Assessment of Probability of Success for Hydrogeothermal Wells

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To our state of information, this is worldwide the first hydrogeothermal borehole which is insured by an assurance company.

Objectives

Hydrogeothermal energy in the low-enthalpy range up to 150 °C can be used for heat purposes, but also for electric power generation, and heat and power cogeneration (HPC). A study by the Office for Technology Impact Assessment of the German Parliament estimated the geothermal power generation potential in Germany as 10^{21} J. Only around 1 % of this potential involves **hot water aquifers**. Despite this low percentage, geothermal power plants in the short to medium term in Germany will primarily involve the use of hot water from aquifers. Some central barriers, especially the high investment risk, hinder the industrial integration of geothermal energy use into energy supplies. Although the data base is often insufficient because of nonexistent comparing objects, a good quantitative assessment of the geological risks is required. A concept of the assessment of **probability of success (POS)** will be discussed based on a case history for a **geothermal plant located south of Munich** (Bavaria, Germany; Fig. 3).

Definition

Exploration risk is the risk of not successfully achieving (economically acceptable) minimum levels of thermal water production (minimum flow rates) and reservoir temperatures.

Essential Parameters

$P = \rho_F \, c_F \, Q \, (T_i - T_o)$

with

P	capacity	[W]
ρ_F	density	[kg m^{-3}]
c_F	specific heat capacity	[J kg^{-1} K^{-1}]
Q	flow rate	[m^3 s^{-1}]
T_i, T_o	(Input-, Output-) temperature	[°C]

The depth of the aquifer has to be determined as exactly as possible by seismic measurements. The project manager has to declare, at which **flow rate** Q_2 (Q_1) for a given max. drawdown of the water level and at which **temperature** T_2 (T_1) the geothermal well will be (partly) successful. Then the probability of success (POS) can be calculated (Fig. 1).

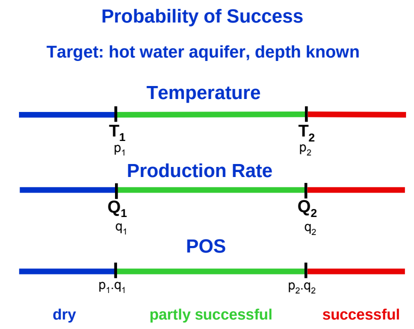

Fig. 1: The probability of success (POS) can be defined in the simplest way by determining the probability of each risk separately and multiplying the single probabilities.

Hydraulic Parameters - Regional Analysis

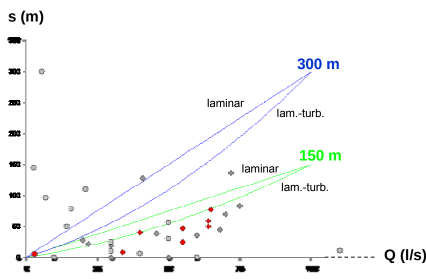

Fig. 2: Production rates Q with drawdown s for wells in the Upper Jura (locations: Fig. 3). Theoretical curves for a production rate of 100 l/s with a max. drawdown of 300 m (blue) and 150 m (green); straight line: laminar flow; parabola: laminar-turbulent flow. All wells below the curves are successful for assessing the POS.

Fig. 2 shows that the productivity of geothermal wells (rectangles) is higher than that of wells drilled for water demand and balneology (circles). The reason is that geothermal wells which were dry were **stimulated** for instance with acid treatment. This fact should be taken into account in the assessment of POS. Therefore the success values a_i should be weighted by factors (u_i, w_i):

$$POS = (\Sigma\, u_i\, w_i\, a_i) / (\Sigma\, u_i\, w_i)$$

Wells drilled for geothermal utilization are doubled weighted ($u_i = 2$). Additionally, the spatial distance (this means also geological similarity) to the planned well can be considered. The success values of the wells drilled in the Central Molasse Basin (red points) are also doubled ($w_i = 2$). The POS for a production rate of 100 l/s (drawdown 300 m) is $q_2 = 0.85$ (s. Fig. 5).

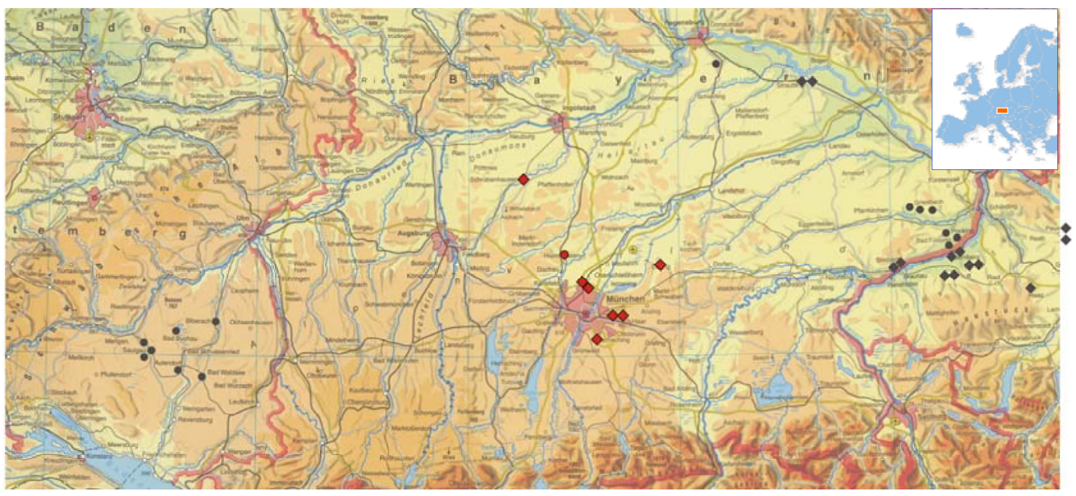

Fig. 3: Borehole locations in the South German / Upper Austrian Molasse Basin with hydraulic parameters of the Upper Jura (Malm)

