Exploration for the Bad Waldsee Geothermal Project and its Implementation as an Example for IMAGE

Joerg Uhde
CEO
Public Services
Bad Waldsee
Agenda

✓ Who we are and where we are
✓ Our geothermal project
✓ Geophysical exploration program
✓ IMAGE-TNO reprocessing of seismic data
✓ Productivity risk insurance and public funding
Who we are…

Public services Bad Waldsee were founded in 2013 focussing on two major projects:

- Developing a new district heating grid with a geothermal source
- Developing a 18 MW_{el} wind farm in a close by municipal forest area
- Additionally public services will be developed e.g. the operation of two thermal wells and an open air bath; public transport; parking lots
Where we are...

Figure 1 (left) Location of Bad Waldsee in the SW’ern German Molasse basin. The image shows the location of the cross section (Figure 2).

Figure 2 (above) Geological cross section through the Molasse basin showing the Upper Jurassic and the Upper Muschelkalk aquifers. In the Upper Jurassic, the different facies are illustrated: reef and basin carbonates of the Swabian facies and the Helvetian facies (modified after Jodocy and Stober 2009).
Where we are...

Figure 1 (left) Location of Bad Waldsee in the SW German Molasse basin. The image shows the location of the cross section (Figure 2).

Reef dolomite rock and massive limestones
layered facies
Helvetian facies

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Geothermal district heating…

- 80% of expected heat can be distributed by a simple pipeline network to municipal institutions like health clinics and spas.
- Additionally, private homes and SMEs shall be connected to the grid in a 2nd phase.
- Residential area concepts will be developed for three residential neighbourhoods.
Geothermal district heating...
Stages of our geothermal project …

- **Project idea** 2012
- **preliminary study** 2013
- **feasibility study** 2014
- **EFRE-funding approval** 2015
- **investment decision** 2016-18
- **successfull drilling**
- **district heating network** 2019/20
- **production**
- **Exploration**
- **costs (million EUR)**
  - 30
  - 10
  - 5
  - 1

- **Risc**
What we can expect...

In Baden-Württemberg (Germany), the Upper Jurassic thermal aquifer is of shallow depth; therefore, the low temperature thermal water is rather used for spa purposes including heating of nearby buildings.

Between 1977 and 1985, the first geothermal wells have been drilled in the central Upper Jurassic aquifer of the SW German Molasse basin. The projects showed production rates of up to 50 l/s, temperatures of 40°C to 50°C, and total dissolved solids of 0.45 to 0.55 g/kg (Bertleff et al. 1988).

Expected 40 l/s @ 75°C will supply ca. 3.5 MW\textsubscript{th} and ca.18’ 500 MWh\textsubscript{th} p.a.
Project development step by step…

- Acquisition of seismic and bore data for subsequent reprocessing and depth imaging
- Developing a preliminary geological model
  - 3D seismic survey
  - Building a complex 3D geological model
  - Reservoir and drilling engineering
  - Risk evaluation and management
  - Drilling and reservoir development
Support at the highest level…

The objective of the four year project IMAGE (Integrated Methods for Advanced Geothermal Exploration) is to develop new methods to scrutinize and appraise geothermal systems in such a way that exploration wells can be sited with greater accuracy than before, thereby maximizing the success rate and reducing the cost of drilling associated with geothermal projects.

Established in 1998 DMT Petrologic is dedicated to providing competent geophysical services and innovative data solutions to the oil and gas and geothermal industry. The company is renowned for its modern services for reservoir characterization.

The scientific working group at the KIT - Karlsruhe Institute of Technology, Institute of Applied Geosciences, Division of Geothermics is one of the most prominent scientific institutes in Germany. This group will serve as an evaluation committee for the final target planning.
Possible research for IMAGE

1. Reprocessing and Acquisition of data
   1.1 Elevation and Refraction static corrections
   1.2 Review, analysis and evaluation of well velocity measurements, external data
   1.3 Generate seismic attributes and analysis of attributes
   1.4 Supporting design of a 3D seismic survey

2. Modelling
   2.1 Interpretation, depth migration, geological model, structural model
   2.1.1 Petrophysical analysis of newly acquired vsp and log data
   2.1.2 Add available geological information from wells, review analysis and evaluation
   2.1.3 Stress field assessment
   2.2 Modelling plane selection for 3D model
   2.3 Fractures and anisotropy in permeability

