Mechanisms and fluid-dynamics driving saline waters within the North East German Basin: Results from thermohaline numerical simulations.

Laureato in Fisica (Scienze della Terra)
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vom Fachbereich Geowissenschaften
der Freien Universität Berlin
zur Erlangung des akademischen Grades eines
Dr. rer. nat
genehmigte Dissertation
Berlin, 2005

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Tag der Disputation: 10. Juni 2005

Figures list **Pages**

Acknowledgments

This work would not have been accomplished without the help of many people, whom I would like to thank.

First of all, I would like to thank Prof. Ulf Bayer (FU, Berlin) for his supervision and fundamental support throughout the project. I greatly benefited from his wide experience of numerical modelling and from the fruitful discussions of the results. Thanks to Prof. Asaf Pekdeger (FU, Berlin) who has also supervised this work.

At the same time I am obliged to Prof. Hans Diersch and Dr. Volker Clausnitzer (WASY, Berlin) for the tutorial relating to FEFLOW and the intense exchange of new ideas.

Deep reaching fluid flow group[(*)] is greatly acknowledged for important contributing. Especially, I would like to thank Christoph Jahnke (BTU, Cottbus) and Dr. Maja Tesmer (FU, Berlin) for making available the data and for the fruitful co-operation during these years of research.

Dr. Magdalena Scheck-Wenderoth has provided the geological data and is acknowledged for her support and help. I thank Dr. Frank Wenderoth for his advises in numerical modelling.

I wish to thank Björn Lewerenz for supplying computer help.

I acknowledge the German Science Foundation (DFG, Germany) for providing financial support via the GeoForschungsZentrum Potsdam.

Thanks to the SPP 1135 team group (Dynamics of Sedimentary Systems under varying Stress Conditions by Example of the Central European Basin System) for the nice meetings around Germany and the interesting workshops.

A sincere “Thank You” to Prof. Brian Horsfield and all colleagues here at the GFZ for the interest showed for my research and for offering a solid work environment.
Significant support was also coming from the administrative personnel of the GFZ. Many thanks to Gisela Schmidt at the GFZ library for the speed with which she furnished me with papers and books.

Thank you Yuriy Maystrenko for the nice time we spent sharing the office at the GFZ.
Thanks to Dr. Andrew Cavanagh, for the good music, the delicious Scottish salmon and English corrections.

Merci pour tout mon ami Wolfgang Momber.

A warm thank to Katrin Rehak for being near especially in the final stage of the thesis.

Finally, I thank my parents and all my family for their love and support during my studies.

And to whose I have forgotten to acknowledge explicitly: accept both my apologies and thanks!

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Abstract

In several areas of the North East German Basin (NEGB) saline water comes close to or even reaches the surface. Although this phenomenon has been observed during the past two centuries, the origin and mechanisms of brines within the NEGB aquifer are not fully understood. In geothermal systems, the driving forces can be intrinsic to the basin, like thermal variations, and/or external due to hydraulic head. In order to clarify the possible mechanisms of brine transport, thermohaline simulations have been carried for 2D and 3D model scenarios.

For this purpose, a hydrogeological model of the NEGB has been developed which contains the major stratigraphic and hydrogeologic units from the Quaternary to the Upper Permian. In contrast to normal groundwater models for freshwater, large-scale simulation of coupled flow, mass and heat transfer requires a proper fluid density model. Field measurements of pore fluid pressure and temperatures, as well as laboratory investigations of solute content provided density input data. The brine stratification is unstable in the deeper underground suggesting that convective flows are favoured.

The governing equations of density driven flow have been solved by the use of the finite element software FEFLOW 5®. The numerical approach of thermohaline simulations has been performed by testing different grid resolutions. The 2D model allows to quantify the interaction between diffusive solute transport, thermally and head-driven flow (forced versus free convection). The main fluid-dynamics of salt migration throughout the NEGB have been inferred from temporal analysis of the transport processes. Additionally, viscosity effects have been taken into account and have been evaluated. Based on these 2D numerical results, a regional picture of the transport processes affecting the NEGB has been tracked down. The 3D regional model (230x330 km) indicates that salt water occurring close to the surface may mainly be driven by hydrostatical forces from the surrounding highlands, describing part of the phenomena. In addition, a smaller 3D scale model (10x10 km) has been constructed with a grid resolution accounting for temperature effects. The results point towards that thermally induced flow, which may play a dominant role in areas with minor topography.

In summary, the complex pattern of near surface occurrences probably results from the interaction of hydrostatic and thermal forces.

Scenarios that allow for mixed convection are needed to understand the mechanism behind numerous previously unexplained field observations of deep-groundwater occurrences near the basin surface. The potential presence of large-scale convection cells has implications both for the fundamental understanding of basin processes as well as for socio-economic issues.