Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Novel Approach for the Exploration of the Muschelkalk Aquifer in Switzerland for the CO_2-free Production of Vegetables

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Keywords: novel approach, horizontal borehole, greenhouses, hydrothermal, Upper Muschelkalk, Triassic, testing, logging

ABSTRACT

In Switzerland, the Grob vegetable gardening and cultivation company, with around 7 ha of greenhouses in Schlattingen, produces different types of vegetables. The heating of the greenhouses requires about 20,000 MWh of energy per year. Using a mix of fossil fuels currently produces annual CO_2 emissions of about 5,000 tons, which should be substituted by the use of geothermal energy.

Because of the lack of detailed geological resp. hydrogeological data sets of the region of Schlattingen it was decided to conduct an intensive investigation program in a first vertical borehole (1,508 m bgl), including drilling into the basement with partial coring.

The geological and hydrogeological data acquired were used to prepare a geological and finite element hydrothermal model of the Muschelkalk aquifer for the planning of a second inclined borehole. On this basis it was decided to select a novel approach with an almost 800 m long horizontal drilling section in the Muschelkalk aquifer and a total length of 2,013 m to explore as many tectonic structures as possible to increase the chances of success for a higher flow rate. Using a rotary steerable system (RSS), the horizontal drill paths could be implemented into the 33 m thick aquifer (1,112 to 1,145 m bgl). The results of the first pumping test show that the production flow rate was slightly enhanced in comparison with the borehole Schlattingen 1. An additional sectionwise stimulation is planned to increase the flow rate further.

1. INTRODUCTION

In Switzerland, the Grob vegetable gardening and cultivation company, with around 7 ha of greenhouses in Schlattingen, produces different types of vegetables (mainly cherry tomatoes) more or less all year round. The heating of the greenhouses requires about 20,000 MWh of energy per year. Using a mix of fossil fuels (80 % gas and 20 % oil) currently produces annual CO_2 emissions of about 5,000 tons.

Nagra (Swiss Cooperative for the Disposal of radioactive waste) supported the project as well as other organisations from the public and private sector. Besides a financial contribution to get access to the acquired data Nagra was in charge of planning and executing the drilling and testing operations on behalf of the Grob company. Nagra has an interest to acquire data regarding geology, hydrogeology and rock mechanics for the extension of existing regional data bases and modelling of Northern Switzerland, which are used in the framework of its investigations for a deep geological repository for radioactive waste.

Based on a pre-study in 2007 and a feasibility study in 2010, a geothermal project for heat production was initiated and, after receiving a risk guarantee for the first borehole from Canton Thurgau, the project was initiated in November 2010. The risk guarantee was essential because the likelihood of success was estimated to be in the range of only 20 % based on regional data and existing studies.

Because of the lack of detailed data in the region of Schlattingen it was decided, in cooperation with Canton Thurgau, to conduct an intensive investigation program in a first vertical borehole (SLA-1), including drilling into the basement with partial coring (1,508 m bgl), hydraulic packer testing combined with water sampling in all aquifers, geophysical logging, checkshot measurements and determination of the primary stress. Additional rock mechanical and thermal conductivity laboratory measurements were performed. The data were used for the planning of chemical stimulation with hydrochloric acid (HCl) of the finally selected Upper Muschelkalk aquifer, namely mainly the so-called Trigonodus Dolomite from 1,112 to 1,145 m bgl. The stimulation was successful and the transmissivity could be increased by about one order of magnitude, resulting in a flow rate of about 6 l/s. The aquifer temperature, with about 62°C, was higher than expected and resulted in a temperature gradient of ≈ 4.6°C/100 m. This means that the predefined threshold for partial success had been reached, leading to a continuation of the project.

For the project continuation, all the data acquired from SLA-1 were combined with existing regional data, analyzed and interpreted. In this paper, the basic dataset for the planning and execution of the novel approach by drilling a horizontal borehole section in the target aquifer is described. This is followed by a description of the drilling activities. Finally the results from the newly drilled borehole Schlattingen 2 (SLA-2) are presented with conclusions and lesson's learned.

2. RESULTS FROM THE VERTICAL BOREHOLE SLA-1

Potential geothermal reservoirs in Schlattingen are the aquifers in the sedimentary formations of the Mesozoic cover, namely the regional aquifers Malm, Upper Muschelkalk and Buntsandstein, plus the Upper Crystalline (basement) if the rock is densely fractured and/or highly altered. From an economic point of view, especially considering the expected drilling costs (cost / benefit ratio), the Upper Muschelkalk was defined as the first priority target formation in the case where the transmissivity is high enough to establish a minimum flow rate of about 7 l/s. To reach the numerous objectives an intensive investigation program was conducted in the vertical borehole (1,508 m bgl):

- Coring from 725 to 989 and from 1,116 – 1,184.7 m
- Thermal conductivity measurements on rock cores and cuttings
- Geophysical logging (GR, FEL, DIL, DLL, Gamma-Gamma Log, Neutron-Neutron Log, Full Wave Sonic; CAL-4, CAL-6, CBL, CCL, T/Cond.) from 130 – 1,508 m bgl (10 x logging runs)
- Checkshot measurements
- Hydraulic packer tests (Malm, Dogger, Upper Muschelkalk, Buntsandstein, Rotliegendes, Upper Crystalline), partly in combination with formation water sampling in the aquifers
- Stress measurements (15 tests)

The drilling of the vertical borehole SLA-1 started in December 2010 and was finalized after several interruptions in January 2012. A schematic geological profile of Northern Switzerland is shown in Figure 1. The installation site in Schlattingen is located 10 km east of Schaffhausen and 0.6 km south of the Rhine River close to the border with Germany. The hilly topography around the SLA-1 location features wide NW-striking ridges separated by wide glacially shaped valley floors. The maximum relief is 200 m.

Geologically, the drilling location is situated in the Swiss Molasse Basin between two regional faults. The Randen Fault some 2 km to the north strikes approximately NW and has a maximum normal fault offset of 250 m (Nagra, 2008). The Neuhausen Fault about 5 km to the south is well known from Nagra's 3D seismic survey (Nagra, 2000). It also strikes NW and has a maximum normal fault offset of 100 m. Focal mechanisms from the basement are consistent with shortening directed NNW (Kastrup et al., 2004). However, compared with active tectonic regions the seismicity is low and GPS-derived strain rates in the Molasse Basin of north-eastern Switzerland are well below 0.5 mm/y (Sue et al., 2007).

