1 Executive Summary

The federal state of Niedersachsen (Lower Saxony) pursues the ambitious goal to maximize the use of its geothermal potential for the supply of thermal heat and electrical power. The political requirement for the generation of electrical base load power was 5 MW_{el} net per geothermal power plant or more.

To achieve this objective economically requires a supply of thermal fluids to a geothermal power plant at high rates and high temperatures, and at minimized capital expenditure and operating costs. To provide the high temperatures, deep wells are necessary under typical geological conditions in Niedersachsen. To achieve the necessary high rates at the depths considered, fracture systems must be developed to allow an efficient heat exchange and to reduce the inflow resistance into the well. The fracture systems may be either naturally present or artificially created. Also, high rate fluid supply requires wells of large diameter for low outflow resistance out of the well. The construction of the subsurface systems demands materials and electronic components which operate reliably under the deep hot, hard rock conditions. The systems must be sustainable, a challenge in view of the corrosivity and scaling tendency of the high salinity formations brines, encountered at sub salt levels in Northern Germany. Total costs of geothermal projects are dominated by the costs for the construction of wells and geological heat exchangers. Well costs for deep natural gas wells in Niedersachsen average approx. 2.5 Million Euro per 1.000 m, which is too high to achieve satisfactory economics for geothermal application. Well cost analysis shows that a significant cost reduction is only possible by a novel approach to the construction concept of deep wells.

To meet all these challenges requires a multi-disciplinary approach focusing first of all on the issues that have the largest impact, i.e. the safe construction of wells under “hot-hard rock” conditions and the development of sub-surface heat exchangers at significantly reduced costs and risks. To this end the „Niedersächsisches Ministerium für Wissenschaft und Kultur“ (MWK) has initiated a research collaboration program “Geothermal Energy and High Performance Drilling” (gebo). The collaborative program, co-financed by Baker Hughes, is a 5-year effort funded with approx. 12 Million Euro. The program, coordinated by the “Energie-Forschungszentrum Niedersachsen” (EFZN), combined the traditional strengths of the participating Niedersachsen based universities and research institutions in geosciences, drilling technology, materials science and technical systems. More than 40 gebo financed scientists and engineers collaborated to evaluate existing and develop new concepts, materials and components. The program was carried out in close coordination with the participating industry. gebo university based research excels with a high-risk, “high-end” approach, that will typically not be covered by typical industry development activities. Although all projects were directed towards improving the economics of geothermal energy recovery from petrothermal systems, significant gebo “spin-off” effects are expected to benefit a broader industrial sector, in particular from the materials and systems technology research.

The objective was pursued in 32 projects organized in four focus areas: Geosystems, Drilling Technology, Materials, and Technical Systems. The accountability for achieving the overall objective rested with a Steering Committee, make up of a speaker, the focus area coordinators and representatives of the participating industry. Steering Committee and MWK were advised by the gebo Advisory Board, comprising members from the international research community, industry, geothermal operators and the banking sector.

The opening event for the program was in May 2009. While first projects resumed their work as early as February 2009, staffing for some projects took as long as mid 2010. Reasons were administrative restrictions and difficulties in finding the required skills. In the meantime precautions have been taken to ensure a timely successful completion of all projects by 2014. Altogether, progress of the gebo program was in line with the plan documented with the formal application document as of June 2009.

Main achievements to date were as follows:

Coordination and General Overview: Communication and steering efforts to establish a common knowledge basis for the parties from very different disciplines and the alignment of their contributions towards the goal set was recognized as a major challenge. To this end Steering Committee, Advisory Board and monthly “Jour Fixe” meetings were successfully carried out. In particular the latter proved very effective in aligning the individual efforts and to share knowledge.

Early emphasis has been put on networking with international organizations (Geoforschungszentrum Potsdam; Marinnovation, Frankreich; University Stavanger, International Research Organization Stavanger; Texas A&M University; US Department of Energy) which has provided and will provide valuable input.

Progress achieved was documented in more than 150 publications of which more than 35 have appeared in referenced in traceable journals and conference proceedings and 9 patent applications up to end December 2014. Progress achieved in the 4 focus areas is summarized below.

