Impact of the Wisconsinian Glaciation on Canadian Continental Groundwater Flow Dynamics

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Pleistocene glaciations and their associated climatic conditions are suspected to have had a large impact on groundwater flow dynamics over the entire North American continent. Because of the myriad of complex flow-related processes involved during a glaciation period, numerical models have become powerful tools for examining groundwater flow system evolution in this context. Here, a series of key processes pertaining to coupled groundwater flow and glaciation modeling, such as density dependent (i.e., brine) flow, hydromechanical loading, subglacial infiltration, isostasy, and permafrost development, are included in the numerical model HydroGeoSphere to simulate groundwater flow over the Canadian landscape during the Wisconsinian glaciation (-120 ka to present). The primary objective is to demonstrate the immense impact of glacial advances and retreats during the Wisconsinian glaciation on the dynamical evolution of groundwater flow systems over the Canadian landscape, including recharge and seepage dynamics in both the subglacial and the periglacial environments.

It is shown that much of the infiltration of subglacial meltwater occurs during ice sheet progression and that during ice sheet regression, groundwater mainly exfiltrates on the surface, in both the subglacial and periglacial environments. The average infiltration/ exfiltration fluxes range between 0 and 12 mm/a and about 15–70% of the subglacial meltwater infiltrated into the subsurface as recharge, with an average of 43%. Considering the volume of meltwater that was generated subsequent to the last glacial maximum, these recharge rates, which are related to the bedrock type and elastic properties, are historically significant and therefore played an immense role in the evolution of groundwater flow system evolution over the Canadian landmass over the last 120 ka.

The significant impact of the ice sheet on groundwater flow is also evident by increases in the hydraulic head values below the ice sheet by as much as 3000 m down to a depth of 1.5 km into the subsurface. Results also indicate that the groundwater flow system after glaciation did not fully revert to its initial condition and that it is still recovering from the glaciation perturbation. This suggests that the current groundwater flow system cannot be interpreted solely on the basis of present-day boundary conditions and it is likely that several thousands of years of additional equilibration time will be necessary for the system to reach a new quasi-steady state. Finally, we find permafrost to have a large impact on the rate of dissipation of high hydraulic heads that build at depth and capturing its accurate distribution is important to explain the current hydraulic head distribution across the Canadian landscape.