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Geothermal Doublets Munich Riem and Pullach i. Isartal in Comparison: Geological and Drilling Concepts for Minimizing the Geological Risk in the Deep Malm Aquifer.

Drilling of Geothermal Doublets in the Munich Region from 2003 to 2005

In 2003, the geothermal doublet Munich Riem for the Munich public utility company (Stadtwerke Muenchen GmbH) was successfully completed at the eastern edge of the Munich-Riem fairgrounds. This was followed in the winter/spring 2004 by the successfully drilled well Unterhaching GT1 for the municipality Unterhaching. Finally, after the municipality Pullach i. Isartal decided in the summer of 2004 to go forward with the Pullach geothermal project, the geothermal doublet in Pullach was successfully drilled in the summer of 2005 (Fig. 1).

Concept Design of the Geothermal Doublets Riem and Pullach i. Isartal

During the concept design and execution planning, the geothermal projects for the trade fair town Riem and the town of Pullach i. Isartal underwent comparable project phases that included feasibility studies, reprocessing of existing seismic 2-D data of the hydrocarbon industry, and a concluding risk analysis, in which the results of the feasibility study were examined after the detailed analysis of the seismic data.

After an EU-wide prequalification and invitation to tender, as well as intense bidder negotiations, a day-rate drilling contract was entered into in each case on the basis of the geological and drilling concept design, with the drilling company assuming the role of general contractor. Major criteria for the decision included – in addition to the economic efficiency – the drilling company's many years of experience with deep drilling operations in the Northern Alpine Molasse zone, as well as the selection and quality of the subcontractors and service companies. Both clients (Stadtwerke Muenchen GmbH and Innovative Energie für Pullach GmbH) were willing to accept the full responsibility for any risks with respect to geological and drilling problems, which is customary in the deep drilling industry. Neither project was insured against drilling or discovery risks.

The minimum requirements for the existing district heating network of the trade fair town Riem and for the planned district heating network in Pullach, which were determined by means of economic viability studies, amounted to a thermal output of approximately 6 MW in each case, with the goal that the base load should be covered by geothermally produced thermal energy. Generating electric power by geothermal means was not an option in either project, because of the anticipated temperatures (limiting for Riem) and delivery rates (limiting for Pullach). This permitted the wells to be designed with a final drilling diameter of 6 1/8" (156 mm) to cover the requirements.

For logistical and site related reasons, the doublets were designed with deviated wells to be drilled from a combined drilling site, which, however, would require consistent directional drilling.

Time Schedule

The time schedule for the projects had to be designed as tight as possible due to the relatively high investment costs for the wells and contractually agreed upon day-rate drilling. This schedule is shown for both projects in the tables below.

Table 1: Time Schedule, Geothermal Project Munich Riem

March 18, 2003	Award of the drilling work to a general contractor (RAG AG)
June 18, 2003	**Start of drilling operations for Riem Thermal 1**
July 28, 2003	**Completion of drilling and testing operations, final depth 3,275 m (MD)**
August 20, 2003	**Start of drilling operations for Riem Thermal 2**
October 13, 2003	**Final depth reached at 3,225 m (MD)**
November 5, 2003	**Completion of all testing operations and pull-out of the drilling rig**

Table 2: Time Schedule, Geothermal Project Pullach i. Isartal

September 6, 2004	**Start of drilling site development (firm Bernegger Ges.mbH)**
September 10, 2004	Award of the drilling work to a general contractor (ITAG Tiefbohr GmbH & Co. KG)
End of 2004	Start of the long-distance heating network planning
December 5, 2004	**Start of drilling operations for Pullach Thermal 1**
February 16, 2005	**Completion of drilling and testing operations for Pullach Thermal 1, final depth 3,300 m (MD)**
February 21, 2005	**Start of drilling operations for Pullach Thermal 2**
May 14, 2005	**Completion of the well Pullach Thermal 2, final depth 4,120 m (MD)**
June 2, 2005	**Deepening of the well Pullach Thermal 1 to 3,550 m (MD)**
June 23, 2005	**Drilling of sidetrack Pullach Th 1a starting at 2,814 m (MD)**
July 6, 2005	**Completion of sidetrack Pullach Th 1a, final depth 3,930 m (MD)**

A total of 9,166 meters were drilled in the Pullach well project during the period December 2004 to July 2005, including the sidetrack. In the geothermal project Riem, a total of 6,500 meters were drilled during the period July 2003 to October 2003.