To ensure fit-for-purpose contributions a sample petrothermal system was defined, consistent with the political requirements, and a construction concept to develop the system is proposed. Some of the key requirements are a true vertical depth (TVD) of 6.000 m, a fluid production of 100 l/s, and a bottom hole flowing temperature of 200 °C.

The well bore construction concept assumes conventional or casing drilling down to approx. 1.000 m followed by conventional or coiled tubing drilling of a constant diameter well of size 10 3/4 in. to the target depth. The lower section is assumed to be cased with a folded pipe to be expanded to a diameter of 8 5/8 to 9 in. once setting depth is reached.

Focus Area Geosystem: For the success of a geothermal project, the hydraulic properties and temperature of the geothermal reservoir are crucial. New methodologies in seismics, geoelectrics and reservoir geology are currently being tested at locations where structures of interest are found at or near the surface before applying them to target depth. Tools were developed (Benchmark models and experimental techniques) that help in the evaluation and interpretation of acquired data. Special emphasis was placed on the investigation of rock properties, on the development of early reservoir assessment even during drilling, and on the interaction between the drilling apparatus and the reservoir formation. The propagation of fractures and the behavior of fluid and heat transport within the regional stress field were investigated using different approaches (field studies, seismic monitoring, multi-parameter modeling). Geologic structural models have been created for simulation of the local stress field and hydromechanical processes. Furthermore, a comprehensive dataset of hydrogeochemical environments was collected allowing characterization and hydrogeochemical modeling of the reservoir.

Focus Area Drilling Technology: Project work addressed features and processes related to drilling and the construction of geothermal wells under hot-hard rock conditions. Particular emphasis was placed on differences in processes (borehole hydraulics, borehole stability, rock destruction, cuttings transport, drill string dynamics, etc.), procedures (pipe handling, drilling process) and reservoir simulation (heat recovery) of geothermal relative to standard oil and gas well construction caused by the hot-hard rock environment and the selected construction concept. In order to drive geothermal plant economics, the current well construction concept was focused on a mono-diameter well design. Efforts were also directed towards integrating the different process models with a view to develop a concept for a drilling simulator that is able to support well planning and execution. Several novel geothermal one and two well designs were defined for evaluation of viability, energy recovery, and costs.

Focus Area Materials: The fatigue resistance and life cycle of modern drilling technologies are restricted by the severe environmental conditions. The mechanical loads caused by drilling in increased depths and through hard formations, as well as high ambient temperatures in wells are very critical. Moreover, the strains caused by ambient pressures and corrosive media are of great importance. New materials, material coatings, tools and systems are required. Therefore, the following efforts are being made: For a proper design of drilling systems the strains must be characterized realistically; high strength, heat resistant and corrosion resistant materials and coatings as well as material-adapted processing techniques and novel composite designs must be developed. The achieved objectives were a test environment for stress analysis, realistic synthetic load spectra and first life time calculations. Furthermore, functional coatings and welding techniques were being developed as well as geometries of folded tubulars which were also expanded in simulations.

Focus Area Technical System: Electronics in downhole tools (Measurement While Drilling “MWD”) use large scale integrated electronic circuits for control and measurement tasks, but such electronic components are not commercially available for the expected ambient temperatures at present. Therefore, one contribution for the gebo project was to investigate the possibilities for a realization of MWD-electronics on the basis of “Silicon on Insulator” (SOI) technology and to identify the best-suited processor architecture designs. With active cooled circuit boards it is possible to protect these components against high temperatures. A high-temperature resistant die attach was developed for electronic devices and sensors to be used for data logging during extreme conditions. For the navigation of the drilling assembly and for the determination of the ambient formation characteristics, various sensors for operation temperatures up to 250 °C were developed and tested. The feasibility of a complete new antenna design for a Ground Penetrating Radar inside the BHA was investigated, so the drill process could be optimized thanks to the detection of boundary layers (“frac zones”) within the hard-rock geothermal pay zone.