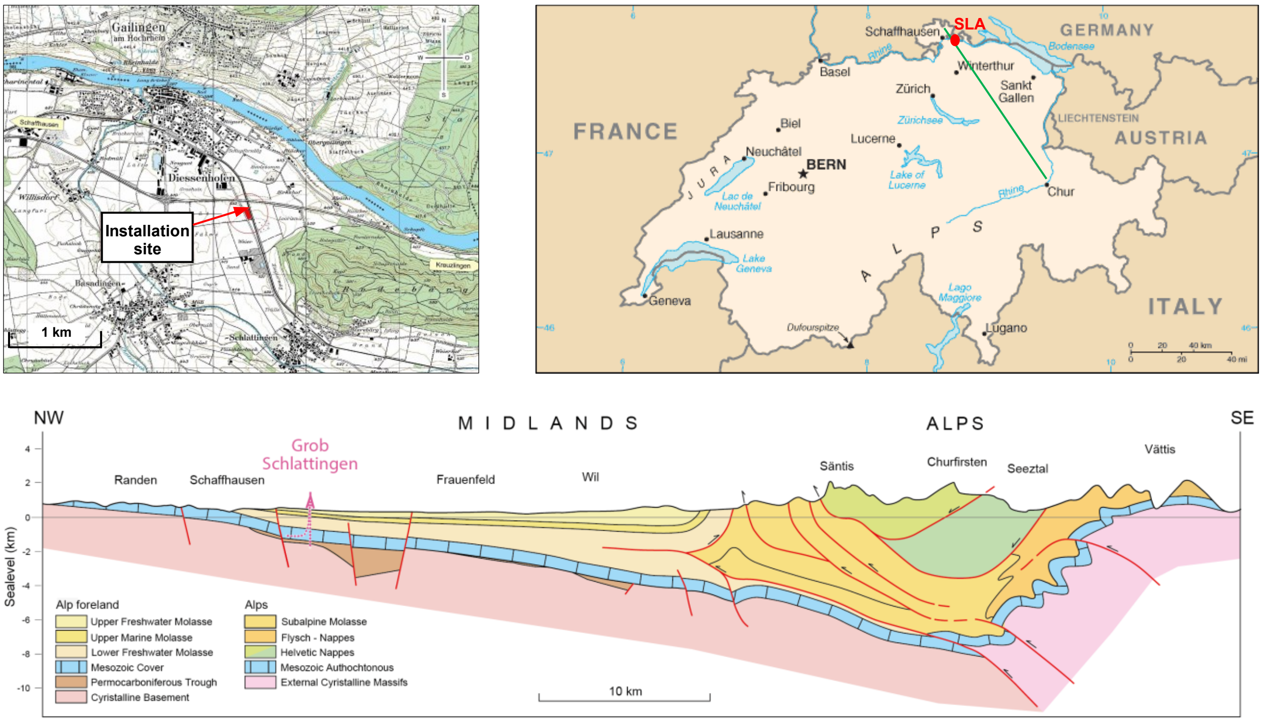

Figure 1: Location of the Schlattingen boreholes and schematic cross-section of Northern Switzerland.

The geological profile of the geothermal borehole Schlattingen 1 is presented in Figure 2. The sedimentary sequence at the location of the borehole comprises marine limestones, shales and marls which are unconformably covered by Tertiary rocks of the Alpine Molasse. Further to the west the evaporitic rocks of the Triassic formations (= Middle Muschelkalk) near the base of the sedimentary layer served as a regional detachments and enabled thin-skinned thrusting and the formation of the Jura fold and thrust belt in the Late Miocene. However, at the location of SLA-1 the sediments are considered to be unaffected by the Alpine thin-skinned thrusting.

It is worth noting that Permian sediments (Rotliegendes) with a thickness of about 78 m were encountered in the borehole before drilling into the crystalline basement. This means that the borehole appears to be located at the edge or at the shoulder of the so-called North Helvetic Permo-Carboniferous Trough. The main target of the project, the Upper Muschelkalk, had a thickness of 57.5 m consisting of two formations: the Trigonodus Dolomite and the Hauptmuschelkalk. In fact, only the upper part of the 33 m-thick Trigonodus Dolomite is significantly transmissive. In general, the Trigonodus Dolomite consists of porous or clayey dolomite with marly intermediate layers, dolomitic mussel beds and oolitic dolomites (Fig. 1).

In total, 13 hydraulic packer tests were carried out between February 2011 and October 2011 in borehole Schlattingen SLA-1. 11 tests were conducted in single or double packer configuration and 2 tests as open-hole production tests. The transmissivity profile presented in Figure 3 shows values ranging between 2.2E-12 m²/s (BD 3) and 7.3E-05 m²/s (B1). The lowest value was derived from the test covering parts of the Lower Malm and Upper Dogger formations and the highest was measured in the Buntsandstein formation. The equivalent freshwater head is calculated to meters above sea-level; the values varied between 393 m asl (K2) and 606 m asl (BD1). Considering a borehole elevation of 416 m asl, all tests indicate artesian conditions with the exception of the tests conducted in the Malm formation and the crystalline basement. Compared to the lower Buntsandstein and Crystalline aquifers, the Upper Muschelkalk has a lower transmissivity value with 1.1E-6 m^2/s. Regardless of this, this zone was chosen as the target zone due to the relatively low mineralization of the water with about 3 g/l total dissolved solids compared with the Buntsandstein (18.5 g/l TDS). It is also the formation which can be much more easily stimulated to obtain at least the minimum required flow rate.

