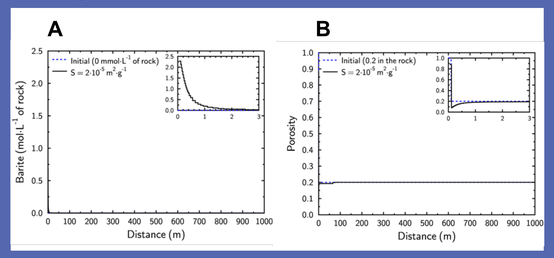
Relationships between fluid and gas permeability have been established such that the regularly measured gas permeability can be recalculated to fluid permeability giving a better representation of the reservoir.



Correlation between measured brine permeability (in mD) and gas permeability (in mD) for samples from two Danish geothermal reservoirs. The dashed line shows the 1:1 ratio.

Formation water chemistry

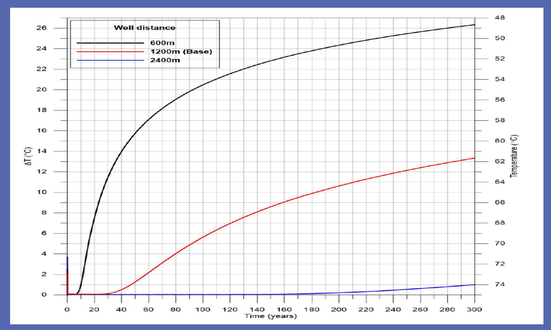
The composition of the formation water in the three Danish geothermal plants has been measured and used for geochemical modelling to evaluate the risk of scaling, where especially barite showed a tendency to precipitate upon cooling of the brine.



Amounts of A) barite and B) porosity calculated after 10.6 years of production for one of the Danish geothermal plants.

Thermal development

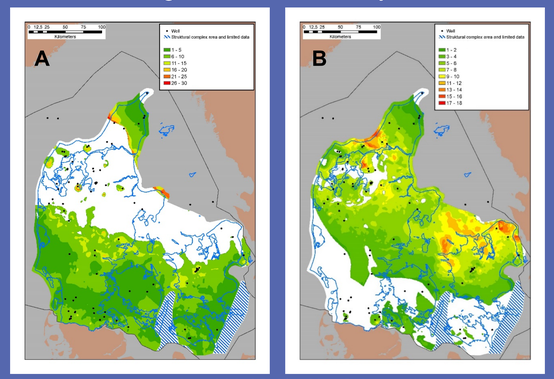
Simulations of the thermal development of the reservoirs during long-term geothermal exploitation demonstrate significant heat extraction from the layers present above and below each reservoir, which ensures that only a small decrease in production temperature occurs over several decades.



Modelled effect on temperature of the reservoir distance between injection and production wells.

Resource estimation

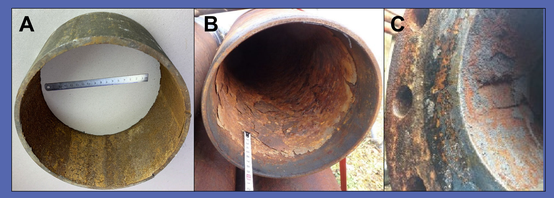
The regional geothermal resource estimation has been updated based on a new comprehensive 3D temperature model of four reservoirs in the subsurface, confirming the presence of a huge geothermal resource with wide geographical extent covering most of the country.



Resource estimation H1 (GJ/m2) of the utilizable fraction of energy for A) Bunter/Skagerrak reservoir and B) Gassum reservoir. See: http://dybgeotermi.geus.dk

Corrosion and scaling

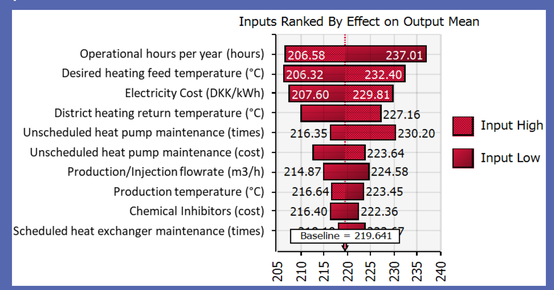
The causes of injection problems have been investigated including corrosion and scaling processes, showing that careful choice of well-lining, tubing materials and surface finish besides cautious operation of plants are of utmost importance to prevent operational problems.



A) Thisted plant: Pipe section showing only superficial corrosion after 30 years of service. B) Sønderborg plant: Mill scale in new tubing. C) Margretheholm plant: Lead deposits inside piping at production well.

Business case

A geothermal business case has been developed to give a lifetime assessment of geothermal plants including feasibility, design, drilling, construction, production and abandonment, showing that the operational costs are closely linked to the existing infrastructure and to the choices made when designing the geothermal plant.



Tornado plot of an OPEX scenario (DKK/MWh).

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