2 General Information

2.1 Organizational overview

2.1.1 Management structure

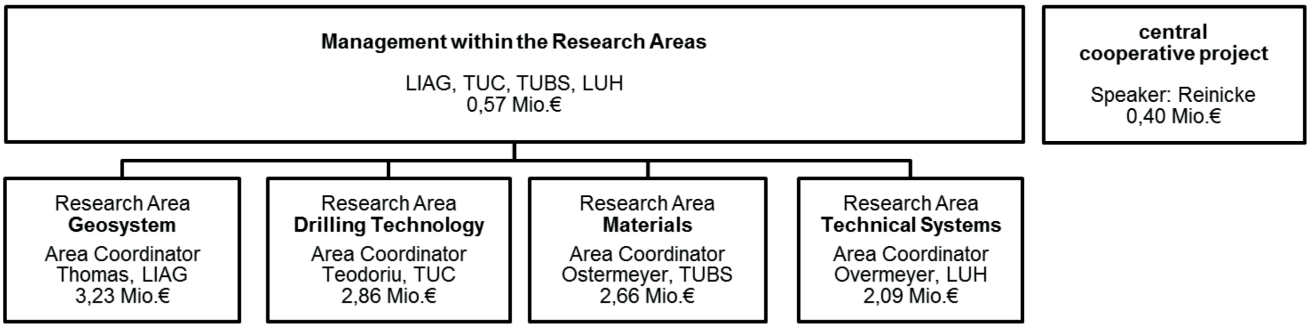

Figure 1: Organisation of the Collaborative Research Program gebo

Baker Huges Contacts were:

- Geosystem — Dr. Anne Bartetzko
- Drilling Technology — Dipl.-Ing. Jörg Lehr
- Materials — Dr.-Ing. Hendrik John
- Technical System — Dr.-Ing. Thomas Kruspe
- Steering Committee — Dr.-Ing. Joachim Oppelt

2.1.2 Summary table of the technical projects

No.	project title	responsible
	Geosystem, Dr. Thomas, LIAG	
G1	Detection of Fault Zones Using Seismic Methods	LIAG: Thomas / Buness
G2	Detection of Fault Zones Using Electric and Electromagnetic Methods	LIAG: Grinat / Günther
G3	Heterogeneous Rock Properties, Drilling Efficiency and Fracture Propagation	UGOE: Philipp
G4	Characterisation of Enhanced Geothermal Reservoirs by Diagnostic Methods	BGR: Wegler
G5	Hydromechanics of Geothermal Reservoirs	LIAG: Schellschmidt / Schulz
G6	Hydraulic, Heat and Tracer Tests at Wellbore and Reservoir Scale	UGOE: Sauter
G7	Modelling of Coupled Thermo-hydro-mechanical Processes in Georeservoirs	UGOE: Sauter
G8	Electrical Impedance Tomography for the Characterisation of Geothermal Systems	TUBS: Hördt
G9	Hydrogeochemical Processes in Geothermal Systems	TUC: van Berk

Drilling Technology, Dr. Teodoriu, TUC

B1	Cost effective drilling methods for „hot-hard-rock“ conditions	TUC: Teodoriu
B2	Drilling Simulator	TUC: Teodoriu
B3	Automation of the drilling process by application of a flexible drill string	LUH: Overmeyer, Denkena
B4	Geo parameters from well logging and their utilization	TUC: Hou, LIAG: Wonik
B5	Assurance of efficient drill cuttings transport	TUC: Brenner, Reinicke
B6	Computer simulation of fluid dynamics	TUBS: Krafczyk
B7	Drill string dynamics and modeling	TUBS: Ostermeyer
B8	Monitoring and control of drill string loads	TUC: Teodoriu
B9	Innovative drilling concepts for geothermal energy exploitation	TUC: Teodoriu, TUBS: Ostermeyer

Materials, Prof. Ostermeyer, TUBS

W1	Life cycle of Coated High-Performance Materials	TUBS: Rösler
W3	Materials and Surfaces for Extreme Demands	TUBS: Klages
W4	Coatings with High Electrical Conductivity and Abrasion Resistance	LUH: Bach
W5	Materials, Welding and Machining Technology for Deep Drilling	LUH: Bach (IW), Denkena (IFW)
W6	Desing of Folded Tubulars for Casing Applications	LUH: Bach (IW), Denkena (IFW)
W7	Design of Fatigue Resistant Mechanical Components for Drill String Applications	TUBS: Ostermeyer TUC: Esderts
W8	Technical Systems Reliability of Downhole Components	TUC: Esderts, Beck

