ADAPT Permafrost Drilling with Recovery standard protocol

ADAPT Permafrost Drilling protocol aims to sample the top 2 meters of the permafrost, which do not include the active layer. However, at higher latitudes in the continuous permafrost zone, it may be more difficult to drill into permafrost. In this case, only the first meter of permafrost is drilled. This depth is considered sufficient to record the expected impacts of global warming which should be limited to the top layer of permafrost in high Arctic latitudes.

Drilling into permafrost and recovering undisturbed core samples is not an easy task and requires experimentation and skills. To help research teams that have not yet developed this field expertise, ADAPT acquired a drill and will deploy an experienced research assistant to lead logistics, drilling and sampling activities. The detailed step-by-step methodology is not presented here, but can be provided upon request.

In each previously determined soil pit dug for the active layer soil sampling, 2 holes are drilled from the estimated permafrost table (for a total of 4 boreholes per ADAPT site).

> Hole 1: recover frozen cores for the analysis of physical properties (ground ice content and structure, ground water content, grain-size determination, laboratory tests for thermal conductivity measurements). See Figure 1.
>
> Hole 2: recover frozen cores for carbon content and microbiological analyses.. NOTE: The complex method used to extract uncontaminated sub-samples from permafrost frozen cores has been developed by Scott Lamoureux's team and requires prior experimentation and skill. These frozen cores will be sent directly to Queen's University for microbial analyses. The depths of sub-sampling for carbon content follows the depths determined by the permafrost monitoring standard protocol, i.e. at -80, -100, -120, -140, -160, -180 and -200 cm (see ADAPT Permafrost Monitoring standard protocol). Only the first meter of permafrost is sampled for C/H/N determination, which will be performed at CEN's radiochronology laboratory.

All core samples must be kept frozen for laboratory analyses and permafrost characterization. These samples must be sent to CEN.

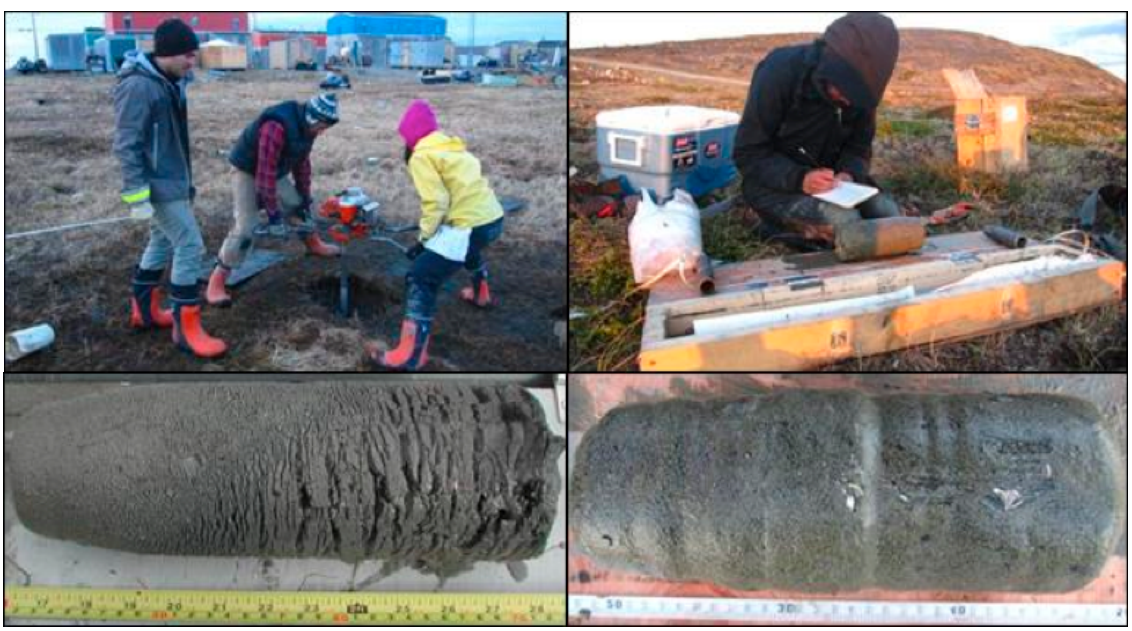

Figure 1. *Drilling with core recovery.*

Permafrost characterization and laboratory analyses

Permafrost contains varying amounts of ice that is present in various structural organizations depending on 1) the type of material in which it is found, and 2) water availability. At the micro-scale, the mixture of ice and soil particles of a given grain size and fabric results in a cryotexture; at the macroscopic scale the permafrost-facies is rather referred to as the cryostructure. Both cryotexture and cryostructure can be interpreted in terms of the processes by which the permafrost was initially formed and developed, for example by cryosuction which created lenses of segregated ice, by pressures that created injection ice or by water filling in contraction cracks which generated ice-wedges. Near the ground surface, past climate change and freeze-thaw processes have produced thaw unconformities and cryoturbations resulting in a wide range of cryostructure types. Being able to observe and analyze permafrost composition and structural organization on numerous samples extracted from the field is necessary to better understand its genesis and to define its characteristics. For infrastructure projects in the Arctic, precise knowledge of the thermal and geotechnical properties of permafrost are required to select the proper structural and thermal design. The physical properties of permafrost are also used as input variables for the parameterization of thermal models and thaw settlement prediction.