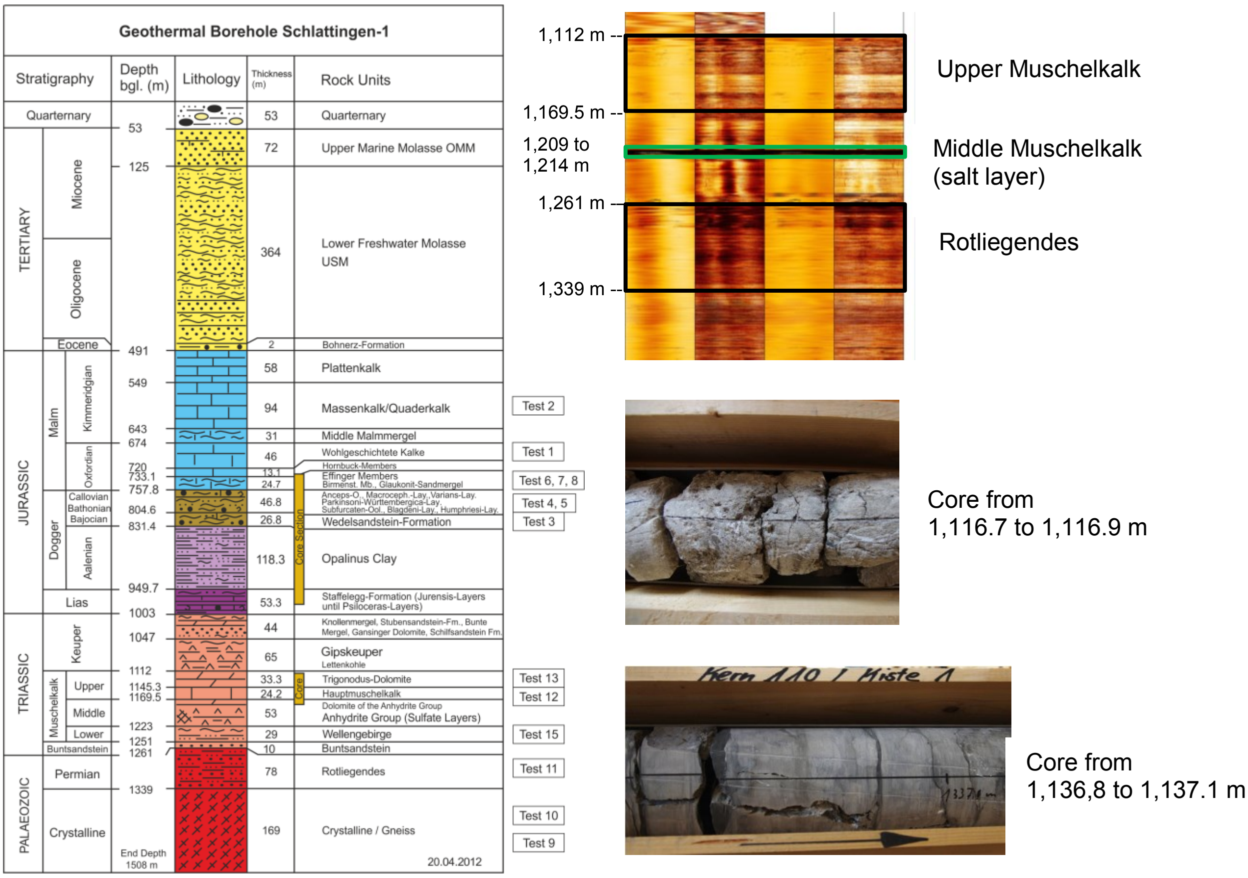

Figure 2: Geological profile of the geothermal well Schlattingen 1 and position of the measurements of the minimum horizontal stress (left) and section of the ABF-Log and drillcores of the Upper Muschelkalk (right).

Important for the planning of the stimulation of the borehole SLA-1 with the injection of hydrochloric acid (HCl) and the application submitted to the cantonal authorities were the stress measurements performed in the open hole by minifrac test. The method uses a double packer system to isolate a one meter long interval of the open borehole that is then pressurized at injection rates of 2 l/min up to the breakdown of the formation. Repeated pressurization of the interval allows the stress acting on the newly created fracture to be determined. The total injected volume during such a test is in the range of a few liters and the size of the fracture that extends from the borehole normal to the minimum principal stress can be considered to be in the range of a few meters at most. The orientations of the newly created fractures were determined with the help of BHTV logging runs that compare the borehole wall image before and after the stress measurements. In some cases additional impression packer tests were performed.

The minimum horizontal stress was determined directly from the shut-in pressures of the data logs. The vertical profile of the principal stresses is shown in Fig. 4. It was assumed that one of the principal stresses is vertical and the vertical stress component was calculated from the overburden using an average density value of 2.5 Mg/m^3. The values for the maximum horizontal stresses shown in Fig. 4 have to be treated with some caution. They were derived using the relation of Hubbert and Willis (1957), which requires that one principal stress orientation is parallel to the borehole, that the borehole is perfectly circular at the time of the test and that the induced fracture is hydraulically impermeable. For hard rocks the latter assumption cannot be made as it is rather unlikely that the fracture will close completely after depressurization; even small asperities can keep them open. In the case of soft rocks the assumption is likely to be valid.

After the completion of the borehole with a 5” slotted liner in the Upper Muschelkalk section from 1,112 to 1,185 m bgl, a stimulation with hydrochloric acid (HCl) was performed in three steps with a concentration varying between 15 and 20 % w/w (6.023 mol/l). Due to the requirements of the authorities it was not permitted to reach the frac pressure to avoid any induced seismicity. The injection pressure was therefore limited to the range of the re-opening pressures derived from the stress measurements.

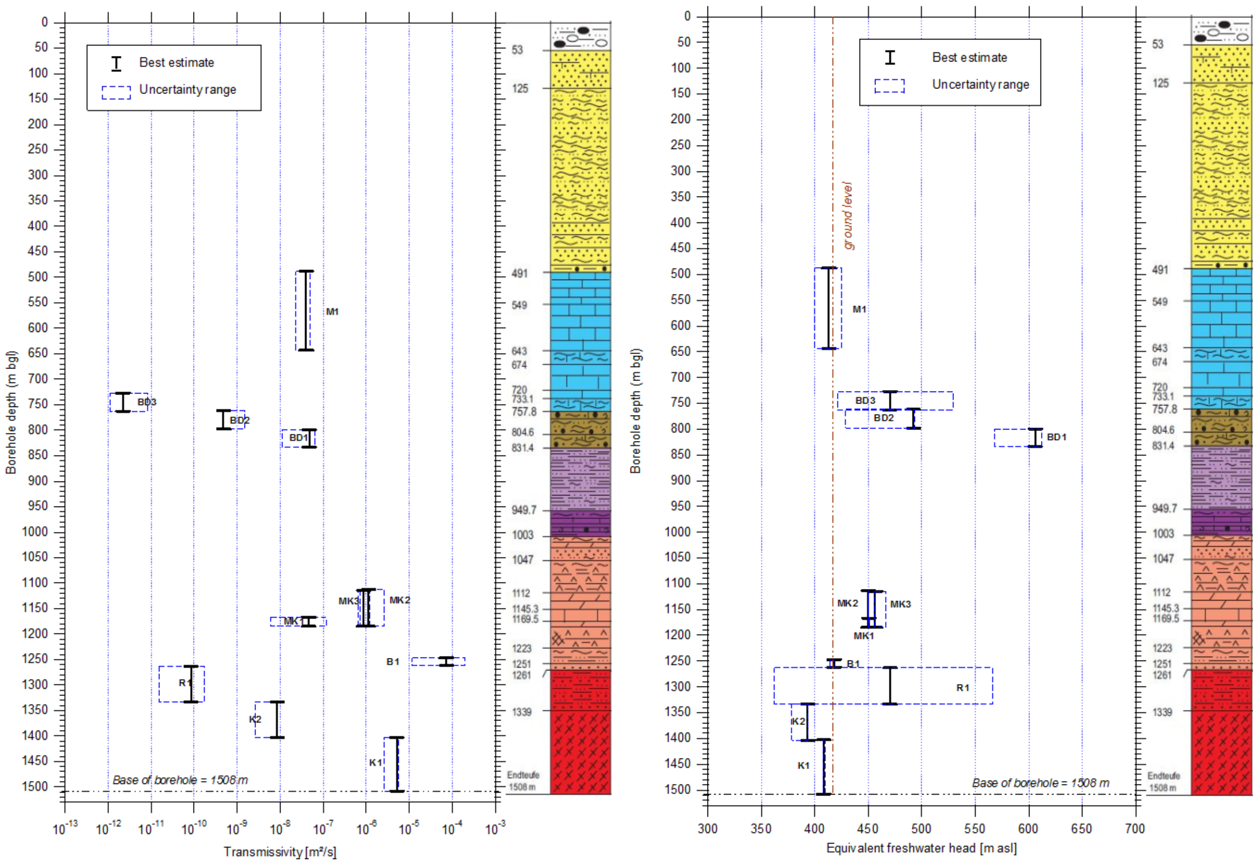

Figure 3: Transmissivity (left) and equivalent freshwater head profile of Schlattingen 1.

