SE9700389

Glaciation and Ground-Water Geochemistry in the Fennoscandian Shield: Deep Oxygenated Ground Water of Glacial Origin

Pierre D. Glynn and Clifford Voss
U.S. Geological Survey, 432 National Center, Reston, VA, 22092, USA

Regional-scale (1000 km) numerical simulations of ground-water flow (Provost, Voss and Neuzil, 1996) in the Fennoscandian shield suggest that, during the advance of an ice sheet, recharging glacial basal meltwaters may reach depths of several kilometers in only a few thousand years. These glacial meltwaters can be expected to have a fairly low total dissolved solids content but may be highly enriched in oxygen. Observations by Stauffer and others (1985) on Greenland ice cores suggest that basal meltwaters could have dissolved oxygen concentrations 3 times greater than that of water at equilibrium with modern atmospheric oxygen levels, because of the dissolution of air bubbles trapped in the ice during its formation. Because of the low concentrations of dissolved organic carbon that might be expected in these glacial meltwaters, the only readily available reductants that might come in contact with the recharging meltwaters would be the iron(II)-rich minerals, such as pyrite (FeS_2), iron-rich biotite [$K(Fe,Mg)_3AlSi_3O_{10}(OH)_2$], iron-rich chlorite [$(Fe,Mg)_5Al_2Si_3O_{10}(OH)_8$] and magnetite ($Fe_3O_4$), all of which are common in granitic rocks. Preliminary reactive-transport calculations based on estimates of the relative abundance and reactivity of these oxygen-reducing minerals along the fractures and in the granitic rock matrix of the Fennoscandian shield suggest that the movement of an oxygen front produced by the recharge of glacial meltwater along a single representative fracture would be approximately 2 times slower than the movement of the water along the fracture. Our calculations show that porosity changes caused by mineral dissolution/precipitation would be small and would not significantly affect the groundwater velocity along the fracture. Therefore, we estimate that oxygenated water could reach a depth of 1 kilometer within a few thousand years. Dissolved oxygen in ground water flowing along a fracture zone or crushed-rock zone that contained abundant reactive reductive minerals would not reach the same depths as quickly as dissolved oxygen in ground water flowing along a single fracture (with the same aqueous volume as the fracture zone or crushed rock zone). The common occurrence of fairly amorphous iron oxyhydroxides observed in borehole cores (to depths of 924 m at Äspö and 400 m at Klipperås) that were collected by the Swedish Nuclear Fuel and Waste Management Company at many sites in Sweden (and usually described as "rust") supports our idea that oxygenated glacial meltwaters may have reached depths of 1 kilometer or more during the last glaciation.

References

Provost, A., Voss, C., and Neuzil, C. 1996. Glaciation and regional ground-water flow in the Fennoscandian Shield. Abstract. Workshop on the Impact of Glaciation on Rock Stresses,

Ground-water Flow and Hydrochemistry - Past, Present and Future. Stockholm, Sweden, April 17-19 1996.
Stauffer, B., Neftel, A., Oeschger, H., and Schwander, J. 1985. CO_2 concentration in air extracted from Greenland ice samples. In: Greenland Ice Core: Geophysics, Geochemistry and the Environment. Eds. Langway, C.C., Oeschger, H., and Dansgaard, W. Geophysical Monograph 33. American Geophysical Union, 85-89.