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Geothermal Energy

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Workshop "Geothermal fluids in saline systems"

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Abstract

Earth's crust offers a vast resource of heat that can be used and converted into energy both for electricity and heating/cooling purposes. The utilization of this geothermal energy can make an important contribution to meet the targets of the envisaged energy turnaround. So-called "conventional" geothermal plants exploiting hot hydrothermal reservoirs have long been a fully commercial contributor to the energy provision in favorable geological settings such as Iceland or Tuscany/Italy. The concept of Enhanced Geothermal Systems, however, is a much younger approach to make the heat stored in Earth's crust available for a stable supply of heat and power, independent of specific geological conditions. Such systems offer an enormous potential for a sustainable energy concept since they provide base-load energy and therefore constitute an important cornerstone in a future energy mix as counterpart to the increasing share of fluctuating energy sources being furthermore poor on CO_2 emissions and practically inexhaustible. This *Geothermal Energy* article collection is intended to document a workshop held at the Karlsruhe Institute of Technology (KIT) on the 24th and 25th of November 2016. The workshop was planned as a discussion platform for the Helmholtz Program "Renewable Energies; RE" Topic 4 "Geothermal Energy Systems" with the partners German Research Centre for Geosciences (GFZ), KIT and Helmholtz Centre for Environmental Research (UFZ) jointly working together over the Helmholtz Program-Oriented Research (POF-3) funding period 2015–2019.

Editorial

Topic 4 of the Renewable Energy Program of the Helmholtz Association focusses *inter alia* on the sustainable and cost-efficient use of geothermal reservoirs for base-load supply of heat and electricity by EGS. Current EGS projects show the limitations of such systems. Firstly, the localization of a potential reservoir prior to drilling still remains a major challenge. Secondly, the mining risk is often too high to invest in survey and drilling costs are high as well. Thirdly, operation and management of a geothermal system face specific challenges with respect to the often aggressive chemical environment of the thermal waters. Finally, the societal integration has to be pushed forward as e.g., public acceptance of geothermal plants is often low due to possible seismic events.

EGS demonstration projects such as the geothermal plant in Soultz-sous-Forêts in the Upper Rhine Graben or the GFZ geothermal research platform Groß Schönebeck have shown the general technical feasibility of the EGS approach using innovative stimulation

techniques. The operation, however, is often interrupted due to technical reasons mainly having its nature in the hydro(bio)chemical complexity of the fluid system.

Fluids from the deep subsurface are not only of high temperature, but usually of high salinity and complex chemical composition. The reactions of fluids frequently result in precipitation of unwanted and often radioactive scales. Correct handling and understanding of those fluids and their chemical interactions is essential for a safe and reliable geothermal power plant. This handling of hot and saline fluids, however, is often extremely difficult, due to their high reactivity, aggressivity, and complicated chemical interactions.

Problems usually start with analytical issues because the high salinities of several 100 g/L require strong dilutions. In addition, the complex formation with ligands affect the measurements and delicate materials simply corrode. Furthermore, the prediction of chemical reactions in a reservoir demands the application of geochemical modeling tools. However, even equilibrium calculations are often inaccurate due to high salinities that require the application of Pitzer coefficients for calculating ion activities. These Pitzer parameters, however, are not known to date for many chemical components, relevant for geothermal systems. Similarly, kinetics or electrochemical reactions have hardly been investigated.

All these issues related to the problematic handling of saline fluids were addressed during the workshop with a special focus on analytical methods, on lab and field investigations and monitoring techniques, as well as on thermodynamic/chemical modeling coupled to thermo-hydraulic tools.

Beside the manuscripts submitted and published in this collection several other oral presentations were given, which are shortly summarized in this preface to give the interested reader a feeling of the broadness of topics addressed during the workshop. Furthermore, 14 poster presentations were given. All abstracts of the oral and poster presentations can be provided upon request from the corresponding author.

