Geothermal exploration – ensuring an optimized utilization of geothermal energy in low-enthalpy sedimentary settings

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Summary

An adequate comprehensive understanding of the subsurface geology is a pre-requisite for a precise planning and successful operating of geothermal applications and reduces the financial risks considerably. An exploration concept is needed which is tailored for the geological setting to be evaluated and the level of exploration performed prior to the geothermal exploration. We present examples from ongoing geothermal exploration projects encompassing, for example, studies on the geological structure, including the stress field, on the hydraulic and thermal properties of geological formations, and on the temperature prognoses for target reservoirs.

Introduction

From a global view, only a marginal part of the underground heat is used until now. The construction of district heating (and cooling) networks is seen as the most competitive geothermal energy technology for the near future. In addition, methods using enhanced geothermal systems (EGS) are available. The direct use of thermal fluids from aquifers and from EGSs include costs and risks, which can be reduced by a better knowledge and understanding of the subsurface, including a proper characterization of rock and field properties. Therefore, an integrated geothermal exploration is needed to optimize the utilization of geothermal resources.

Approach

We follow up a concept of geothermal exploration that incorporates several branches of geosciences: geophysics, geology, geochemistry, hydrogeology and pure geothermics (including heat flow and temperature studies) (Fig. 1). The design of this concept is heavily dependent on the state of exploration that the sedimentary basin has undergone prior to the geothermal-targeted exploration. If the basin was already explored for hydrocarbons, a wealth of legacy data is available to be incorporated into geothermal studies. Usually, as a result of previous exploration, the main features of the basin and the basin filling are already known. In-depth information however is usually restricted to geological formations that formed the targets of hydrocarbon research. Although the implementation of legacy data into geothermal exploration is indispensable, they need a careful quality screening and, if necessary, a re-interpretation. The preferred way to characterize geological formations according to their lithology and their hydraulic and thermal properties is the use of borehole information (well-log analysis) and core (laboratory measurements). The drilling of geothermal exploration/appraisal wells may become necessary if well logs or cores are not available to decipher and quantify the aquifer/aquitard system of a basin and delineate suitable “geothermal” aquifers. The qualification of these aquifers or geological formations for a geothermal use also includes a temperature prognosis. If the general structure of the basin is known, e.g. by seismic profiling, a regional temperature model can be generated using the surface heat flow and the thermal and hydraulic properties of the formations as inputs and measured temperatures (logs, BHTs, DSTs) to verify the model. Recent developments in pilot geothermal projects in sedimentary basins have shown that the hydrochemistry of the aquifers may be the most sensitive parameter for a successful and economic installation of a heat or power plant. This calls for a comprehensive investigation of the fluid chemistry of a basin (retrievable through borehole tests) and its impact on geoengineering aspects. Although the aforementioned steps of the exploration technology do not follow a strict hierarchy, they show that both the regional scale as well as the local (borehole) scale needs to be considered. The subsequent increase of data and specific knowledge, however, calls for a thoroughly integration of all available data to obtain an enhanced understanding of the subsurface conditions. Only through such integration, a thorough planning of surface installations can be assured and the overall risks of geothermal projects reduced (Fig. 1).

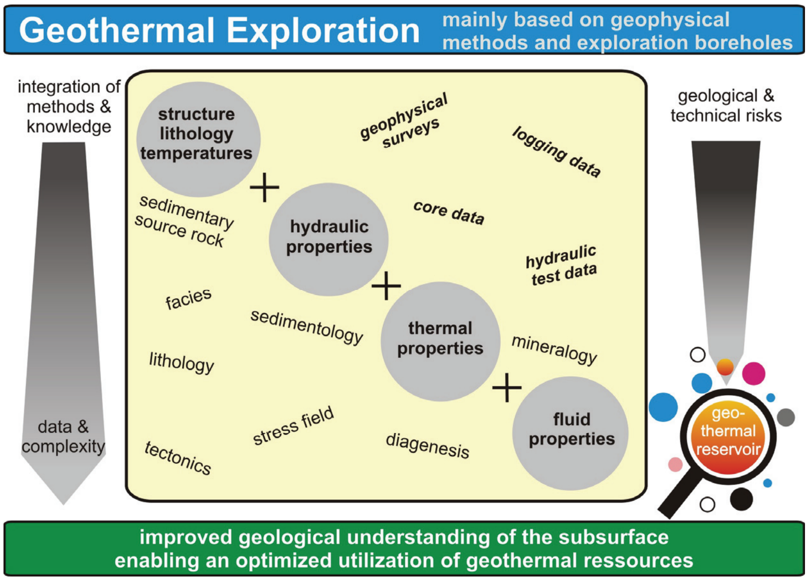

Figure 1 *Find the hidden reservoir! To decipher the properties of the subsurface, a specific exploration concept needs to be developed, integrating all accessible geological and geophysical data to minimize geological and technical risks*

Examples

The **geothermal potential of Alberta**, Canada, is investigated by re-interpretation of available data of the oil and gas exploration and by selective core investigations. Methods applied include 3D geological modelling merging a dataset from more than 7000 boreholes, the reinvestigation of hydraulic core data, and the realization of new core measurements where data is scarce (Weides et al., 2012). In the **North German Basin**, the evaluation of rock thermal properties to describe the thermal field was in the focus over several year of research. Parameters measured include thermal conductivity, thermal diffusivity, heat capacity, density, porosity, and pore content. The methods to assess these properties comprise laboratory measurements and approaches to deduce thermal properties from well-logs (Norden & Förster, 2006; Norden et al., 2008; Fuchs & Förster, 2010). In order to enhance the properties of a geothermal reservoir, **EGS technology** is applied to stimulate a deep geothermal reservoir by increasing reservoir permeability and thus, well productivity. Because production and injection rates of geothermal systems are much larger than from oil and gas wells, the stress field plays an important factor for the EGS development. An iterative concept of stress-field determination is developed from the EGS site Groß Schönebeck, Germany (Moeck, 2012).

Conclusion

An integrated geothermal exploration is needed to optimize the utilization of geothermal resources.

References

Weides, S., Moeck, I. & Majorowicz, J. 2012. Geothermal Exploration of Paleozoic Formations in Central Alberta, Canada. Proceedings, 74th EAGE Conference, Copenhagen.

Moeck, 2012. Iterative development of stress models for deep geothermal reservoirs. Proceedings, 74th EAGE Conference, Copenhagen.

Norden, B., Förster, A., 2006. Thermal conductivity and radiogenic heat production of sedimentary and magmatic rocks in the Northeast German Basin. AAPG Bulletin 90(6), 939–962.

Norden, B. ,Förster, A., Balling, N., 2008. Heat flow and lithospheric thermal regime in the Northeast German Basin.Tectonophysics 460, 215–229.

Fuchs, S., Förster, A., 2010. Rock thermal conductivity of Mesozoic geothermal aquifers in the Northeast German Basin, Chemie der Erde 70(S3), 13–22.