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Numerical investigation of the interaction of different driving forces on groundwater flow and temperature pattern in a theoretical basin and in the Buda Thermal Karst, Hungary

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The study firstly displays the results of a theoretical, basin-scale two-dimensional numerical investigation of buoyancy-driven free thermal convection and gravity-driven forced convection in order to understand deep groundwater flow patterns and the occasion of measured temperature anomalies. Several model scenarios were investigated within a wide range of values of geothermal gradient, regional relief, model depth and anisotropy of hydraulic conductivity corresponding to the non-dimensional thermal Rayleigh numbers (Ra=0-6336) and the modified Péclet numbers (Pe^*=0-323). Time-dependent free thermal convection, which was facilitated by higher geothermal gradients and greater model depths, mainly influenced the flow system in the deeper part of the midline and the discharge zone of the theoretical model. Contrarily, increasing regional relief and anisotropy strengthened the formation of steady-state forced thermal convection, especially in the upper part of the model. Various boundary conditions, an isothermal, a constant heat flux and a 'free' thermal boundary condition were prescribed at the bottom of the model to test the sensitivity of the numerical solution. Generally, the constant heat flux bottom boundary condition favoured less intense heat transfer into the model domain compared to the isothermal condition. In addition, we found that the effect of temperature-dependent viscosity intensified the time-dependent free thermal convection.

Based on the conclusions of this theoretical study, the combined effect of forced and free thermal convection was examined along a geological section across the Gellért Hill area from Buda to Gödöllő Hills (Fodor, 2011). In the Buda Thermal Karst, the presence of forced and free thermal convection was numerically proved for another simplified section (Havril et al., 2016). In the recent study we made the simulations for a detailed geological section, and the origin of the heat anomalies were evaluated by the comparison of the measured data (e.g. temperature-depth profile) and the numerical results. This study draws attention to the importance of the understanding of the interaction of forced and free thermal convection in deep carbonate sequence, which can improve the methodology of the geothermal exploration, for instance, in thermal water research and geothermal energy utilization. The project was supported by the ÚNKP-18-3 New Excellence Program of Ministry of Human Capacity, the Hungarian Scientific Research Fund (K 129279) and the János Bolyai Research Scholarship of the Hungarian Academy of Science. This insert type of result is part of a project that has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 810980. The conference participation was subsidised by the József an Erzsébet Tóth Endowed Hydrogeology Chair.

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