3. Developing a 3D block model
   3.1 Review of the DMT - Petrel file - workshop
   Evaluate drill paths
   3.2 Mapping depth structure and thickness

4. Publication of results
Geophysical exploration program

- During a work over operation in the thermal well Bad Waldsee GB 2 the LIAG team Petrophysics and Borehole Geophysics started a measuring program in week 26/2016

- This program included caliper and temperature logs, borehole imaging and a VSP

- Due to a borehole plug induced by scalings at – 540m the program was suspended until October 2016

- Based on the imaging deficiencies of 2D seismic profiling and on the results of the preliminary 2D geological model a 3D seismic survey has become indispensable at least for well engineering and the POS-Study

- Design of a 3D seismic survey
Data research
Reservoir simulation represents an essential tool for engineering and later management of a geothermal reservoir. Therefore existing seismic profiles from O&G exploration and borehole data were selected for data reprocessing and a subsequent reservoir modeling and simulation in order to determine:

- reservoir structure, fault locations, permeability structures as potential targets
- fluid recharge and discharge locations for the protection of the existing two thermal wells
Bad Waldsee Seismic Lines

- Seismic lines are in time domain (Top of seismic is 0 sec)
- Paper profiles, wells, maps are in depth
- Visualized map lies in - 3000 m NN
- Arrow shows North, green side up means view from top of data
DMT - Reprocessing of seismic lines

Generation of (time-)areas from reflector picks for a velocity model (top Malm)
DMT - Reprocessing of seismic lines

Generation of (time-)areas from reflector picks for a velocity model (top Muschelkalk)
Comparison between original data, DMT reprocessed data and IMAGE-TNO reprocessed data

- Original data: field data and stacks from ExxonMobil and Wintershall
- DMT reprocessed data: migrated stacks made from reprocessed pre-stack field data
- IMAGE - TNO reprocessed data: stacks made from original data and from reprocessed DMT stacks

Comparison to:
1. see how much overall improvement was achieved with both methods
2. see the differences and reinforcements between the two reprocessing methods
TNO reprocessing of Bad Waldsee seismic data

✓ Reprocessing method: Non Local Means (NLM) seismic filter, developed in European IMAGE project

✓ NLM is non-linear algorithm: continuity enhancing, edge-preserving, amplitude preserving Filters seismic pixels by averaging only with neighbouring pixels having similar neighbourhoods

✓ Is ranked as best-performing algorithm for image de-noising in IEEE Digital Image community

✓ One of the first applications on seismic data

✓ Performs well on common workstations, has been parallelised by TNO on High Performance Cluster
IMAGE – TNO Reprocessing of DMT seismic data

DMT REPRO
DAT 730023

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IMAGE – TNO Reprocessing of DMT seismic data

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IMAGE – TNO Reprocessing of original seismic data

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IMAGE – TNO Reprocessing of original seismic data

IMAGE - TNO REPRO
DATA 8604

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IMAGE – TNO Reprocessing of original seismic data

ORIGINAL DATA 8802

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IMAGE – TNO Reprocessing of original seismic data

TNO REPRO
DATA 8802

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Conclusions

✓ Two methods of reprocessing both show great improvement in data: better amplitudes, continuity, faults

✓ Two methods of reprocessing differ in improvement: DMT pre-stack reprocessing usually superior. However, TNO post-stack reprocessing is often similar to DMT results

✓ TNO reprocessing of DMT results even better: two methods enhance each other

✓ TNO-DMT reprocessed data gives more confidence in model and may lead to new geological insight

✓ SBW is now working with best possible seismic datasets ---> lowest possible risk from seismic model
Productivity risk insurance for geothermal projects - requirements

1st step: Feasibility study

2nd step: Independent expert report for the assessment of the feasibility study
- Reservoir model

3rd step: Technical description
- Well engineering
- Permits
- Qualified project management,
- Drilling company/-rig
- Detailed economic efficiency calculation
- POS - Study

4th step: Financing

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Public funding is a key to success …

We successfully participated at the local contest for the European Regional Development Fund EFRE receiving non-refundable subsidies of up to 3 Mio EUR.

A condition precedent subsidy from the local state of Baden Wuerttemberg may cover the finder’s risk of the first well up to 1 Mio EUR.

The state owned KFW Bank offers programes for public entities: loans with partial takeover of risk to finance geothermal wells. The risk mitigation scheme will cover the finders risk and therefore promotes geothermal district heating projects.
Thank you very much for your attention and interest!

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