Supplement Material 1

Computed tomography (CT) scanning of a 109-cm long sediment core collected in June 2015 in Gull Lake, Bylot Island, Nunavut, Canada

Methods

Computed tomography (CT) scanning is based on X-ray imaging of density contrasts within a given material. CT scanning has a high-density contrast resolution, spanning 4096 values (12-bit) of tomographic intensity (Boespflug et al., 1994). This technique allows for visualizing sedimentary structures in three dimensions (3D), an obvious advantage over classic X-ray imaging methods (radiography) constrained to predefined visualization plans (2D). Collected data can also be used to determine quantitative correlations between tomographic intensity values ('CT numbers') and sediment density, and to calculate volumetric content of given fractions of the scanned object.

Imaging was conducted on the 2015 core (109 cm) using a Siemens SOMATOM Definition AS+ 128 medical scanner hosted at Institut national de la recherche scientifique (INRS) in Québec City, Canada, as reported by Calmels and Allard (2004). X-ray theory and technical aspects were first described by Hounsfield (1973) and the apparatus used in this study is described by Boespflug et al. (1994). CT scanning was done at a voltage of 140 keV, a current of 300 mAs, a pitch of 0.55 and a rotation time of 1s. Spatial resolution (pixel size) was 0.166 mm for transversal sections (x,y) and 0.6 mm along the longitudinal axis (z), giving an elementary volume resolution (voxel size) of 0.166 x 0.166 x 0.6 = 0.017 mm^3. As the scanner is in a sliding gantry configuration, the core was placed on a fixed bench at the centre of a ring containing the X-ray source, which moved along and rotated around the samples during analysis (Fig. S1). The core was therefore scanned in a helical or spiral movement, allowing imagery to be conducted in all spatial directions.

Sediment density was calculated as the tomographic intensity (Hounsfield, 1973):

$$TI = \left(\frac{\mu}{\mu_w} - 1\right) \times 1000$$

where TI is the tomographic intensity in Hounsfield Units (HU), and μ and μ_w are the linear absorption coefficients of the core and of distilled water at ambient temperature and pressure, respectively. The coefficient μ varies mainly according to the density and the mean atomic number of the main elements composing the scanned material (Boespflug et al., 1994). Hence, TI varies according to sediment bulk density, mineralogy, as well as porosity. For natural materials, TI values will range from -1000 HU in air to 0 in water and to > 3000 HU in common minerals and rocks, with intermediate values in peat and mineral sediments (Table S1).

Images were saved under the DICOM (.dcm) format, the standard format in medical imaging. Such images can be used to transform TI data into real density values (in g cm^{-3}) according to Boespflug et al. (1994). Most lake-sediment and soil samples generally show TI values ranging from around 0 to around 2000, depending on their porosity and water content, corresponding to real densities varying between ~ 1 and 3 g cm^{-3}. The free software Fiji (ImageJ) was used to visualize, calibrate and analyze obtained images. Low-density or high-porosity materials (e.g., air, water, peat) appear in dark tones, whereas high-density or low-porosity materials (e.g., clay, sand, rock) appear in light tones (Fig. S2).

References

Boespflug, X., Ross, N., Long, B., and Dumais, J. F.: Tomodensitométrie axiale: relation entre l'intensité tomographique et la densité de la matière, Canadian Journal of Earth Sciences, 31, 426-434, doi: 10.1139/e94-039, 1994.

Calmels, F., and Allard, M.: Ice segregation and gas distribution in permafrost using tomodensitometric analysis, Permafrost and Periglacial Processes, 15, 367-378, doi: 10.1002/ppp.508, 2004.

Hounsfield, G. N.: Computerized transverse axial scanning (tomography): Part 1. Description of system, The British Journal of Radiology, 46, 1016-1022, doi: 10.1259/0007-1285-46-552-1016, 1973.

Rogasik, H., Onasch, I., Brunotte, J., Jegou, D., and Wendroth, O.: Assessment of soil structure using X-ray computed tomography, in: Applications of X-ray Computed Tomography in the Geosciences, edited by: Mees, F., Swennen, R., Geet, M. V., and Jacobs, P., Geological Society, Special Publications, London, UK, 151-165, 2003.