Technical System, Prof. Overmeyer, LUH

T1	High Temperature Electronics	LUH: Blume, Barke
T2	Joining and Packaging Techniques for High Temperature Electronics	TUBS: Waag, Peiner
T3	Packaging of Electronic Components for High Temperature Applications (substrate and heat dissipation)	LUH: Overmeyer
T4	Thermal Management	TUBS: Schilling, Ludwig
T5	High Temperature Sensors	LUH: Reithmeier. Rissing
T6	Fluxgate Sensors for 250 °C	TUBS: Schilling, Ludwig
T7	Intelligent Sensor-based Drilling Tools	LUH: Overmeyer

Management of Projects and Collaborative Research Program

GS, BS WS, TS	Management within the research areas	Speaker of research areas
Z	central cooperative project	TUC: Reinicke, EFZN: Mattioli

2.1.3 List of all gebo project managers

name, first name, academical title	**Institute**	**project no.**
Bach, Friedrich-Wilhelm, Prof. Dr.-Ing.	LUH, Institut für Werkstoffkunde	W4, W5, W6
Beck, Hans-Peter, Prof. Dr.-Ing.	TUC, Institut für Elektrische Energietechnik	W8
van Berk, Wolfgang, Prof. Dr.	TUC, Institut für Endlagerforschung	G9
Brenner, Gunther, Prof. Dr.-Ing.	TUC, Institut für Technische Mechanik	B5
Blume, Holger, Prof. Dr. Ing.	LUH Elektrotechnik, Institut für Mikroelektronische Systeme (IMS)	T1
Denkena, Berend, Prof. Dr.-Ing.	LUH Maschinenbau, Institut für Fertigungstechnik und Werkzeugmaschinen (IFW)	B3, W5, W6
Esderts, Alfons, Prof. Dr.-Ing.	TUC, Institut für Maschinelle Anlagentechnik und Betriebsfestigkeit	W7, W8
Grinat, Michael, Dipl.-Geophys.	LIAG, S2, Geoelektrik und Elektromagnetik	G2
Hördt, Andreas, Prof. Dr.	TUBS, Institut für Geophysik und Extraterrestrische Physik	G8
Hou, Michael Zhengmeng, apl. Prof. Dr.-Ing. habil.	TUC, Institut für Erdöl- und Erdgastechnik	B4
Klages, Claus-Peter, Prof. Dr.	TUBS, Institut für Oberflächentechnik	W3
Krafczyk, Manfred, Prof. Dr.-Ing. habil.	TUBS, Institut für rechnergestützte Modellierung im Bauwesen	B6
Ludwig, Frank, Dr. AOR	TUBS Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik	T4, T6
Ostermeyer, Georg-Peter, Prof. Dr.-Ing. habil.	TUBS, Institut für Dynamik und Schwingungen	B7, B9, W7, **WS**
Overmeyer, Ludger, Prof. Dr.-Ing.	LUH Maschinenbau, Institut für Transport- und Automatisierungstechnik (ITA)	B3, T3, T7, **TS**
Peiner, Erwin, Dr. rer. nat...	TUBS, Institut für Halbleitertechnik	T2
Philipp, Sonja, JProf. Dr.	UGOE, Geowissenschaftliches Zentrum, Abteilung Strukturgeologie und Geodynamik	G3
Reinicke, Kurt M., Prof. Dr.	TUC, Institut für Erdöl- und Erdgastechnik	B5, **gebo-speaker**
Reithmeier, Eduard, Prof. Dr.-Ing.	LUH Maschinenbau, Institut für Mess- und Regelungstechnik (IMR)	T5
Rissing, Lutz, Prof. Dr.-Ing.	LUH Maschinenbau, Institut für Mikroproduktionstechnik (IMPT)	T5
Rösler, Joachim, Prof. Dr.	TUBS, Institut für Werkstoffe	W1
Sauter, Martin, Prof. Dr.	UGOE, Geowissenschaftliches Zentrum, Abteilung Angewandte Geologie	G6, G7
Schellschmidt, Rüdiger, Dipl. Geophys.	LIAG, S4, Geothermik und Informationssysteme	G5
Schilling, Meinhard, Prof. Dr. rer. nat.	TUBS, Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik	T4, T6
Schulz, Rüdiger, Dr.	LIAG, S4, Geothermik und Informationssysteme	G5
Teodoriu, Catalin, Dr. Dr.-Ing.	TUC, Institut für Erdöl- und Erdgastechnik	B1, B2, B8, B9, **BS**

