Supplementary material

1. CT-scan

To further investigate the cryostratigraphic characteristics of the ice, all samples were observed under X-ray computed tomography (CT) scanning (*Siemens SOMATOM Sensation 64*). This technique relies on the calculation of the linear attenuation coefficient that measured the density of an object passed through an X-ray beam at different angles. A CT-scan produces cross-sectional images (usually 512 by 512 pixels matrix) of an object where each pixel of the image is assigned an X-ray attenuation value (μ), also called a CT number. CT numbers are then standardized using the Hounsfield scale where the radiodensity of water (μ_{water}) is arbitrarily defined as 0 HU (Hounsfield units) according to Equation 1. Different shades of gray are assigned specific CT numbers to create the displayed image using a specific image processing software (Fiji) dedicated to DICOM (Digital Imaging and Communications in Medicine) images. In permafrost samples, unconsolidated sediments and rock (high density minerals) appear white, as the attenuation of these materials is very high. Gases inclusions and water appear black and other materials, such as ice, can have various shades of grey depending on their density.

$$HU\ value = \frac{\mu - \mu_{water}}{\mu_{water}} \times 1000\ , \qquad (1)$$

This tool helps refine cryostratigraphic characterization of permafrost cores as it can reveal characteristics otherwise difficult or even impossible to observe with the naked eye. It allows visualization and characterization of the internal components of the frozen sample, such as the ice, grain-size variations and gas inclusions. From a quantitative perspective, it has been used to segment images into regions of ice, gas and sediment in order to quantify the volumetric content of the sample scanned (Calmels et al., 2010; Dillon et al., 2008).

2. Ice crystallography

The typical method of measuring ice texture and fabric requires that an ice core or block is sliced into 1-cm thick vertical and horizontal sections with a band saw, and then thinning it to the desired thickness (< 0.5 mm) following the standard microtoming procedure. Three photographs were taken of each sample at different angles (0˚, 45˚, 90˚) under cross-polarized light in order to show the crystal boundaries as clearly as possible. The analysis is based mostly on qualitative observations, although statistics on crystal dimensions and geometry were obtained from digital analysis of thin section photographs. It should be noted that the values obtained from these parameters does not represent exact values and gives limited information since a thin section is only a two-dimensional representation of the crystals ("sectioning effect"). A digital image analysis using ImageJ software allowed delineating and measuring three geometrical parameters of each crystal. The area (mm^2), the long-axis (mm) and the circularity ratio determine the crystal texture (size and shape). The long-axis is a measurement of the primary axis of the best-fit ellipse to an ice crystal. The circularity ratio (C) is dimensionless parameter used to describe quantitatively the shape or outline form of a crystal. It is a function the perimeter P and the area A:

$$C = \frac{4\pi A}{P^2}, \tag{2}$$

As C approaches 1, crystals become more circular, and as it approaches 0, crystals become very narrow relative to their length. Therefore, the circularity ratio is a measure of the deviation of a crystal cross-section shape from a perfect circle.