Invited speaker Thomas Kölbel (EnBW, Energie Baden-Württemberg AG) gave a talk on the operator perspective of challenges concerning saline geothermal fluids. At the end of his presentation showing the development of geothermal energy in Germany and France, he summarized some views and wishes. Concerning EnBW's own research strategy, the long-term goal is to provide electricity and heat from deep geothermal energy in the German energy market. The research areas from the operator's perspective should focus on flexible concepts, systems scale-up and multi-well/lateral systems, combined heat and power generation, optimization of current techniques and improvement of reliability, introduction of new technologies, and improvement of security and sustainability. Finally, reflections on the research community included the willingness to work also on the operator's demands and being flexible with "short reaction times." The experience made by EnBW is that large projects are often very time-intensive, so researchers should not lose sight of "small" project ideas.

The workshop was subdivided into three sessions entitled "Thermodynamics and Fluid Characterization," "Secondary phases," and "Modeling approaches." The following presentations have not been submitted as full manuscripts to this article collection, but are in press or published in peer-reviewed journals elsewhere:

- Marcus Altmaier et al. (KIT) gave an overview of the conceptual and experimental approach concerning the thermodynamic description of high ionic strength systems (SIT, Pitzer) critically evaluating the relation between "measured pH" and the molal proton concentration $-\log[H^+]$ in high ionic strength media. Examples include the solubility and speciation of trivalent elements, e.g., Nd(III) in NaCl, $MgCl_2$, and $CaCl_2$ media and the presentation of the OECD-NEA Thermodynamic Database Project, the NEA-TDB State-of-the-Art Report on Pitzer modeling of high ionic strength systems and the German THEREDA thermodynamic reference database.
- Xavier Gaona et al. (KIT) presented the fundamental experimental work on the U(VI) solubility and speciation in concentrated NaCl and $MgCl_2$ solutions building to a large extend the basis of the Pitzer consistent dataset currently considered in the German thermodynamic database project THEREDA. A second contribution focused on the effect of temperature in the range from 5 to 90 °C on the solution speciation for U(VI) and its thermodynamic description.
- Harald Milsch et al. (GFZ) presented a comprehensive evaluation of the existing thermophysical fluid data published in the literature on the parameters density, viscosity sonic velocity, specific heat, thermal conductivity, and electrical conductivity and its statistical evaluation. Goal is to develop and establish site independent mixing rules to predict thermophysical characteristics of site-specific saline fluid by composition only. Where gaps are identified new analytical results are provided through GFZ experimental developments, where off-the-shelf solutions are not available.
- Andrea Vith-Hillebrandt et al. (GFZ) presented different analytical techniques to characterize dissolved organic carbon (DOC) in geothermal fluids to be used as a tool to characterize the in situ geochemical reactions as well as microbiological processes. The special focus in the presentation was set on the origin and fate of low- and high-molecular weight polar organic compounds.
- Henning Francke (GFZ) presented the tool BrineProp for the calculation of fluid properties (*inter alia* density, enthalpy, specific heat capacity, viscosity, and thermal conductivity for the liquid and aqueous phase) in the geothermal context ranging roughly for $T = 1–150$ °C, $p = 1–500$ bar and chloride salinity up to saturation. This code is available online and can be downloaded under: https://github.com/Heineken/BrineProp.
- Finally, Haibing Shao (UFZ/TU Freiberg) presented the water–rock interaction influenced by in situ THM conditions, which can significantly alter the fracture permeability due to geometrical changes of the fracture surfaces and the aperture distribution/void spaces. The model was set up using the FEM-based open source simulator OpenGeoSys with IPhreeqc and takes into account the aqueous-geochemical system as well as pressure solution process at asperity contacts. Based on this study, pressure solution is an active process under high contact stress and in terms of a near-equilibrium aqueous system some type of Al-bearing secondary mineral should be formed along the flow path in the system investigated.

To summarize, our motivation for this article collection was to sensibilize the geothermal energy community to the topic and give a small insight into part of the Helmholtz Program "Renewable Energies; RE" Topic 4 "Geothermal Energy Systems" related to the thermal water circuit.

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