Thomas, Rüdiger, Dr. rer. nat.	LIAG, Ltg., Forschungsschwerpunkt Geothermische Energie	G1, **GS**
Waag, Andreas, Prof. Dr. rer. nat. habil.	TUBS, Institut für Halbleitertechnik	T2
Wegler, Ulrich, Dr. rer. nat.	BGR, B4.3, CTBT, seismologisches Zentralobservatorium	G4
Wonik, Thomas, Dr.	LIAG, S5 - Petrophysics and Borehole Geophysics	B4

2.1.4 Participating public facilities as well as expressions of interest from industrial and other partners

The gebo Collaborative Research Program comprised scientists and technicians of different research institutions and universities who were working in 33 projects. The individual projects were assigned to one of the 4 main research fields or focus areas. They were described in more detail in one the “Main Field” pages.

The gebo Collaborative Research Program started its activities in 2009 with 7 project partners participating:

- Federal Institute for Geosciences and Natural Resources, Hanover
- Energie-Forschungszentrum Niedersachsen, Goslar
- Leibniz Institute for Applied Geophysics, Hanover
- Gottfried Wilhelm Leibniz University, Hanover
- Technische Universität Carlo-Wilhelmina zu Braunschweig
- Clausthal University of Technology, Clausthal-Zellerfeld
- Georg-August University Göttingen, Göttingen

Baker Hughes, as an industry partner, participated by providing its experience as well as financial funds.

2.2 Scope and Objectives Overview

2.2.1 Introduction

“The federal state Niedersachsen (Niedersachsen) pursues the ambitious goal to make comprehessive use of its geothermal potential for the production of thermal heat and electric power”. This was the statement of the Niedersachsen Minister for Science and Culture, Mr Lutz Stratmann on the occasion of the startup event of the new Collaborative Research Program “Geothermal Energy and High Performance Drilling, gebo” on May 20, 2009.

Despite relatively moderate temperatures in the geological subsurface, the preconditions in Niedersachsen are good, for this state to achieve its goals: It possesses a considerable geothermal potential. The knowledge of the geological subsurface, resulting from more than 20.000 oil and natural gas wells, and 2D and 3D seismic, is good. In addition, the scientific and industrial infrastructure for exploration and development of the geological subsurface is excellent. The development of deep geothermal energy is, however, connected with high costs and risks. They result in particular from the expensive and time-consuming construction of the necessary deep boreholes and required geological heat exchangers.

The goal of the gebo Collaborative Research Program was to carry out research and survey new concepts to improve the economic efficiency of geothermal energy recovery from deep geological formations. With its focus on innovative aspects of drilling and of subsurface heat exchanger development, the association addresses those aspects of geothermal power projects for which both costs and risks are the highest (ca. 70% of the total investment). The gebo Collaborative Research Program united the traditional strengths of the participating universities of the federal state of Niedersachsen and (independent) research institutions in geosciences, drilling technology, materials science and technical systems. In the association, more than 100 scientists and engineers collaborated to develop and evaluate new concepts, materials and components.

The project was carried out in close coordination with participating industry. The gebo Collaborative Research Program focused on broad-scale, partly extremely high-risk problems in the “High-End” area of research; at the same time, the participating industry was carrying out applied systems developments. From the work, directed towards improving the economics of geothermal energy recovery from petrothermal systems, significant gebo “spin-off” effects were expected to the industrial sector, in particular from the materials and systems technology research.