Development of the Deep Malm Aquifer in both Geothermal Projects

Contrary to the original expectations, no significant mud losses were encountered in the well Riem Th 1 in the top regions of the Malm, which would have pointed to a more strongly developed karstification of the stratigraphic succession. Minor mud losses of approximately 1 cbm/h occurred only in the deep Malm zeta (at 3,100 m MD). At the base of the Malm zeta, the losses then increased to 8 cbm/h, but noticeably decreased again during the last 100 m until final depth was reached at 3,275 m. Based on the petrographic characterization of the drill cuttings, the mud losses can be correlated to dolomitized limestones and dolomites within the deeper Malm layers in the Malm zeta and Malm epsilon.

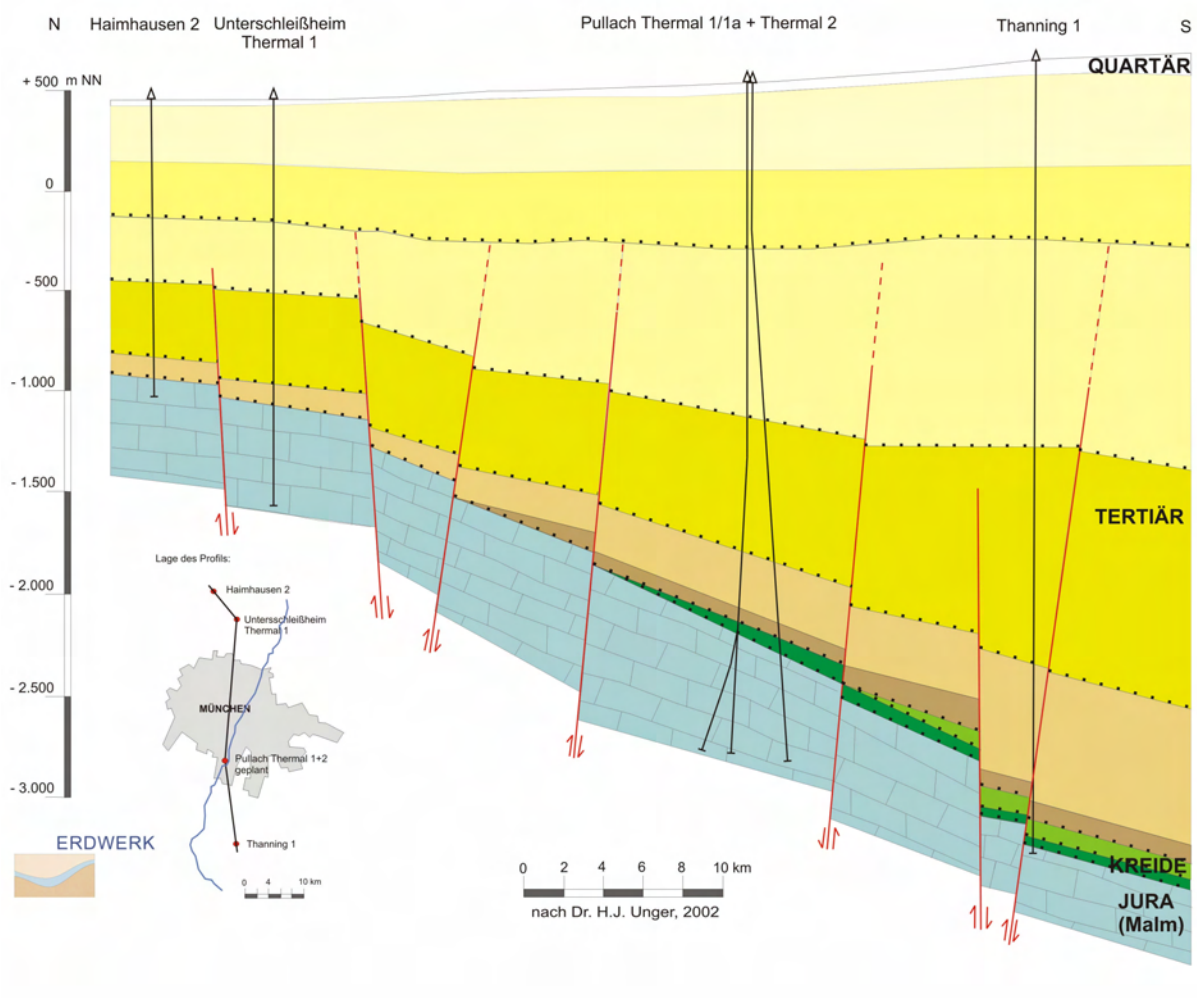

Fig. 1: Geological N-S section through Munich

Based on the reprocessed seismic 2-D data at the location Riem, is was possible to determine a clear development target for the well Riem Th 2 in the region of a fracture zone in the area surrounding the so-called Markt Schwabener Verwurf. In the immediate vicinity of the fault zone, which was shown on the seismic map, total mud losses occurred, which amounted to a loss volume of 800 cbm over the course of a few hours, under conditions that were still manageable from a drilling perspective. By using a very low-concentration polymer water-based drilling mud, it was possible to temporarily stop the losses, allowing the well to be deepened by 255 m to 3,225 m (MD).