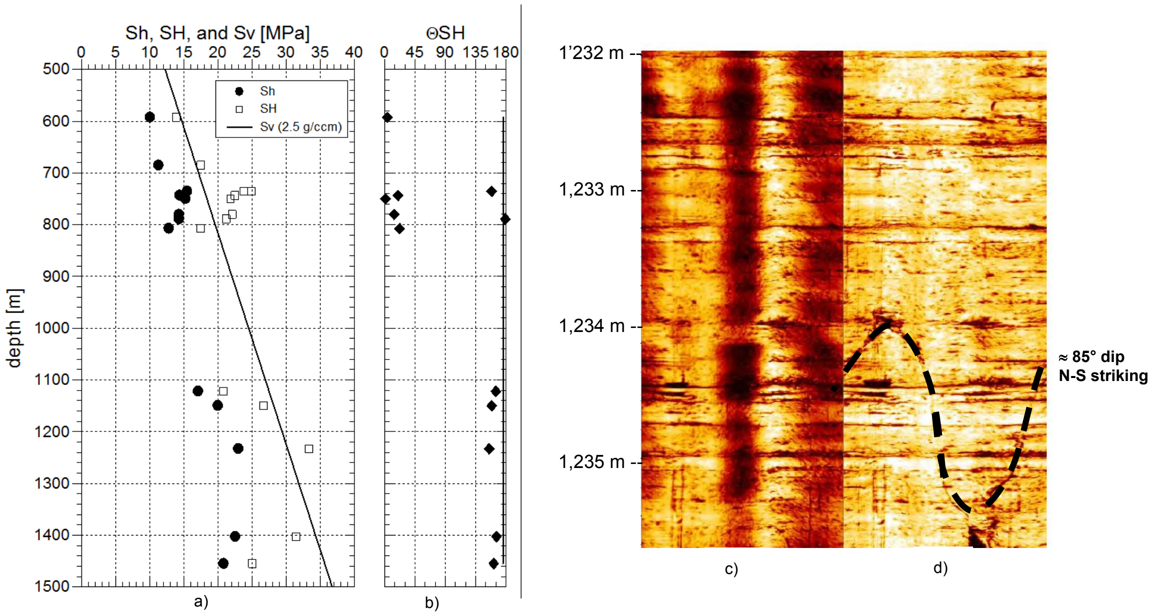

Figure 4: Left (from Vietor et al., 2012) - Stress magnitudes (a) and maximum horizontal stress orientation (b) determined in the borehole SLA-1; Right – Example of BHTV-logs of the test section at ≈ 1,234.5.0 m depth before (c) and after (d) minifrac testing.

Nevertheless, it was possible to stimulate the Upper Muschelkalk in such a way that an increase in the transmissivity in the range of one order of magnitude resulted. This was confirmed by an open-hole long-term pumping test (Fig 5) with a best estimate for the transmissivity of 1.33E-05 m^2/s (outer zone) and 4.65E-05 m^2/s (inner zone) assuming a composite model. The success of the stimulation in reaching the required minimum heat quantity (= combination of flow rate and temperature) allowed the project to proceed.

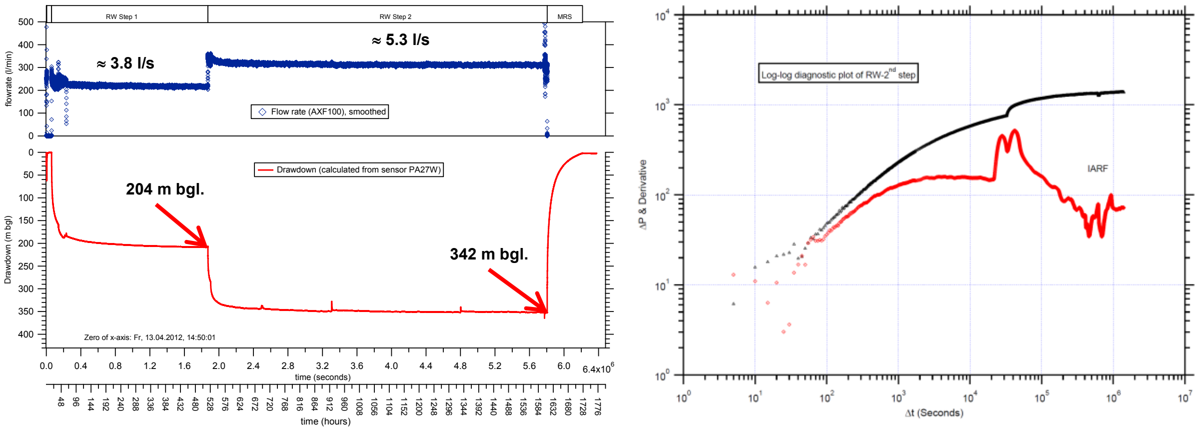

Figure 5: Long-term pumping test of the Upper Muschelkalk aquifer in SLA-1 after stimulation – Test overview with flow rate und drawdown (left) and log-log diagnostic plot with derivative of the second step of the RW-phase (right).

3. PLANNING OF THE HORIZONTAL BOREHOLE SLA-2

In preparation for the planning of the inclined borehole, a three-dimensional layered model was set up with the aim of accessing the long-term development of the regional groundwater in the area of influence of the geothermal utilization with a doublet or singlet. Also the required minimum distance between the two boreholes to avoid a thermal short-circuit was evaluated. For these numerical hydrothermal simulations, a finite element code (SPRING) was used which can produce 2D and 3D models of non-steady-state flow and heat transport problems. The lateral model area extends 35 km from the outcrop area of the Upper Muschelkalk as the limited infiltration area in the NW corner (cf. Fig. 1) in the direction of the SE. The boundaries were made up by the so-called Neuhausen Fault and the Randen Fault where the groundwater flow is restricted. The following Figure 6 shows the static hydraulic head and the temperature distribution of the modelled area. Based on the model, a minimum distance of between 400 to 600 m is required to avoid a thermal short-circuit between the two boreholes. From the thermal point of view it would be an advantage if the borehole SLA-2 were directed to the E or SE to access the higher temperature region. Favourable rated was also a drill path in direction of the regional Randen fault zone (NE to E) which might be accompanied by a zone of higher fracture intensity (Egli et al., 2014).

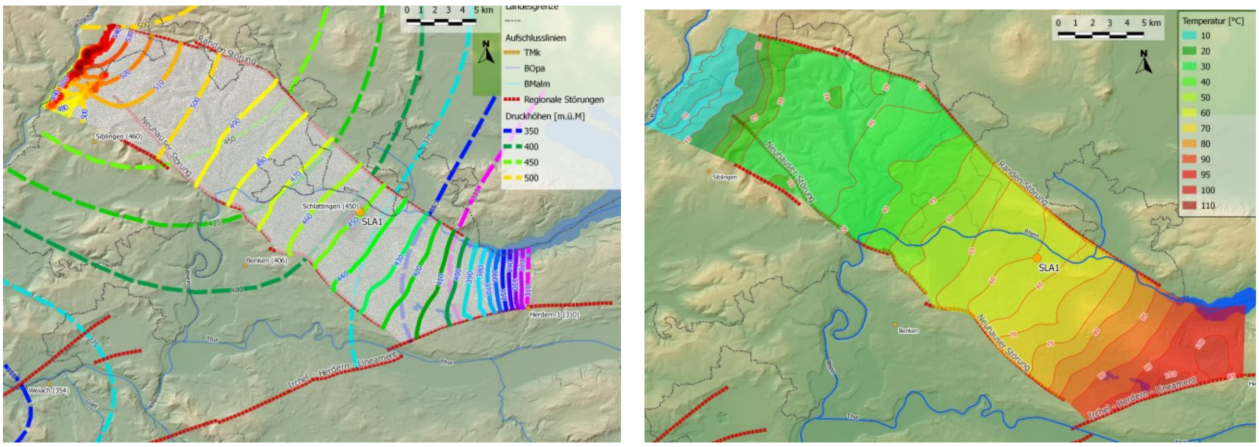

Figure 6: Static hydraulic head distribution (left) and temperature distribution (right) in the modelled area.

