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Geological CO_2 Storage Supports Geothermal Energy Exploitation: 3D Numerical Models Emphasize Feasibility of Synergetic Use

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Abstract

Geological storage of CO_2 in deep saline aquifers is considered as option for reducing anthropogenic greenhouse gas emissions into the atmosphere. Most often the same aquifers might allow for provision of geothermal energy potentially resulting in a competitive situation. Within the frame of the present study we evaluated the feasibility of synergetic utilisation of a reservoir suitable for both, CO_2 storage and geothermal heat exploitation, by 3D numerical simulations of simultaneous CO_2 and brine (re-) injection and brine production. Based on structural and petrophysical data from a prospective storage site in the North East German Basin different scenarios were investigated taking into account reservoir permeability anisotropy and varying flow related descriptions of existing faults. Simulation results show that for an isotropic horizontal permeability distribution synergetic use is feasible for at least 30 years. Nevertheless, permeability anisotropy and open faults do have an impact on the CO_2 arrival time at the brine production well and should be taken into account for implementation of a synergetic utilisation in the study area.

Keywords: CO_2 *storage; saline aquifer; brine production; geothermal heat provision; synergy*

1. Introduction

Geological storage of the greenhouse gas carbon dioxide (CO_2) in deep saline aquifers is on the one hand viewed as a promising measure for mitigating the adverse impact of increasing anthropogenic emissions on the global climate-change but on the other hand also linked to several risks as any technology. Especially large-scale pressure build-up as a result of CO_2 injection, potentially with substantial impact even 100 km away from the injection zone is associated with the risk of cap rock fracturing, reactivation of existing faults or induced seismicity [1-3]. Further major concern is that pressurization may force displaced brines to migrate along leakage pathways from the storage formation

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into shallow groundwater reservoirs with potable water resources [4]. To prevent overpressurisation and associated risks in saline aquifers the extraction of formation water from the storage reservoir by active brine production concurrent to CO_2 injection has been shown to be a potential strategy [5-6]. Even with passive water production which requires that aquifer pressure exceeds the hydrostatic pressure near the production well, the pressure build-up in the formation can be significantly reduced especially in the near-well area [7]. Birkholzer et al. [8] introduced the concept of "impact-driven pressure management (IDPM)", a method for local pressure relief via targeted brine extraction in particular at discrete geological features with a higher risk potential such as critically stressed faults to prevent (re-)activation. In addition to risk mitigation brine-extraction volumes can be significantly reduced and the extracted brine volume must not necessarily be equal to the injected CO_2 volume to achieve a pressure relief. If not re-injected into the storage formation or another neighbouring high-permeable formation, the extracted brine can for instance be used for freshwater production or geothermal heat provision [9]. However, the use of geothermal brines from low-enthalpy systems (temperature below 100°C) is not always economically profitable, whereby the technical infrastructure required for geological CO_2 storage may support heat exploitation, if the same reservoir is for instance used synergetically by both technologies. This might also prevent competitive situations, since the same aquifers most often allow for geothermal heat provision and geological CO_2 storage.

We therefore decided to investigate the feasibility of synergetic reservoir utilisation of a deep sandstone reservoir located in the Northeast German Basin (NEGB) suitable for both, CO_2 storage and/or geothermal heat exploitation. By this means, and to avoid disposal of native brines above the surface, an injection strategy was developed taking into account concurrent brine production for geothermal heat provision and its re-injection into the storage formation together with the CO_2. Based on structural and petrophysical data from the prospective storage site in the NEGB and in order to assess a conceptual synergetic utilisation, large-scale numerical flow simulations at regional scale (about 42 km x 42 km) coupled to heat transfer were carried out using the TOUGH2-MP simulator [10]. Different scenarios were investigated considering existing faults as open and closed, respectively, as well as anisotropy of the reservoir permeability to account for preferred flow directions resulting from a heterogeneous facies distribution in the storage formation.

1. Study Area

The prospective CO_2 storage site Beeskow-Birkholz is located in the southeastern part of the German state of Brandenburg in the NEGB (Figure 1). The potential storage horizon is part of a saline multi-layer aquifer system of Mesozoic age characterized by an anticline structure that extends in west-northwest and east-southeast direction. This Mesozoic anticline developed due to salt tectonic movements of the deeper-lying Upper Permian Zechstein [11]. The northeastern and southwestern boundaries of the study area are confined by the Fuerstenwalde Guben and Lausitzer Abbruch fault systems. The Detfurth formation sandstone of the Middle Bunter with a formation top located at a depth of about 1,080 m and an average thickness of 23 m was chosen to evaluate the feasibility of a synergetic reservoir utilisation, since it offers the greatest thickness of three permeable formations situated in the Middle Bunter potentially suitable for both, CO_2 storage and/or heat provision. The underlying permeable sandstone formation of the Middle Bunter is separated from the Detfurth formation by a sealing unit consisting of mudstones with a thickness of 60 m. The cap rocks overlying the Detfurth formation are multi-barrier seals made up of mudstones and anhydrite. For a more detailed stratigraphic description of the study area, the reader is referred to Tillner et al. [12].