2.2.2 Background and genesis of the joint project

The comprehensive use of deep geothermal energy is to make a significant contribution to climate protection and a secure energy supply in the future. This is the conclusion of a report on geothermal energy enacted by the federal cabinet on May 13, 2009. By 2020 approx. 280 MW are to be installed to generate electrical power from geothermal energy. Assuming a capacity of 5 MW_{el} per power station, more than 50 stations must be built to achieve the objective.On the basis of two wells per station, more than 100 wells with sustainable high production capacities need to be constructed within the next 10 years. After 2020 an acceleration in the growth of the installed power production is expected with up to 850 MW installed capacity by 2030.

Niedersachsen’s preconditions for a usage of geothermal power from the deep subsurface are good: the geothermal potential is available, the knowledge concerning deep geological subsurface is profound, and the infrastructure for its exploration and development is nowhere better in Germany.

The geological conditions in Niedersachsen are challenging, however. The wells in Niedersachsen have neither the high production rates for thermal water as in the Molasse Basin (South Germany) nor do they have the high temperatures in the shallow sub-surface, as in the Oberrheintalgraben. In Niedersachsen wells must be drilled down to 6.000 m in order to reach a temperature level of 200 °C up to 250 °C, which is required for an efficient generation of electrical power. In addition, Niedersachsen brines are of high salinity, expected to lead to corrosion and scaling problems in the primary cycle of the thermal system. Hence, the resulting technological challenges for an efficient development of the huge potential are reflected by the goals of the gebo research association.

2.2.3 Current State of Research

There are 3 different systems for the recovery of geothermal energy:

- Hydro-thermal systems: utilization of the energy which is contained in the water of the deep subsurface
- Petro-thermal systems: utilization of the energy, which is contained in the rock of the deep subsurface (Hot-Dry-Rock (HDR), Hot-Wet-Rock (HWR), Hot-Fractured-Rock (HFR), Enhanced Geothermal System (EGS))
- Deep heat probe (borehole heat exchanger): uses wells up to 3.000 m deep in which a heat transfer liquid circulates in a closed system for heat production.

With the exception of wells in areas affected by volcanic activities, all three systems require deep boreholes. To achieve high production rates of hydro-thermal or petro-thermal systems, wells are drilled to connect to naturally existing fracture systems in the subsurface or fracture systems are generated in hydraulic treatments after the well has been drilled. To generate electrical power, only petro-thermal systems are relevant and to a certain degree hydro-thermal systems, if conditions are favourable.

The currently available technology for the construction of deep wells is adapted for the needs of the oil and natural gas industry. Oil and natural gas wells are constructed to provide a safe connection between a reservoir in the subsurface and the surface installations for the duration of the exploitation. This is also valid for geothermal wells, especially for hydro-thermal wells with final depths of 3.000 – 4.000 m. For petro-thermal systems, aiming at recovering the heat stored in “dry and hard” rock, well requirements are quite different from those in typical oil and natural gas wells:

- the average temperature is higher
- the target is not a relatively soft reservoir rock but hard rock, for example, volcanic rocks
- thermal operations require sustainable heat exchangers with large contact areas, either naturally existing or artificially created
- minimization of the hydraulic resistance in the wells during production and injection requires large cross sectional areas for flow
- the average depth is larger.

All these less favourable conditions require new solutions. At the same time, the system costs must be decreased: approximate cost in the oil and natural gas industry for 5.000 m wells are ca. 2,5 – 3,0 million Euros per 1.000 m. Well costs this high, are not economically efficient for deep geothermal systems. The main goal of the gebo Collaborative Research Program was therefore to make solid contributions to

- decrease the cost of drilling
- improve drilling technologies for hard and hot rock drilling
- improve the chance of success for achieving economic rates

2.2.4 Objectives of the joint project (goals)

The overriding objective of the gebo collaborative research program was making essential contributions for a safe construction of wells under the “hot-hard-rock” conditions existing in Niedersachsen and their further development to a geothermal system with sustainable geological heat exchangers.

