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ScienceDirect

Procedia Engineering 191 (2017) 158 – 163

Procedia Engineering

www.elsevier.com/locate/procedia

Symposium of the International Society for Rock Mechanics

Geomechanical Characterization of a Host Rock for Enhanced Geothermal System in the North-German Basin

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Abstract

The North-German Basin offer at depth of approximately 5000 m sufficiently high temperatures for efficient and economic heat extraction by geothermal wells. The permeability of the carboniferous strata at that depth is very low so that conductive pathways have to be created by hydraulic fracturing. For some planned projects we conduct the characterization of the carboniferous strata as exposed in “analogous outcrops”. The geological setting for fracking is demanding, as the strata comprise strong sandstone, shale and weak coal seams. All necessary petrophysical properties will be collected by extended testing. The regional horst-and-graben system allows for mapping in outcrops and extrapolate the structural content towards the rock mass at depth.

Peer-review under responsibility of the organizing committee of EUROCK 2017

Keywords: enhanced geothermal system; rock chractacterization; structural characterization

1. Introduction

The North German Basin (NGB) is together with the Upper Rhine Valley and the southern Molasse basin the preferred area for deep geothermal wells in Germany Several commercial (Neustadt / Glewe) and research projects (GeneSys; Groß Schönebeck) have been developed. The prognosis of temperatures at depth for Germany is shown in Figure 1. Some planned projects focus on the western part of the North Germany Basin and due to the fact that permeability of the target horizons at depth is very low fracking will be executed to create conductive pathways in the otherwise dry and hot rock. This type of heat mining is called Enhanced Geothermal System EGS which aims at producing electricity.

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Peer-review under responsibility of the organizing committee of EUROCK 2017
doi:10.1016/j.proeng.2017.05.167

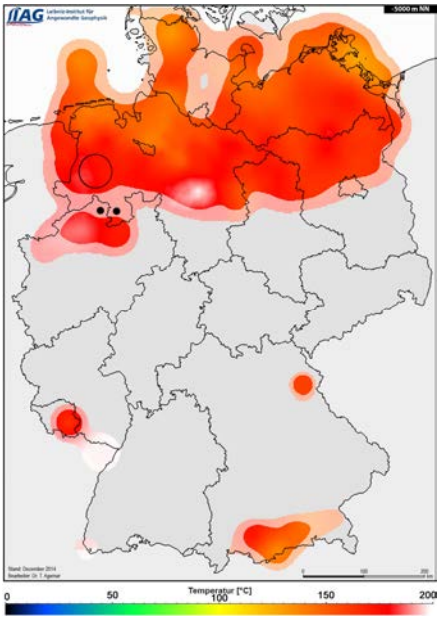

Fig. 1. Estimates of temperatures at depth 5000 m [1], black dots = sampling area, open circle = EGS locations.

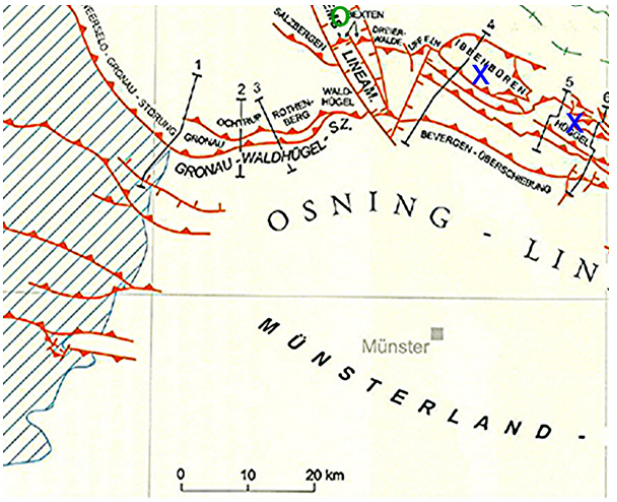

Fig. 2. Tectonic setting near the EGS projects (green circle). Sampling was executed in the horst-structures (blue crosses). Modified after [2].

The red spots in Figure 1 suggest a temperature of around 180° C at a depth of 5000 m. This information seems to be valid since many oil and gas wells were drilled and still are operated in the NGB. We focus in this paper on the area near the border to the Netherlands, on the utmost western part of the NGB. Here several commercial projects are aiming for drilling deep wells and for executing multiple fracking from horizontal drillholes for obtaining high flow rates. This area is well known from exploration on hydrocarbon, 3D seismic lines have been executed and some deep wells have been drilled for exploitation.

1.1. Geological setting

The area close to the Netherlands is characterized by many graben and horst structures (Fig. 2). The target horizon for most projects is the Upper Carboniferous, i.e. Westfal C/D at a depth of around 5000 m. On top of the target horizon there is Permian Zechstein salt. Here it is of particular interest that the in-situ stresses are decoupled by Permian Zechstein salt [3]. Mesozoic and quaternary sediments complete the hanging rocks. As shown in Figure 3, the target rocks (Westfal C/D) crop out just 30 km from the area where EGS projects may take place. Thus, it was possible to characterize relevant rocks from “analogous outcrops”.

The rocks from Westfal C/D comprise argillaceous rocks (shale, sandstone and conglomerate) as well as coal found in numerous seams. The tectonic setting is that of an extensional regime with mainly normal faults leading to graben-and-horst structures.

The implications of the geological setting for borehole stability and hydraulic fracturing are manifold. The major horizontal stress σ_H changes directions above and below the Permian salt [3] and the difference between vertical stress σ_V and major horizontal stress σ_H increases below the salt change. The rock types change frequently according to the sequential sedimentation which leads in case of vertical fracs to the difficulty to propagate a fracture e.g. in stiff argillaceous rocks with interbedded soft coal seams of several m in height. Also present are numerous, mainly steep-dipping small faults, which might get re-activated by the fracking process. In summary, the knowledge about the widely varying properties of the rocks and discontinuities is necessary for a successful exploitation of heat at depth.