Hydrogeological and hydrogeochemical conditions at the continental ice sheet margin - the Greenland Analogue Project (GAP)

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Understanding the long-term evolution of the geosphere and its resilience to natural perturbations such as glaciation is an important element in assessing the safety of deep geological repositories. In Northern Europe and Canada the processes associated with glacial cycles are considered to be the most intense perturbations that could potentially affect the long-term performance of a repository. An important scenario being considered in safety assessments is the stage during glaciation when the ice sheet margin is advancing or retrieving over the repository and a large quantity of glacial meltwater is produced at the surface. In this scenario, dilute and oxygenated melt-water might penetrate down to repository depth and affect groundwater chemistry and redox conditions.. To advance the understanding of processes associated with glaciation and their impact on the long-term performance of deep geological repositories, the Greenland Analogue Project (GAP), a field and modelling study of the Greenland ice sheet and subsurface conditions, was initiated by the Swedish (SKB), Finnish (Posiva), and Canadian (NWMO) nuclear waste management organizations.

Due to the similarities in geology, climate and ice sheet size, the Greenland ice sheet is considered to be an analogue of the conditions that are expected to prevail in Fennoscandia and Canada during future glacial cycles.Reconnaissance field studies were conducted in the Kangerlussuaq region, Western Greenland in 2008 and according to the work program, the investigations will be finalized in 2012. The project is divided into three Subprojects addressing different topics at or in relation to the ice margin: SPA (ice sheet hydrology); SPB (direct observations of ice sheet bed hydrology) and SPC (hydrogeochemistry and hydrogeology). The outcome of the GAP will allow us to increase our understanding of hydrological, hydrogeological and geochemical processes at ice sheet margin, and will allow for the refinement of hydrological models used to simulate glacial conditions.

The main targets of SPA and B are to gain better process understanding of the ice sheet hydrology. Qualitative and quantitative knowledge of the mechanisms, rates and distribution of the melt water recharge from the surface to the bed, location and extent of warm-based areas and hydraulic pressure conditions at the bed are the key issues to be studied. 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. However, it is not understood in detail how; 1) the fracture network behaves under loading, 2) what the proportion of recharging water is compared to the drainage through the bed sediments, 3) what the penetration depth is, and 4) how long the meltwater can sustain its oxic nature or the chemical characteristics of the recharging water when and if it reaches the repository depth.

By the end of 2010 the GAP teams have made a number of research fieldtrips to Kangerlussuaq and additional information has been acquired from literature and co-operative projects. SPA has applied remote sensing techniques, automatic weather stations, radar soundings and seismic to study the morphology and movement of the ice sheet, formation and drainage of melt water lakes and the bed topography. SPB has drilled and instrumented several holes into the ice to investigate the thermal and hydrological conditions at the basal boundary of the ice sheet. The drilling campaign started in 2010 at the ice margin and will continue further inland. SPC has collected information on geology, permafrost and hydrochemistry for site characterization purposes and for the planning of the deep bedrock drilling to be done in 2011. Activities have included bedrock and structural mapping, hydrogeochemical sampling of surface and groundwaters and drilling of two drillholes in 2009. One of the holes was drilled into a talik and was instrumented for groundwater monitoring and sampling. The other hole was drilled to provide information on permafrost conditions in a periglacial terrain typical for the research area and to investigate fracturing in 3D.

The data produced by the subprojects will be tied together by conceptual and numerical models aiming at quantitative analysis of ice sheet hydrology and dynamics, groundwater flow and chemistry, and hydro-mechanical couplings during glacial periods. The results constitute an important contribution towards reducing uncertainties and better constraining the boundary conditions used in the models.