This goal should be achieved by the investigation of highly innovative technology approaches as modelues of an overall concept for a novel construction of deep geothermal wells in hard rock

- in interdisciplinary cooperation of engineers and scientists
- in cooperation between industry and University, researchers and users.

Targets were to

- develop new technologies allowing a proper recording and characterization of the geological subsurface
- assure high well productivities by sustainable geological heat exchangers
- identify and explore ideas and concepts to decrease well construction costs, dominating the initial investment for geothermal power plants
- make critical contributions to the realization of a reliable operation of the modern drilling technology in a hot-hard rock environment with temperaures up to >200°C
- improve hard-rock drilling by developing new materials and tools
- make contributions to manage technical risks caused by high temperatures/production rates, cyclic loading, high salinity brines, etc.

2.2.5 Presentation of the research program

2.2.5.1 Research Area Geosystem

Various geophysical and geological techniques were being employed for the exploration of geothermal reservoirs. Combined seismic, geoelectrical and geological investigations were carried out at the Leinetalgraben north of Göttingen. This allowed for a complex investigation of a north German setting for a geothermal reservoir, characterised by the presence of fault zones. Using hydraulic and transport investigations, fluid flow and heat transport parameters (hydraulic conductivities, specific area, effective porosity, reservoir shape, geomechanic properties) did be quantified. Particular emphasis was also being placed on the assessment of the chemical composition of the highly saline brines and its effect on the formation of borehole skins. Finally, numerical models shall be developed investigating the effect of thermo-hydro-mechanical process coupling as well as for the prediction of the long-term development of the geothermal reservoir.

The following results were expected:

- exploration strategy for fault systems
- knowledge of reservoir characteristics for the optimum choice of the drilling technology
- determination and evaluation of relevant parameters by means of hydraulic, tracer and heat tests
- recommendations concerning reservoir behaviour in long-term simulation for efficient energy production.

Coordinator: Dr. Rüdiger Thomas
Baker Hughes Contact: Dr. Anne Bartetzko

Projects

The research area “Geosystem” consists of four categories, which work on nine projects. The four categories are: exploration, exploitation (development) and characterization of geothermal reservoir, as well as modelling of geothermal energy reservoirs.

The cooperation between the different geoscientific projects was strengthened by an interdisciplinary work package called “benchmark models”. In this work package, a set of representative models was generated which describes geological structures relevant for geothermal exploration in Niedersachsen. The models were the basis for numerical simulation of different physical processes carried out by several geoscientific projects. All Geosystem projects contribute to the work package “benchmark models”, which was coordinated within G8, with their knowledge either on geology, or on the physical parameters that were required to characterise the different geologic formations and the borehole. The intense discussion on the models had considerably increased the mutual understanding among the different disciplines.

Finally, the resulting set of models did be transferred to the other gebo research areas as well as the geoscientific public as representative geothermal reservoir models for the North German basin.