CT-scan analyses

The CT-Scan method is an innovative and non-destructive (preserving sample integrity) tool used to estimate the physical properties of permafrost in undisturbed samples (bulk density, phase composition, thermal properties and thaw settlement potential). For instance, voxel classification on the basis of density scales allows the identification and quantification of ice, sediments and gas inclusions in samples. Precise volume measurements allow the determination of geotechnical properties, such as bulk density, leading to an accurate parameterization of thermal models and thaw consolidation tests. The organization of ice in lenses, reticules, veins and the presence of micro-faults allow for the interpretation of formation (i.e. freezing) processes. Direct measurement of volumetric ice contents from CT-scan images makes it possible to numerically estimate thaw settlement without going through costly and time-consuming thaw consolidation tests. By providing a better understanding of the internal composition and structural organization of permafrost, CT-scans can also provide validation for the interpretation of results from geophysical surveys (ex. electrical resistivity, ground penetrating radar) and thus increase accuracy. Recently, the CT-Scan analysis was used to determine how different ice-rich landforms (palsas, peat plateaus, etc.) were heaved due to ice segregation in particular hydrogeological contexts: aggradation ice in upward accumulating slope sediments (colluvium) was imaged; ice-rich permafrost in a peatland was also analyzed, opening the way for new interpretations of stored carbon content available for greenhouse gas release.

Permafrost samples will be scanned using a Siemens Somatom 64 scanner at the Institut National de la Recherche Scientifique in Quebec City (Figure 2). The cores are scanned over their entire length with slice thickness of 0.4 mm. According to the core diameter (100 mm), pixel resolution of 0.1 x 0.1mm is provided. By selecting a range of TI values corresponding to each of the soil

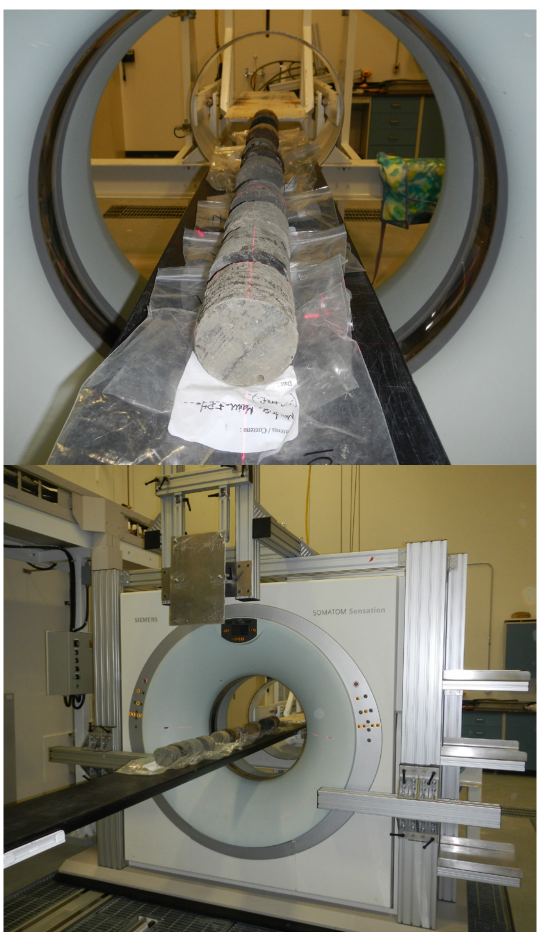

Figure 2. *Siemens Somatom 64 scanner at the Institut National de la Recherche Scientifique in Quebec City.*

components (sediment, ice and gas), voxel classification and quantification of the soil components are achieved using ORS Visual © software of Object Research Systems, therefore providing the fractional volume of the permafrost samples components (soil phase-diagram). Known values of thermal properties for each component (sediments, ice and air) are used to mathematically estimate the bulk thermal properties (conductivity and heat capacity) of the cores. Thaw settlement prediction (thaw strain due to phase change of ice to water) is assessed by subtracting the total volume of ice inclusions (segregated ice) from the permafrost sample.

Analyses on unfrozen core samples

Determination of specific gravity and grain size analyses will be conducted on thawed core samples at CEN laboratories using conventional methods.