Due to the fact that the Upper Muschelkalk was entirely cored, the structures in combination with the analysis of the logging data (ABF = acoustic borehole televiewer) could be studied in detail, especially for the predictions within the framework of the continuation of the project with the drilling of a second borehole (see Fig. 1 and 8).

It was confirmed that N-S-striking, steeply dipping sub-vertical structures occur in the area of the Schlattingen borehole. Therefore it would be beneficial in general if the drilling section in the Upper Muschelkalk could be maximized to intersect as many fractures (= potential flowing features) as possible. Figure 7 shows that fracture recorded in outcrops in the area and cores from SLA-1 predominantly strike roughly N-S, less often NW-SE and NE-SW.

Independent of depth the orientation of the maximal horizontal stress (S_H) is N-S to NNW (Fig. 4). The minimum horizontal stress (S_h) strikes E-W to ENE. The measured orientation could be treated as representative because significant deviations in the orientation of the horizontal stress are very unlikely on the regional scale. Based on this, a deviation of the Schlattingen 2 borehole in an E direction was recommended because the NW-SE striking structures can be intersected and the direction is normal to the dominant fracture network. The frequency of the fractures seems to be maximized in this direction. Due to the fact that it is not feasible to drill across the border into Germany, the drill path to the E has an additional important advantage in terms of the potential drill length.

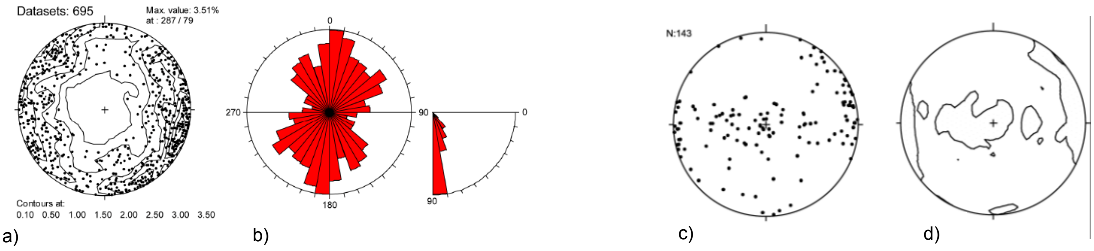

Figure 7: Orientation of regional fracture structures recorded in surface outcrops (left: a) lower hemisphere equal area projection, b) rose diagram) and in cores of SLA-1 (right: c) lower hemisphere equal area projection, d) contour plot of fracture poles).

The last step was the evaluation of all existing 2D seismic lines in the region of the Schlattingen site and the planning and evaluation of a possible drill path. As a support and with the use of existing depth data (Birkhäuser et al., 2001; Nagra, 2008), a structural 3D model was set up to project the possible inclined borehole into the target formation. The reprocessing performed with a pre-stack time migration subsequently shows much more continuation in the reflections. It is clear that a detailed interpretation of small fault structures based on 2D seismics is very limited, but on the other hand the results showed that no major fault zones with a larger displacement are expected, which might severely limit the success of a horizontal borehole.

The following Figure 8 shows the three drill paths considered for the Schlattingen 2 borehole based on the 3D model.

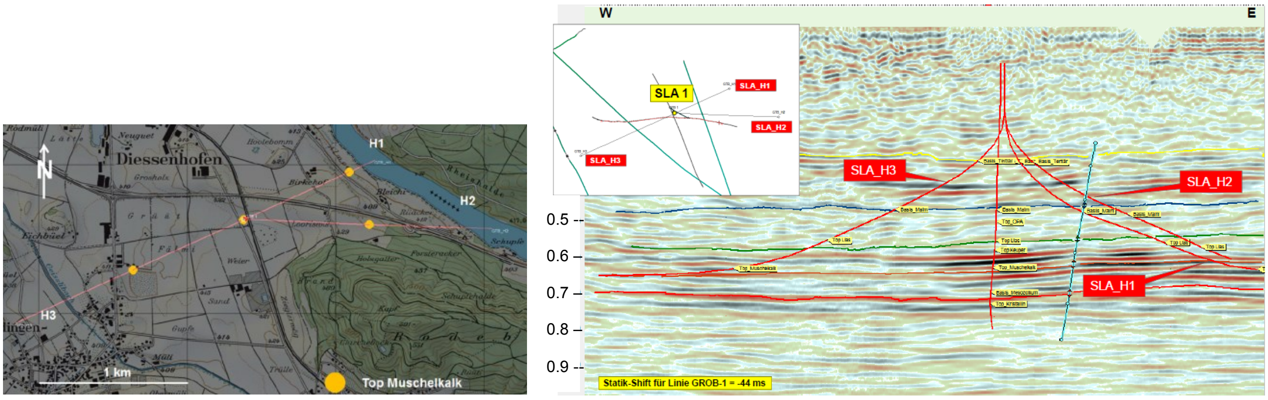

Figure 8: Map with the penetration point Top Upper Muschelkalk (left) and the associated drill path predictions in the 3D model (right; y-axis scale = reflection time [s]).

A major concern for the successful drilling of an inclined resp. horizontal borehole in Schlattingen was the fact that, above the target formation, especially with Opalinus Clay (Dogger) and the Gypsum-Keuper, two potentially very unstable formations have to be intersected. The clay content of the Opalinus Clay is in the range of 50 to 60 %. About 20 % are swelling clay minerals (Wersin et al., 2013). This means that an inhibiting drilling mud must be used in the section above the Upper Muschelkalk section. In the past, a sodium silicate mud (Macek and Gassler, 2001) had already been successfully used, as well as the so-called Ultradrill mud from MI-Swaco in SLA-1. Due to the expected short intervention time in the unstable borehole sections and budget restrictions, instead a potassium chloride mud was chosen for SLA-2.

Moeck and Backers (2013) performed a determination of the stress field and a borehole stability analysis with the calculation of possible mud densities. The structural stress field determination showed a transtensive stress field with S_V equal to S_H and > S_h. The water formation pressure in the Opalinus Clay and Gypsum-Keuper is increased to about 12.5 MPa/km. This requires a higher drilling mud density for this section of 12.5 to 13.0 MPa/km. The target formation can be drilled with a lower mud density of 10.1 to 10.5 MPa/km. Borehole breakouts in the Opalinus Clay cannot be avoided but can be minimized if the45 inclination is limited to an angle of less than 40 ° in this section.

Based on the described preparatory work and preliminary studies, it was decided by the project management to take the risk to implement a completely horizontal drill path in the target aquifer in order to intersect as many structures as possible.

