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Subglacial groundwater flow under the Scandinavian Ice Sheet in southern Denmark during the Weichselian glaciation and its impact on ice-movement dynamics

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Groundwater is the main source of drinking water supply in Denmark. In southern Denmark, deep Miocene aquifers are increasingly considered as a resource of pristine high quality groundwater. Groundwater in these aquifers is up to several thousands of years old and the recharge conditions experienced significant changes in the past. Understanding the groundwater history is important to ensure sustainable groundwater use and protection from potential contamination.
In this study we investigate large-scale changes in the groundwater flow system in southern Denmark during the Quaternary glacial/interglacial cycles with focus on the last (Weichselian) glaciation. Using a finite-difference groundwater flow model (MODFLOW) and a detailed geological representation we show that during the Weichselian glaciation groundwater flow patterns, directions and depths experienced a full reorganization in relation to the interglacial (modern) time as a result of high potentiometric heads imposed by the ice sheet. Of special interest are the feedback mechanisms between the groundwater flow and the ice sheet dynamics. Our simulations show that the drainage capacity of the ice-sheet bed was insufficient to evacuate all the meltwater from the glacier sole as groundwater flow, both under permafrost and no-permafrost conditions. This suggests a widespread decoupling of the ice sheet from the bed and high ice movement velocities by enhanced basal sliding on a layer of pressurized meltwater, which is in turn consistent with the presence of fast-flowing ice streams along the southern fringe of the Scandinavian Ice Sheet during the Last Glacial Maximum. To stabilize the ice sheet, the glacial system generated a system of deep tunnel valleys that drained the excess meltwater to the ice fore-field.
Our study illustrates the advantages of a coupled palaeo-hydrological and glacio-geological approach in deciphering the behavior of past ice sheets and their impact on shaping the Earth's surface.