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Impact of the Wisconsinian glaciation on Canadian continental groundwater flow

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Pleistocene glaciations and their associated dramatic climatic conditions are suspected to have had a large impact on the groundwater flow system 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 to examine groundwater flow system evolution in this context. In this study, a series of key processes pertaining to coupled groundwater flow and glaciation modelling, such a 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 glacial advances and retreats caused during the Wisconsinian glaciation on the dynamical evolution of groundwater flow systems over the Canadian landscape, including surface/subsurface water exchanges (i.e., recharge and discharge fluxes) both in 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, both in the subglacial and periglacial environments. Using mixed, ice-sheet-thickness dependent boundary conditions for the subglacial environment it was estimated that up to 70% of the meltwater infiltrated into the subsurface as recharge. Groundwater age calculations indicate that meltwaters penetrated to depths of more than a kilometer in some regions. Considering the volume of meltwater that was generated subsequent to the last glacial maximum, these recharge rates were unprecedented in history and therefore played an immense role in the evolution of the groundwater flow system over the last 120 ka. Results also indicate that deep-seated portions of the flow system are continuing to evolve because of the glacial loading and unloading. Finally, it is shown that the permafrost extent plays a key role in the distribution of surface/subsurface interaction because the presence of permafrost acts as a barrier for groundwater flow.