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Future ice ages and the challenges related to final disposal of nuclear waste: The Greenland Ice Sheet Hydrology Project

A. Lehtinen (1), L. Claesson-Liljedahl (2), J-O. Näslund (3), and T. Ruskeeniemi (4)

(1) Posiva Oy, Olkiluoto, Eurajoki, Finland (anne.lehtinen@posiva.fi) , (2) Svensk Kärnbränslehantering, Stockholm, Sweden (lillemor.claesson-liljedahl@skb.se) , (3) Svensk Kärnbränslehantering, Stockholm, Sweden (jens-ove.naslund@skb.se), (4) Geological Survey of Finland, Espoo, Finland (timo.ruskeeniemi@gtk.fi)

A deep geological repository for nuclear waste is designed to keep radiotoxic material separated from mankind and the environment for several hundreds of thousands of years. Within this time perspective glacial conditions are expected in high latitudes/Canada and North Europe. Climate induced changes such as the growth of ice sheets and permafrost will influence and alter the ground surface and subsurface environment, which may impact repository safety. In order to understand how climate change, particularly cooling and glaciation, might affect a repository in the long term, the use of present-day analogues helps to reduce the uncertainties and support the assumptions made in safety assessments.

There are major uncertainties concerning hydrological processes related to glacial conditions. The impact of glaciations on any planned repository is a key consideration when performing safety assessments as it is one of the strongest perturbations related to climate change in the long term. The main aspects that need to be further investigated include: 1) to what extent does the meltwater produced by an ice sheet penetrates into the bedrock; 2) what is the pressure situation under an ice sheet, driving ground water flow; 3) how much oxygenated water will reach repository depth; 4) to what depth does glacial meltwater penetrate into the bedrock ; 5)what chemical composition does such water has when and if it reaches repository depth; and 6) can taliks (unfrozen ground in a permafrost area) act as concentrated discharge points of deep groundwater potentially transporting radionuclides in case of repository failure?

Field data is needed in order to achieve a better and integrated understanding of the problems discussed above. Thus, research in a natural analogue site in Greenland has been planned and initiated by the Finnish (Posiva), Swedish (SKB) and Canadian (NWMO) nuclear waste management companies.

The Greenland ice sheet and the Kangerlussuaq area (west Greenland) provides a good analogue for this purpose due to similarities in geology (in the selected study area), and the climate conditions and ice sheet size in Kangerlussuaq resemble the expected conditions in Fennoscandia during future glaciations. In 2005 and 2008 reconnaissance field trips were made to Kangerlussuaq, which confirmed the suitability of the area for the planned studies. According to the present Work Programme the investigations will be carried out in 2009-2012.

The project is divided into four subprojects (SPA, SPB, SPC and SPD) addressing specific and different topics at or in relation to the ice margin: SPA (ice sheet hydrology and glacial groundwater formation); SPB (subglacial ice sheet hydrology), SPC (hydrogeochemistry and hydrogeology) and SPD (periglacial environment: biosphere and permafrost).

The main objectives of SPA and SPB are to gain a better process understanding of supra- and subglacial hydrology. Qualitative and quantitative knowledge of the mechanisms, rates and distribution of the melt water recharge through the ice down to the bed, location and extension of warm-based areas and hydraulic pressure conditions at the base are the key issues to be studied. This will be made by meteorological observations, GPS measurements, radar surveys, drilling through the ice sheet and by ice sheet modelling. SPC will further study the fate of melt water by extending the investigations into the bedrock. It is assumed that the high hydraulic pressures

at the ice sheet bed force water into the fracture network prevailing in the bedrock. However, it is not known how the fracture network behaves under loading, what is the proportion of recharging water compared to the drainage through the bed sediments, what is the intrusion depth, how long the meltwater can sustain its oxic nature and what chemical composition the recharging water has when and if it reaches repository depth (400-700 m). SPC seeks to answer these questions by drilling and instrumenting boreholes drilled into the bedrock and below the ice sheet. SPD is aiming at describing and studying processes acting in the periglacial environment affected by permafrost conditions. The observations will be used within the safety assessment biosphere programs.

From the acquired results we will obtain data, which will allow us to develop better conceptual and numerical models for quantitative analysis of ice sheet hydrology and dynamics, groundwater flow, groundwater chemistry and hydro-mechanical couplings during glacial periods, by reducing uncertainties and better constraining the boundary conditions used in the models. Finally, this project concerns the first in situ investigation of the vital parameters needed to achieve a holistic and realistic understanding of how an ice sheet may impact a deep geological repository for spent nuclear waste and will provide the necessary integrated view of ice sheet hydrology and groundwater flow/chemistry needed when executing safety assessments for the geological repositories in Sweden, Finland and Canada.