4. DRILLING AND TESTING OF THE HORIZONTAL BOREHOLE SLA-2

On February 14th 2013, the drilling activities for the second geothermal borehole in Schlattingen started with a Drillmec MR 8000 drill rig. The rig has a mast height of 36 m and maximum hook load of 200 tons. Until setting of the 9 5/8” casing at 497 m bgl, the borehole was drilled vertically. For this 12 ¼” drill hole, a standard tricone drill bit was used. From this depth on a rotary steerable system (RSS) from Weatherford was used to drill the inclined and horizontal drill path as planned using a PDC drill bit (= polycrystalline diamond compact drill bit with wings) of 8 1/2”. The maximum drilling rate achieved on one day was 313 m. The progress of drilling with this system was very efficient until a break of the drilling jar occurred at 1,302 m along hole just before reaching the target aquifer. After a longer ultimately successful fishing campaign, the borehole was so strongly mechanically damaged resulting in major breakouts and huge amounts of cave material that it had to be abandoned and back-cemented. With the second attempt, the final borehole length of 2,013 m could be reached. After setting the 7” casing at 1,051 m along hole, the drilling was continued with a 6 1/8” PDC drill bit. After 89 days, on April 26th 2013, the drilling and completion activities of borehole

SLA-2 were finalized. Figure 9 shows the drill rig and the casing scheme for the borehole SLA-2. Figure 10 shows the RSS and the inclined borehole paths until reaching the horizontal drilling section.

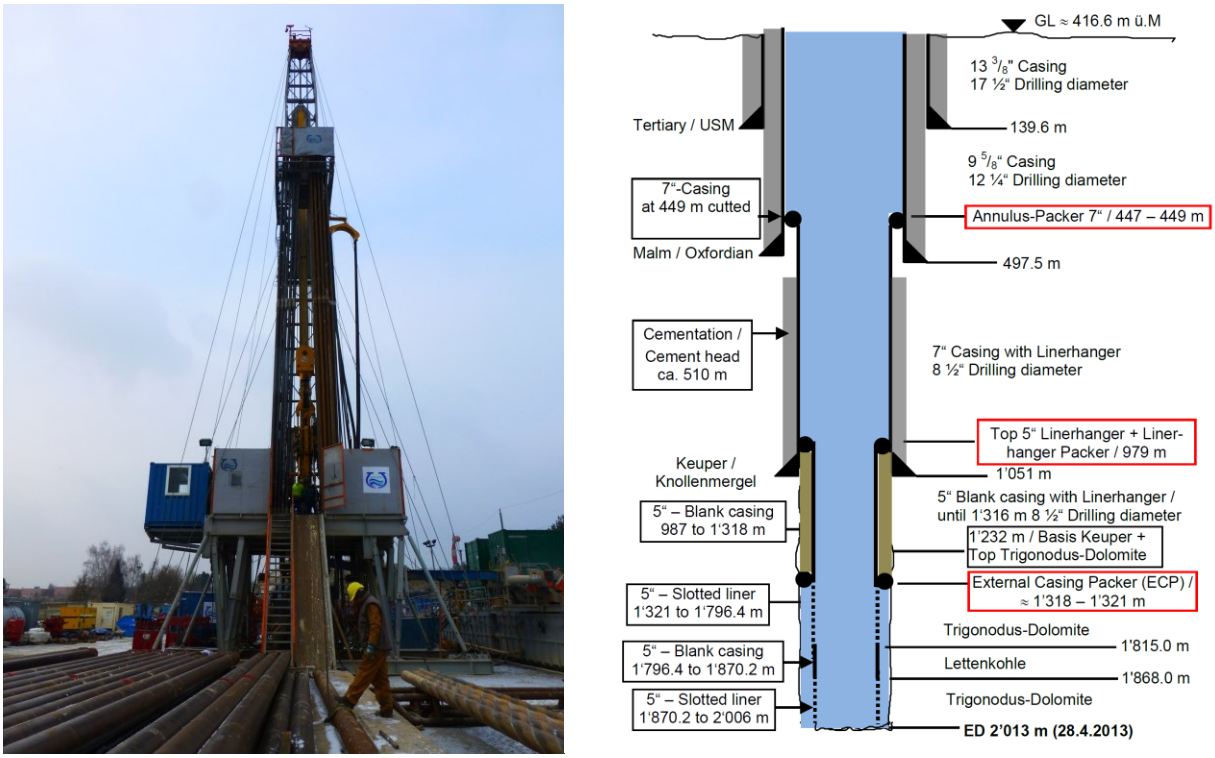

Figure 9: Drillmec MR 8000 (left) and casing scheme of the borehole SLA-2 (right).