For the area of Pullach i. Isartal, the analysis of the seismic documentation within the framework of the geological planning work did not point to any obvious development targets in the form of fault zones in the Malm carbonates for the production well or for the reinjection well. The development concept for the geothermal doublet Pullach therefore initially had to essentially rely on the experience gained from the well Riem Th1.

Due to the hydrogeological conditions that no hydraulically active fault zones and flat karstification in the top region of the deep Malm aquifer could be expected at the location Pullach, planning for the drilling work focused on the goal of developing the greatest possible Malm distances by means of directional drilling. This aspect, as well as the string torques that occur above ground, were the basis for the use of underground motors with directional drilling equipment for the distances drilled in the Malm.

The project was initially based on respective development depths in the Malm of 340 m and 360 m by side-tracking for the wells Pullach Th 1 and Th 2. The following table is a comparison of the data for the actual drilled Malm distances in the wells Riem Th 1 & Th 2 and Pullach Th 1/1a & Th 2.

Table 3: Comparison of the developed Malm thicknesses

Well	Malm Distance Depth [m]		Drilling Distance Malm (Net Thickness)	Well Gradient
	From MD (TVD)	to MD (TVD)		
Riem Th 1	2,787 (2,672)	3,275 (3,019)	488 (347)	max. 44°
Riem Th 2	2,922 (2,509)	3,225 (2,747)	303 (238)	max. 39°
Pullach Th 1 including deepening	2,899 (2,819)	3,550 (3,389)	651 (570)	max. 31°
Pullach Th 1a	2,902 (2,810)	3,930 (3,370)	1,028 (560)	max. 72°
Pullach Th 2	3,508 (2,958)	4,120 (3,443)	612 (485)	max. 40°

Since initial injection tests into the well Pullach Th 1 after successful completion of the well Pullach Th 2 revealed insufficient injectivity of well 1, a deepening of the well was initially pursued into the deeper Malm. Since deepening the well Pullach Th 1 also did not result in the desired injectivity, the well was deviated by means of a sidetrack starting at a depth of 2,814 m (MD) (see Fig. 2). A drilling distance of 1,116 m in NNE direction was drilled with a gradient build-up to 72°. The motor equipment that was utilized was able to produce daily distances of over 180 m in the sidetrack under gradual mud losses with the use of PDC bits in the Malm carbonates.

The mud losses in the wells Pullach Th 1/1a and Pullach Th 2, like in the well Riem Th 1, were essentially concentrated on regions in the deeper Malm. In the case of the well Pullach Th 2, for example, the loss zones were reached only at 3,980 m (MD). In the case of the well Pullach Th 1a, significant mud losses occurred starting at a depth of 3,600 m (MD).

This experience clearly shows that, in the case of lacking fault inventory and karstification phenomena in the deep Malm aquifer, it is necessary to implement the greatest possible drilling distances in the Malm by means of directional drilling in order to be able to come into production.

Moreover, a significant aspect is the fact that when greater drilling depths were reached in the region of the deep Malm aquifer, significantly higher temperatures were developed as well, which, in the case of Pullach, very significantly improved the economic efficiency of the project and increased the efficiency of the geothermal plant, despite a lower specific productivity of the wells.

Factors that Contributed to the Drilling Success

- The consistent use of directional drilling in the deep Malm aquifer substantially contributed to the successful discovery in the projects Riem and Pullach. By using a very low-concentration polymer water-based drilling mud in the deep Malm aquifer and PDC drilling tools, the mud losses in the Malm were kept manageable for the drilling operations and permitted great drilling depths into the deep Malm aquifer, at times with extremely good drilling progress.

- The utilized drilling rigs had sufficient capacities as well as reserves, so that the greatest possible drilling reliability was ensured in all phases of the drilling work and other operations, and geologically/hydrogeologically based design changes were implemented without difficulty.

- The success of the projects in the trade fair town Riem and the town of Pullach i. Isartal greatly depended upon the teamwork of the participating firms, as well as upon the necessary financial reserves for the project, to be able to overcome occurring problems in a carefully considered manner and successfully lead the projects to their ultimate economic success. The drilling operations received intensive technical support with respect to the directional drilling operations, drilling fluid and geological aspects, and also with respect to the equipment and engineering.

Fig. 2: Drilling Section for the Geothermal Project Pullach with Sidetrack