Glaciation and Regional Ground-Water Flow in the Fennoscandian Shield

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Regional ground-water flow in the Fennoscandian shield is strongly affected by surface conditions associated with climatic change and glaciation. These effects are illustrated in a regional-scale analysis based on a series of numerical simulations of variable-density flow in the Fennoscandian shield, including southern Sweden, in a cross-section 1500 km long and 10 km deep). The assumed time evolution of surface conditions over the next 140 ka is based on the sequence reported by King *et al.* (1994).

Results suggest that, during a typical glacial cycle, glacially-caused changes in subsurface flow and chemistry may reach significant depths. However, because the flow system has a long response time relative to the expected period of glacial advance and retreat, glacial perturbations in surface conditions lack sufficient time to laterally propagate through regional distances in the subsurface. For example, recharge supplied by basal melting of an advancing ice sheet reaches a location in the shallow subsurface only as the margin of the basal melting zone passes directly above.

Changes observed during a typical glacial cycle are as follows. Under periglacial conditions, permafrost may impede the free recharge or discharge of ground water, resulting in the settling of dense fluid (brine) and consequent freshening of near-surface water in areas of natural discharge. During glacial advance, recharging basal meltwater can reach depths of a few kilometers in a few thousand years. The vast majority of such recharge is accommodated through storage in the bedrock in the local area below the point of recharge; regional redistribution of recharge water by subsurface flow is minor over the time scale of glacial advance (10 ka). Depending on the basal melting rate, recharge at a given surface location may drop off sharply once the water pressure at the base of the ice reaches the pressure exerted by the weight of the ice (whereupon excess meltwater is assumed to escape via sub-ice paths). Growth in recharge rate is then limited by the rate at which the ice sheet thickens. During glacial retreat, the weight of the ice overlying a given surface location decreases with time, causing meltwater stored in the subsurface to discharge at the base of the ice despite that fact that basal melting continues. The maximum rate of ground-water discharge occurs at the receding ice margin, and some discharge occurs below incursive post-glacial seas.

Major increases in chemical concentration above present day levels due to periodic rise of deep shield brine are not observed in the present simulations, although significant decreases in chemical concentration of shallow ground water (< 1 km) occur during periods of glacial meltwater recharge. Glacial meltwater penetrating the subsurface to depths of a few kilometers during glacial advance may reside in the shallow subsurface for periods exceeding 10 ka. During interglacial periods, the flow field and chemical profile recover much of their unperturbed form.

References

King, L.M., Chapman, N.A., Kautsky, F., Svensson, N.-O., and Marsily, G. de 1994, private communication.

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