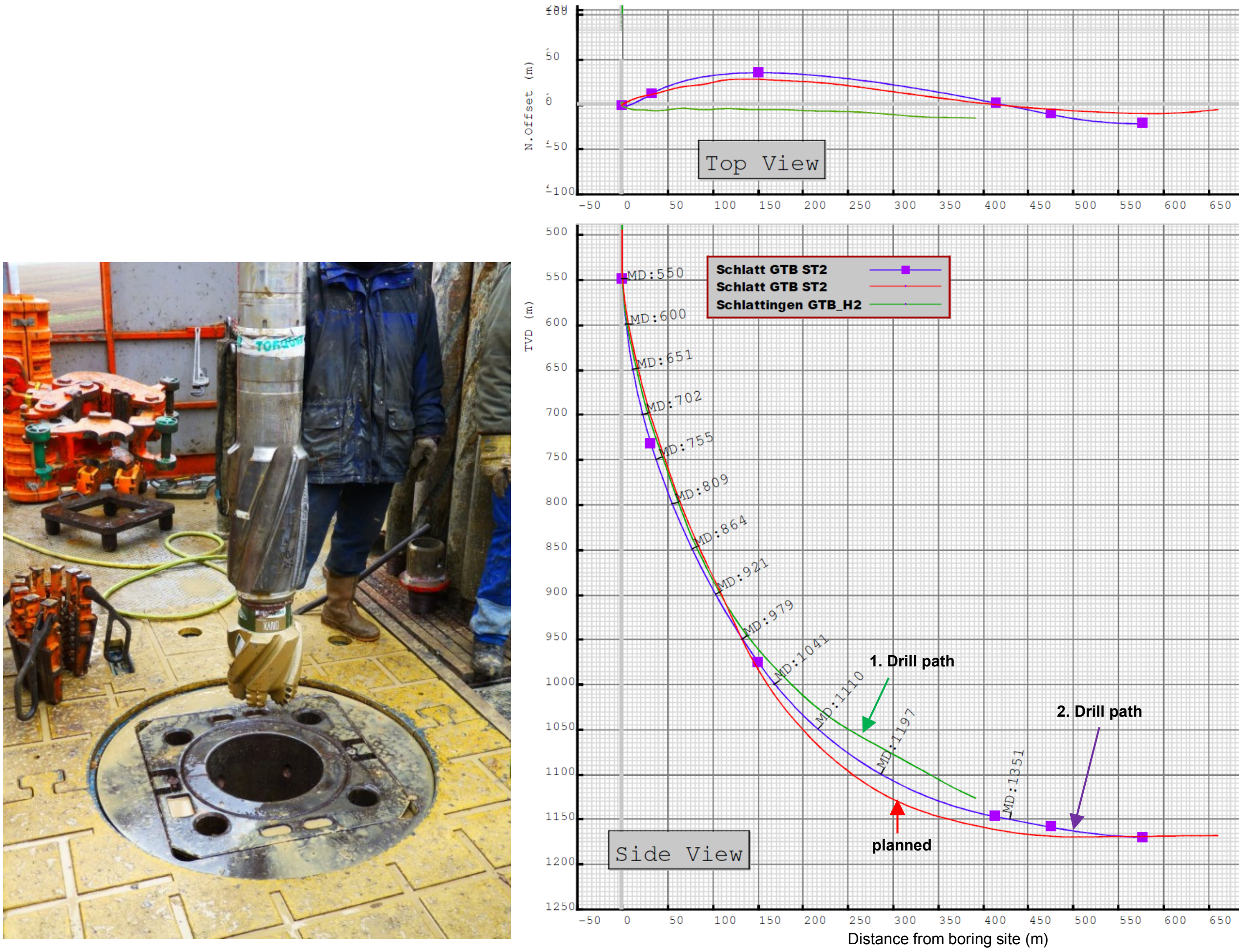

Figure 10: RSS with PDC drill bit (left) and borehole survey of the inclined borehole section (right).

In the inclined part of the borehole before setting the casing, it was not possible to perform the originally planned geophysical logging campaign due to stability problems mainly in the Opalinus Clay and borehole breakouts in the upper part which caused the wireline probe to become stuck during the first logging attempt. However, after setting the casing to the final length of the borehole it was possible to log the entire open borehole section from 2,013 m up to 500 m (Note: logging through the 7” casing from 1,051 m on.). To minimize the risk of potentially losing the borehole, a so-called well shuttle logging tool was deployed. The advantage of the tool is that it is run into the hole with the drill string. In cases of slight difficulty, s smooth rotations of the drill string with circulation of the drilling mud are also possible. The logging starts from the bottom by standard removal of the string and the data are stored in data memory. This means that the quality of the data can only be checked after reaching the surface again. The following tools were used in a single logging run: Electric Imager – CMI, Full-Waveform Sonic, Neutron-Neutron, Gamma (GR), El. Induction (FEL, MAI) and CBL. Based on the permanent sampling of cuttings (every 2 m) and the logging results, a relatively precise geological profile of SLA-2 could be prepared (Fig. 11).

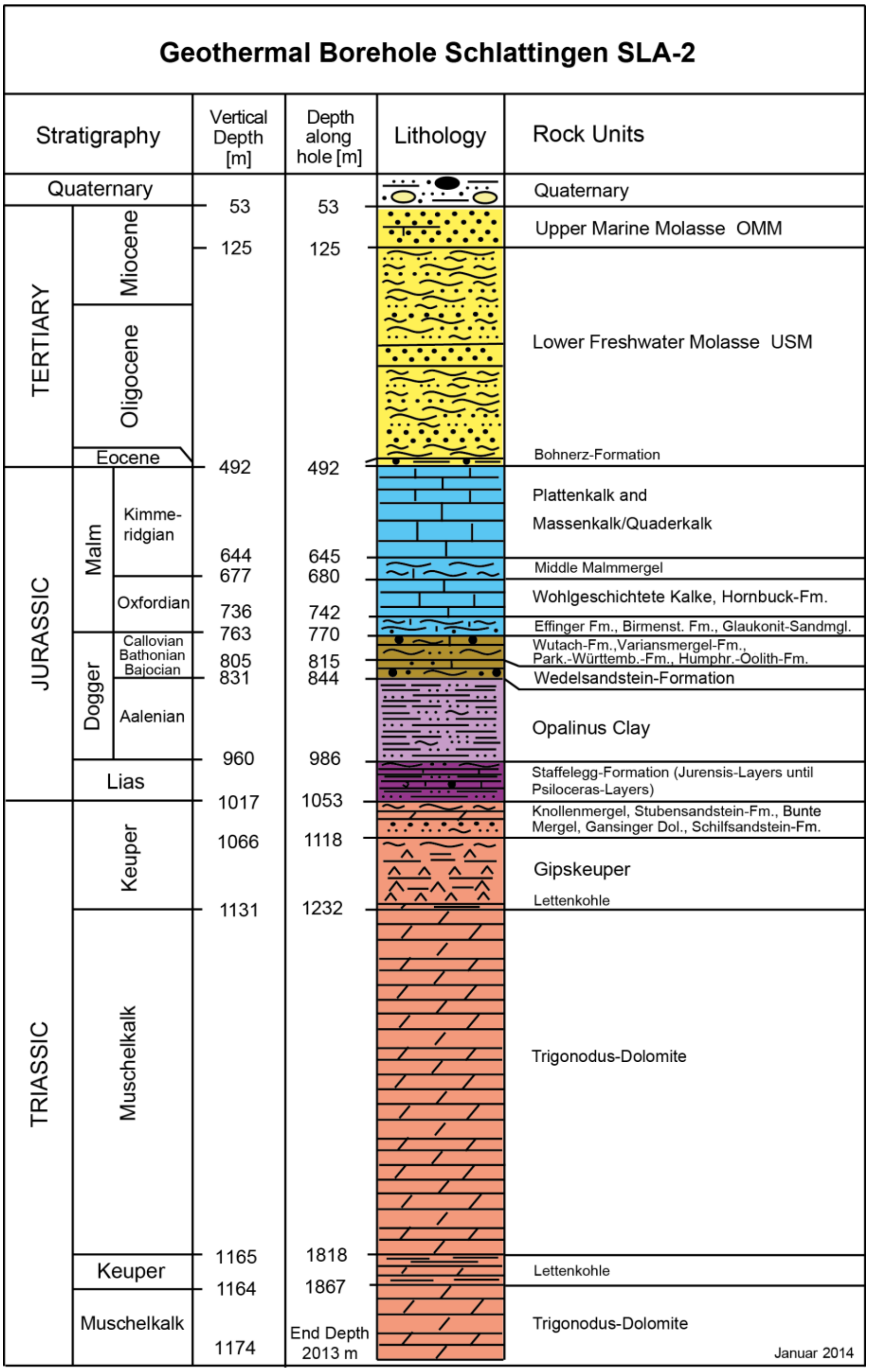

Figure 11: Geological profile of the geothermal well Schlattingen 2

After the analysis of the logging results, it was confirmed that the borehole left the target formation of the Upper Muschelkalk in the horizontal section for 49 m into the hanging wall by intersecting the Lettenkohle (1,818 – 1,867 m along hole). This is also the reason for the installation of a blank casing in this part of the borehole. Figure 12 shows a geological vertical cross-section along the drill path of the second borehole SLA-2 and a contour map of the top of the Upper Muschelkalk with the positions of the geothermal boreholes. The horizontal drilling section in SLA-2 has a length of almost 800 m.

