Geophysical Research Abstracts
Vol. 14, EGU2012-4534, 2012
EGU General Assembly 2012

Present-day thermal signatures of different heat transport mechanisms within the Northeast German basin and their sensitivity to the resolution of the computational mesh - results from coupled 3D numerical simulations

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Sedimentary basins provide a significant portion of geothermal energy. Making geothermal heat an effective source for sustainable energy supply requires a quantitative reserve assessment. Numerical (mathematical) models of sedimentary basins are useful tools for first-order approximations of the geothermal potential on a regional scale. The challenge for numerical investigations within complex geological sedimentary basins is that the thermal field contains superposed signals originating from several heat transport processes, different in nature but physically coupled. An additional difficulty arising from numerical simulations is the error introduced by discretizing a continuous physical system into its numerical counterpart. Different mesh resolutions may lead to different and sometimes contrasting computational findings, thus making the reliability of coupled numerical simulations at least questionable.

By means of 3D numerical simulations we discriminate conductive, forced convective and free thermal convective heat transport within a complex geological setting, the Northeast German Basin. As a second step we explore the sensitivity of each heat transport process with regard to the spatial discretization.

The internal geological structure of the NEGB is characterized by the presence of a highly structured Zechstein salt sequence piercing the sedimentary overburden locally. Moreover, the Zechstein salt is impervious to fluid flow and has a relative high thermal conductivity compared to the surrounding clastic sediments.

Computational results show that these hydrogeological conditions exerts primary constraints on the internal hydrothermal setting of the basin. The impervious nature of the Zechstein salt inhibits groundwater flow to be effective. Accordingly, conduction is the main heat transport mechanism within the salt. In contrast, forced convective heat transport triggerd by topographic gradients affects mainly the temperature distribution within the post-salt sediments. Free thermal convection triggered by buoyancy forces due to gradients in fluid density evolves only locally, where favourable hydrogeological conditions (thick permeable sedimentary layers and low forced convective forces) are met.

It is demonstrated that free thermal convective heat transport is the heat transport process, which is most sensitive to changes in the mesh geometry. Different mesh resolutions correspond to different perturbations that may result in different hydrothermal patterns. However, the overall thermal field within the basin remains stable due to the local character of free thermal convection, an inidication that numerical models of coupled physical systems are indeed applicable for first-order approximations of the geothermal potential.