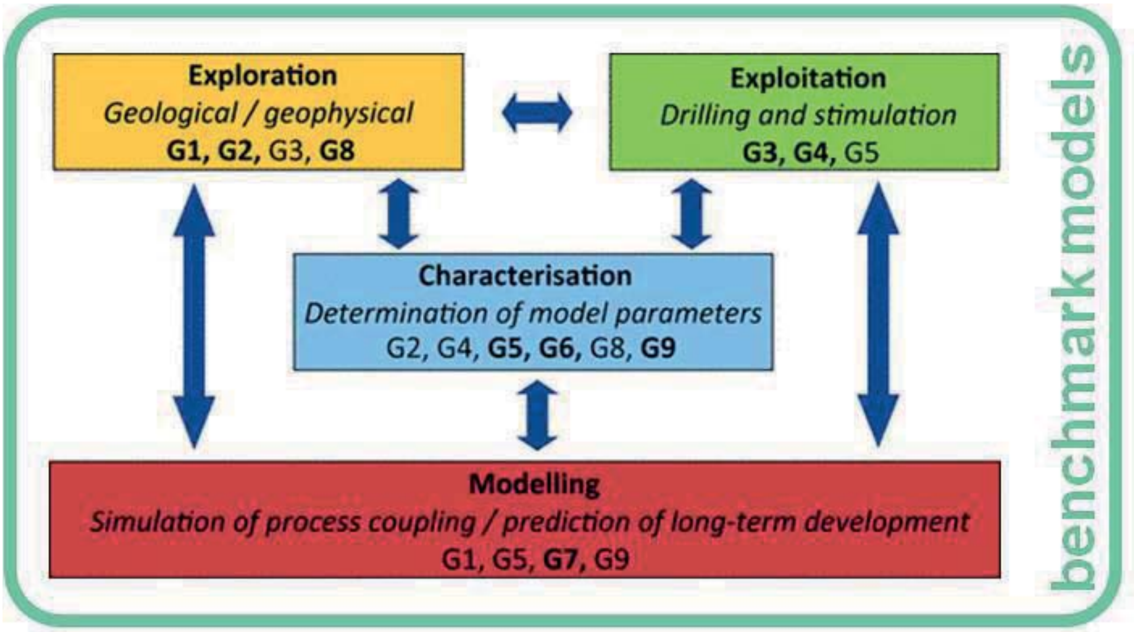

Figure 2: Networking inside the research area Geosystem

G1: Detection of Fault Zones Using Seismic Methods
Dr. Rüdiger Thomas, Leibniz Institute for Applied Geophysics (LIAG)

G2: Detection of Fault Zones Using Electric and Electromagnetic Methods
Dipl.-Geophys. Michael Grinat, Leibniz Institute for Applied Geophysics (LIAG)

G3: Heterogeneous Rock Properties, Drilling Efficiency and Fracture Propagation
JProf. Dr. Sonja Philipp, Geoscience Centre, University of Göttingen, Department of Structural Geology and Geodynamics

G4: Characterisation of Enhanced Geothermal Reservoirs by Diagnostic Methods
Dr. Ulrich Wegler, Federal Institute for Geosciences and Natural Resources (BGR)

G5: Hydromechanics of Geothermal Reservoirs
Dipl.-Geophys. Rüdiger Schellschmidt, Leibniz Institute for Applied Geophysics (LIAG)

G6: Hydraulic, Heat and Tracer Tests at Wellbore and Reservoir Scale
Prof. Dr. Martin Sauter, Geoscience Centre, University of Göttingen, Department of Applied Geology

G7: Modelling of coupled Thermo-Hydro-Mechanical Processes in Georeservoirs
Prof. Dr. Martin Sauter, Geoscience Centre, University of Göttingen, Department of Applied Geology

G8: Electrical Impedance Tomography for the Characterisation of Geothermal Systems
Prof. Dr. Andreas Hördt, Institute for Geophysics and Extraterrestrial Physics, TU Braunschweig

G9: Hydrogeochemical Processes in Geothermal Systems
Prof. Dr. Wolfgang van Berk, Institute for Radioactive and Hazardous Waste Management, Clausthal University of Technology

2.2.5.2 Research Area Drilling Technology

A widespread utilization of geothermal energy requires cost-effective deep drilling. The objective of the research area "Drilling Technology" was to make contributions towards a novel method of constructing deep geothermal wells in hot hard rock formations by exploring highly innovative technology concepts.

Overriding objective was the safe construction of deep wells of high mechanical integrity under hot-hard rock conditions at significantly lower costs. This objective was to be achieved by:

- new drilling technologies to allow utilization of smaller and less complex rigs and facilities
- new technologies to permit drilling with smaller initial well diameters and hence, lower consumption of drilling fluid, pipe steel and cement
- new drilling processes to increase the rate of penetration and the productive drilling time
- new technologies for increased system reliability
- improved drilling and well integrity under high pressures and temperatures

Coordinator:	Dr. Catalin Teodoriu
Baker Hughes Contact:	Dipl.-Ing. Jörg Lehr
	Dipl.-Ing. Carsten Freyer
	Dipl.-Ing. Thomas Dahl
	Dipl.-Ing. Roland May
	Dr.-Ing. Hanno Reckmann
	Dr.-Ing. Dmitriy Dashevsky
	Dr. Anne Bartetzko