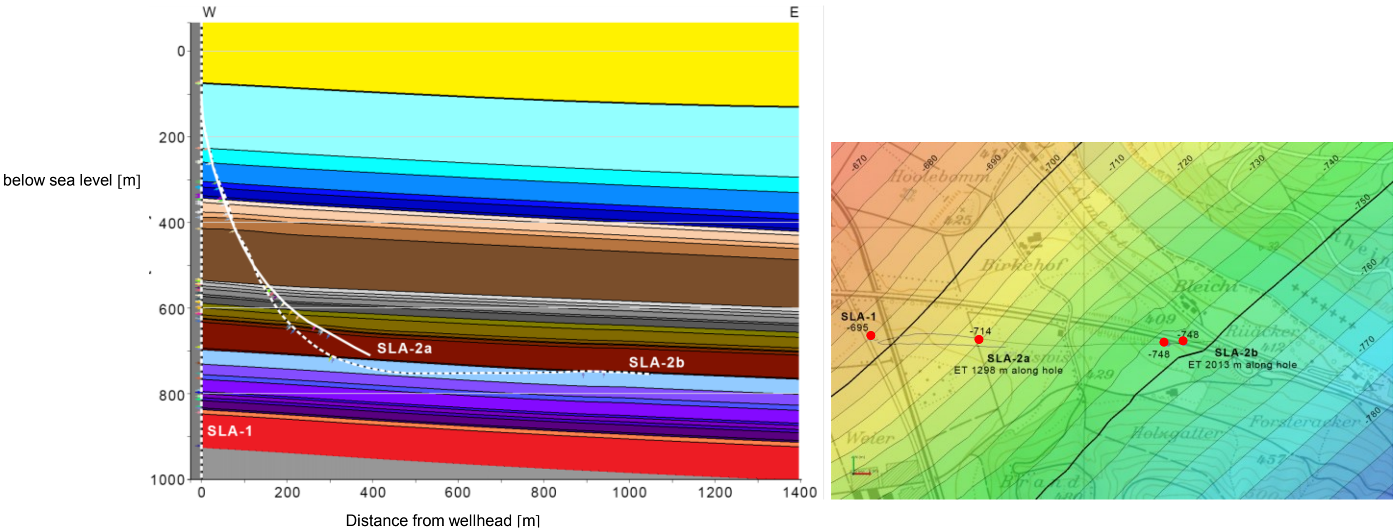

Figure 12: Geological vertical cross-section along SLA-2 (left) and contour map of the top Trigonodus Dolomite with the positions of the geothermal boreholes in Schlattingen (right).

The detailed analysis of the fracture system encountered in the Upper Muschelkalk with a NW-SE to NNW-SSE orientation in the borehole SLA-2 based on the CMI log (Compact Micro Imager) confirmed the prognosis based mainly on surface outcrops (cf. section 3). The existence of NNE-SSW-striking fractures could be confirmed with the borehole but their occurrence is much more limited than expected. The same applies for the ENE-WSW oriented fracture system. The section from 1,950 to 2,013 m along hole is the most transmissive section in borehole SLA-2. Between 1,984 and 1,985 m along hole there are three NNE-SSW-striking fractures with a cumulative aperture of 28 cm. Besides this major fracture zone, additional open fractures striking NW-SE and N-S are detected with apertures > 1 cm. The natural fracture density in this borehole section is quite high. During drilling, massive drilling fluid losses were observed in this section.

A similar open-hole long-term pumping test as in SLA-1 using the same equipment was performed with a duration of 876 hours (= 36 days) and confirmed a slightly higher transmissivity of about 1E-5 m^2/s with a flow rate of about 8 l/s. In total, both boreholes can already provide the required amount of hot water (≈ 13 l/s) to heat the greenhouses more or less entirely using geothermal heat. The aim now is to increase the flow rate in SLA-2 in such a way that this borehole alone can deliver the required heat. The geothermal borehole SLA-1 will be activated to cover peak load or if the borehole SLA-2 is out of operation in the case of repair work and/or pump replacement.

5. ADDITIONAL PLANNED ACTIVITIES

The stimulation of the borehole SLA-2 after completion in two steps using the same approach as in borehole SLA-1 was not so successful overall in increasing the total flowrate because most of the injected hydrochloric acid (HCl) went into the already highly transmissive zone at the bottom of the borehole. Therefore, it is planned to perform a chemical stimulation in sections by separating the lower borehole section with a packer element and stimulating the up to now rather low-stimulated fractures in the top part of the borehole. The success of such a stimulation were evaluated based on a detailed structural analysis, which shows that the fracture distribution and occurrence is comparable with the situation in SLA-1 before the chemical stimulation. It is expected to achieve a similar increase of the transmissivity like in SLA-1of about one order of magnitude in this section.

6. CONCLUSIONS

It has been shown that, for the use of hydrothermal geothermal energy, the approach of drilling a horizontal borehole for the exploitation of a fractured aquifer can significantly increase the probability of success if the fracture network is dominated by sub-vertical features.

If very little or almost no pre-existing information is available, it is particularly important to acquire - as far as possible - geological, hydrogeological and tectonic / rock mechanical information before the drilling of a horizontal borehole for a proper planning. This was also one of the reasons for the intensive investigation program in the first geothermal borehole in Schlattingen (SLA-1). In the case of a very thin target formation or aquifer, as in the Schlattingen region with less than 30 m, it is essential because of the limitations of the drilling equipment and the response possibility on the actual findings. This means that it is also necessary to have very good knowledge of regional and local geological structures to be able to carry out detailed planning with a concrete work program, with the development of alternative scenarios for the project.

Due to the lack of knowledge about deep aquifers with known promising and transferable boundary conditions for geothermal use, as for example in the area of Munich (Germany), it seems to be important, at this stage in Switzerland, to generally acquire with every new borehole the maximum of geological, hydrogeological and tectonic / rock mechanical data from the deep underground. These datasets can help than to develop new concepts for follow-up projects and eventually, on the long term, increase the possibility of success for deep geothermal energy use in Switzerland. It is hard to understand that projects often invest millions of dollars only in drilling costs and fail to acquire minimal usable scientific datasets. The significant costs for the scientific investigations in the Schlattingen boreholes appear to be a good investment not only for the project itself but also for the future of geothermal energy use in Switzerland.

In the case of Schlattingen, it was demonstrated that even a private investor is able to manage such a project in an economic manner and minimize the risk involved if, from the beginning, milestones are defined for the acquisition of the data required to be able to carefully plan the next steps. The integration of partners from the public and private sector in the project was essential for the successful execution of the project from an economic and scientific standpoint. It should also be noted that subsidies could mean that the original scope of the project has to be expanded to fulfil the information needs of the additional partners. In general, the selected stepwise approach (technical, scientific and financial), with definition of milestones already from the planning stage through the execution of the project until finalization with the now possible geothermal use minimizes the risks associated with the projects.

Besides the hydrothermal heat project of Riehen (Canton Basel) in 1989, the Schlattingen project is the second successful deep hydrothermal geothermal project in Switzerland.

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Acknowledgements

The Schlattingen project and the authors would like to thank the following organizations for their significant financial and technical support, which allowed the project to be implemented: Canton Thurgau, Swiss Federal Office of Energy SFOE, Klimastiftung Schweiz, Axpo AG, Elektrizitätswerke des Kanton Zürich (EKZ), Geo-Energie Suisse AG and Nagra.