Paleo-hydrogeological evolution of a fractured-rock aquifer following the Champlain Sea Transgression in the St. Lawrence Valley (Canada)

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ABSTRACT
A conceptual and numerical model of seawater invasion and subsequent leaching have been developed to understand the processes involved in the evolution of groundwater salinity within a regional sedimentary rock aquifer system. In the St. Lawrence Valley, large paleo-environmental changes have occurred during the last glacial-deglacial cycle and the ensuing postglacial period. The region was covered by the Laurentide Ice Sheet until about 13 ka BP, at which time it was invaded by an arm of the Atlantic Ocean, thus forming the Champlain Sea. The seawater salinity eventually decreased, due to sustained meltwater inflow and isostatic rebound, until it formed a shallow freshwater basin, Lake Lampsilis. Subsequently, the drainage system evolved towards its present-day configuration. Along with these spatio-temporal variations in water level and salinity, silts and clays settled at the base of the water bodies. These fine-grained sediments formed thick low-permeability units that retarded the transfer of saline seawater into the underlying fractured rock aquifer, and later impeded the flushing of brackish water from the rock aquifer, which hence still contains brackish groundwater of marine origin over a 2,200 km^2 area. A fully coupled vertical 2D density-dependent flow and mass transport numerical model was set up to simulate the marine and post-marine subsurface migration of salt within the study area. The relative influence of various processes and parameters was then assessed. Results show that salinization of the rock aquifer was a density-driven convection process, and that the accumulation of fines had a profound influence on salt migration, leading to the currently incomplete and uneven desalinization of the regional aquifer system. In practical terms, this study offers a better understanding of regional groundwater dynamics and quality changes, which are key to sustainable management of the resource amid conflicting uses.