Temperature Prognosis - Local Analysis

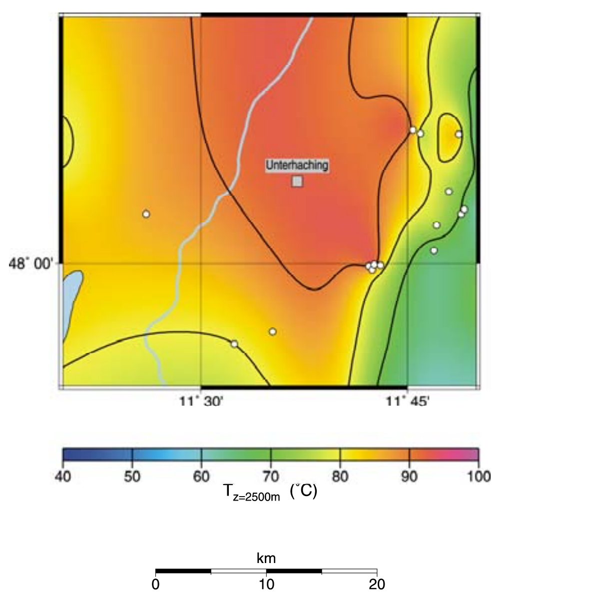

Fig. 4: Temperature isolines at 2500 m depth in the study area; the planned borehole site is located in the centre of the map. The white dots mark boreholes with temperature data.

An aquifer depth of 3000 m (result of reflection seismics) is used for a conservative temperature forecast. Data availability decreases sharply below 2500 m. This depth was therefore selected for the temperature isolines (Fig. 4). The available figures were extra- or interpolated to a depth of 3000 m for the temperature prognosis of the planned borehole. All of the figures lie between **95-115 °C**. These temperatures are the base for calculating the POS. As we have only 7 temperature data points to our disposal, the statistical weight of each data point is 14 %! The POS for 100 °C is diminished to 86 % by the data point in the West (Fig. 4). A probable figure of 107 °C (median value) would be interpreted for the temperature isoline map at 3000 m depth in the study site. Temperatures of 120 °C are also possible; temperatures above 130 °C can be excluded.

Result

Information about the hydraulic parameters of the aquifer can mostly be determined in a regional scale only. Information from boreholes nearby or other boreholes having similar conditions can be weighted in a suitable manner. For the temperature prognosis, local conditions must be considered. The simplest way to calculate the POS of a project is to multiply the single POS of flow rate and temperature. The POS was calculated in this manner for a geothermal well drilled in 2004 in the south of Munich (Bavaria). This POS was the base for a private insurance contract (Munich Re Group). The well is successful.

Probability of Success

In the case investigated here, the condition of the temperature of 95 °C (100 °C) can be fulfilled with a high probability $p_1 = 1.0$ (0.86). The probability of a production rate of 50 l/s (100 l/s) at a drawdown of 300 m is assessed with $p_2 = 0.95$ (0.85). Stimulation measures to reduce the geological risk such as optimum seismic information, acid treatment or deviation of drilling are presumed.

Drilling the well **Unterhaching Gt1** stopped in September 2004 at 3446 m depth (TVD 3350 m) (Top Malm 3007 m). **The borehole is successful**, as the first hydraulic test after an acid treatment shows: The production rate is 65 l/s with a drawdown of ca. 70 m and can be easily increased; the water temperature is higher than 122 °C; the main water inflow lies deeper than 3200 m.

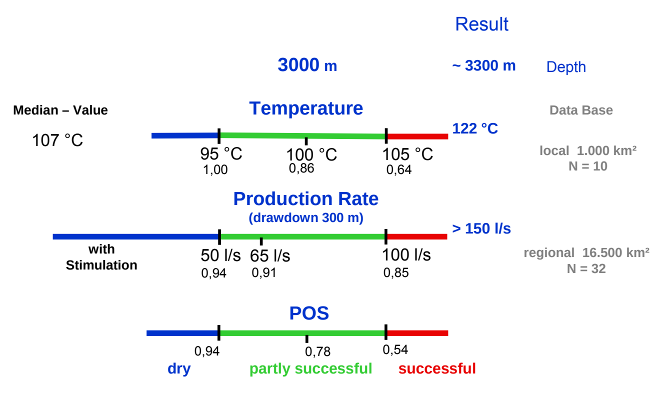

Fig. 5: Probability of Success for the study case and result of drilling