ENGINE COORDINATION ACTION

Summary of the Workshop 1
Defining, exploring, imaging and assessing reservoirs for potential heat exchange
6-8 November 2006, Potsdam (Germany)

The goal of the workshop was to discuss all parameters that should be known before drilling for exploitation of potential geothermal reservoirs. The workshop was strongly focused on debates about the definition of targets, characterization of reservoirs and optimisation of investigation methodology for EGS. To achieve this focus, four thematic sessions were defined (Signatures of temperature field for defining and exploring potential geothermal reservoirs, Signatures of fluid transport in Earth's crust, State of the Art in the exploration of potential geothermal reservoirs, Processes in geothermal reservoirs). Definition of targets, characterization of reservoirs and optimisation of investigation methodology for EGS require, among other topics, a significant improvement of the imaging and modelling of fault and fracture systems, of the knowledge of the paleostress field as well as of the heat flow and temperature distribution at depth. Following the workshop, it is stated that heat, temperature, stress and pathways as well as chemical and mineralogical composition of rocks hosting the geothermal system are besides the structural inventory of the subsurface the key elements that could be put as priority for research needs.
Four main research targets were defined, and the main conclusions can be summarized as follows:

Structural Geology: imaging potential geothermal reservoirs

Geothermal reservoirs are sections at drillable depths containing enough heat for geothermal utilisation. Geophysical methods are suitable to determine the architecture, geometry, and quality of target intervals. However improvement of existing methods and in particular reasonable combination of different, most sensitive techniques (passive and active seismic, MT, and others) are needed to meet the requirements of modern geophysical exploration. The interpretation of geophysical features must be supported and validated by petrophysical laboratory and borehole measurements, as well as modelling. Experiences made in hydrocarbon exploration must be modified for EGS. EGS requires usually more knowledge about fracture and

fault systems with respect to their role as potential water conduits. The reservoir imaging strategy should include large scale approaches supplemented by high-resolution experiments. Further benefit should come from adapted processing techniques.

Heat: finding heat at depth

The extension of large-wavelength heat flow anomalies at depth is often inaccurate due to the improper knowledge of the causes of the heat-flow anomaly. The existence of convective and advective cells, such as those well characterized at Soultz and in the Rhine graben area, hinder a temperature extrapolation to greater depth and can lead to wrong evaluation of thermal gradients. Consequently advective cells have to be properly identified and characterized through detailed geochemical studies comprising definition of water chemistry, application of suitable geothermometric techniques (hydrochemical and gas geothermometers), mapping of CO_2 fluxes from soils, etc. Maps of the heat flow distribution at surface and at the crust-mantle boundary provide far-field conditions for any definition of possible targets for EGS. However, such maps require a basic knowledge of the main lithologies and their thermal properties. In order to properly define temperature and heat distribution for an EGS database thermal conductivity and the radiogenic heat production are now feasible for better constrained modelling. Several physical parameters (density, wave velocity, electrical resistivity…), as well as chemical and mineralogical properties are coupled with temperature and can be imaged by different geological, geophysical and geochemical methods. Thus, the definition of possible targets for EGS could be improved by the use of a 3D modelling platform, in which all solutions from geological, geochemical and geophysical modelling, direct and inverse, could be combined and analysed.

Stress: understanding and stimulating fluid circulation

Evidences exist and show the influence of the stress field on hydro fracturing (ref workshop Ittingen). The knowledge of spatial stress distribution (map and depth) on a local as well as on a regional scale is thus fundamental for any future experiment. Mechanisms of rupture and propagation of an existing fault system and related displacement remain debated, especially in connection with the circulation of fluids and success rate of improving sustainable permeability. The circulation and accumulation of fluids in the crust are fundamentally controlled by the geometry of the fault and fracture systems. The ability of these systems for the channelling of fluids is directly dependant on the stress field (orientation and intensity). Favourable and unfavourable conditions exist depending of the tectonic context and geological environment. However, hydro-fracturing is not the only option to enhance the permeability of reservoir rocks. Selective dissolution should also be taken into account (as a technique to increase *effective* porosity and permeability) as it could be more effective than fracturing, provided that it is applied to suitable lithological frameworks (e.g., sandstones made up of quartz and silicate minerals but also containing relevant amounts of fast-dissolving carbonate minerals) and under carefully selected conditions.

Pathways: defining integrated conceptual models

What starting conditions are necessary to develop/stimulate an EGS? What are the conditions classifying a thermally suited area for the development of an EGS? There

is a need to refer to conceptual models of the main geothermal sites, from extended active geothermal sites to EGS for which heat distribution and permeability networks are available for modelling pathways for fluid circulation, gas-water-rock interaction processes (and their effects on *effective* porosity and permeability) and heat exchange. The cradle of such models should be the geometry of geology. They could be built by integrating the most significant datasets and their interpretation on reference key areas, like Larderello, Bouillante, Soultz, Groß Schönebeck. Such models must be updated as soon as new data or new experiences and results are available. A significant improvement of the knowledge is expected from natural analogues on which hypotheses could be tested about, for example, circulation of fluids in relation with seismicity and heterogeneity of the lithologies, thermal imprint of fluid circulation. The links with other investigation programmes such as nuclear waste storage, capture and storage of CO_2 and oil and gas field development will be developed to take advantage of existing installations and experiences. Workflows encompassing fault interpretation from 3D seismics and geostatistic tools, 3D retro-deformation and fracture interpretation from well data should be further developed to give a base for possible pathway interpretation through time. Palaeostress maps may also help in distinguishing between open or closed pathways. Technological platforms could be promoted to develop new methods and tools, test hypotheses in situ or the accuracy of conceptual models.

Investigation for EGS is of strategic importance for reduction of costs and increase of efficiency in the development of geothermal projects, and Workshop 1 of the ENGINE project has certainly made an important contribution.

References

Bruhn D. & Manzella A. (eds.) 2006, Proceedings of the Engine Workshop 1 "Defining, exploring, imaging and assessing reservoirs for potential heat exchange", 6-8 November 2006, Potsdam, Germany. ISBN 978-2-7159-2986-9. Orleans, BRGM Editions. Collection Actes/Proceedings. ISSN 1773-6161.