Tables and figures

Table S1. Tomographic intensity and density of selected natural materials (Rogasik et al., 2003).

Material	**Tomographic intensity** (HU, Hounsfield Units)	**Density** ($g\ cm^{-3}$)
Air	-1000	0.00
Water	0	1.00
Wet peat	200 - 500	1.12 - 1.25
Silt, clay	100 - 1600	1.07 - 1.83
Sand	800 - 2200	1.44 - 2.08
Rock, quartz	2900 - 3200	2.50 - 2.65

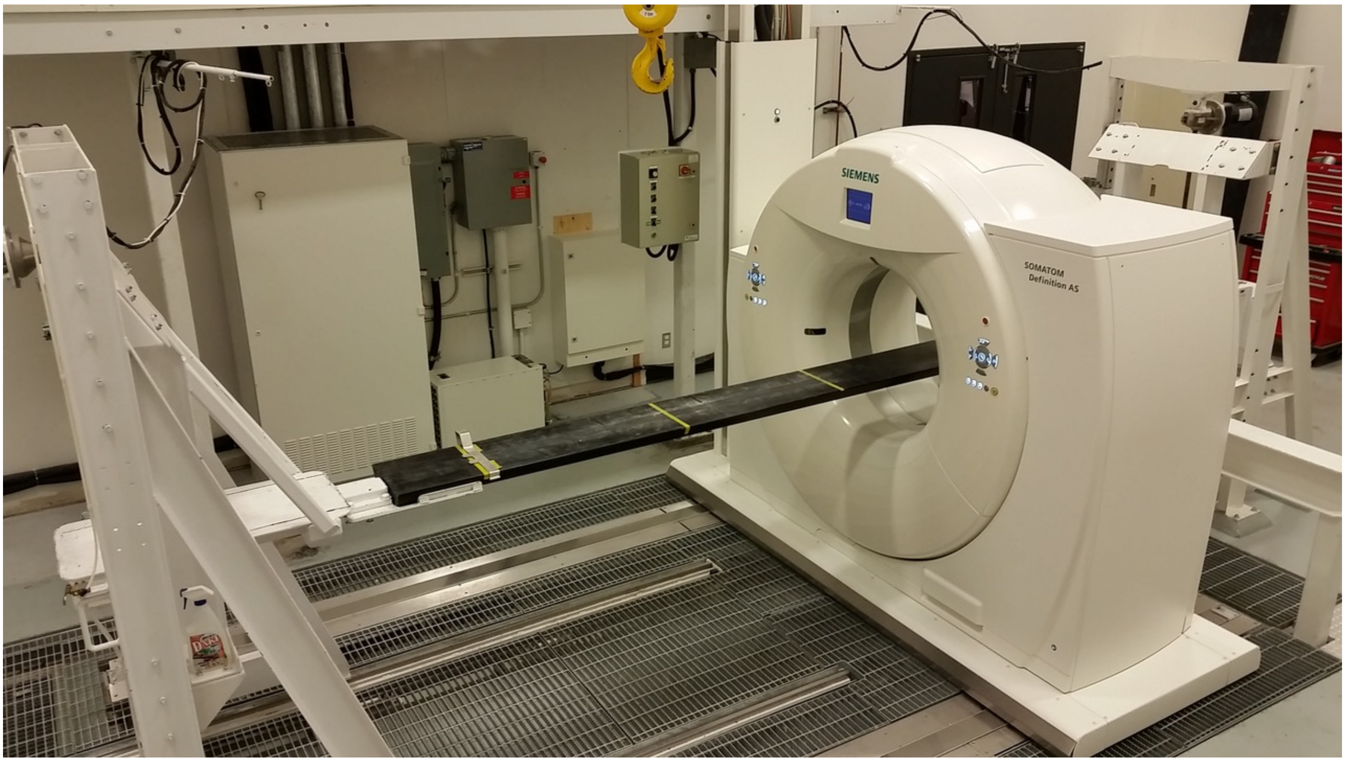

Figure S1: Siemens SOMATOM Definition AS+ 128 medical scanner hosted at Institut national de la recherche scientifique (INRS) in Québec City, Canada.

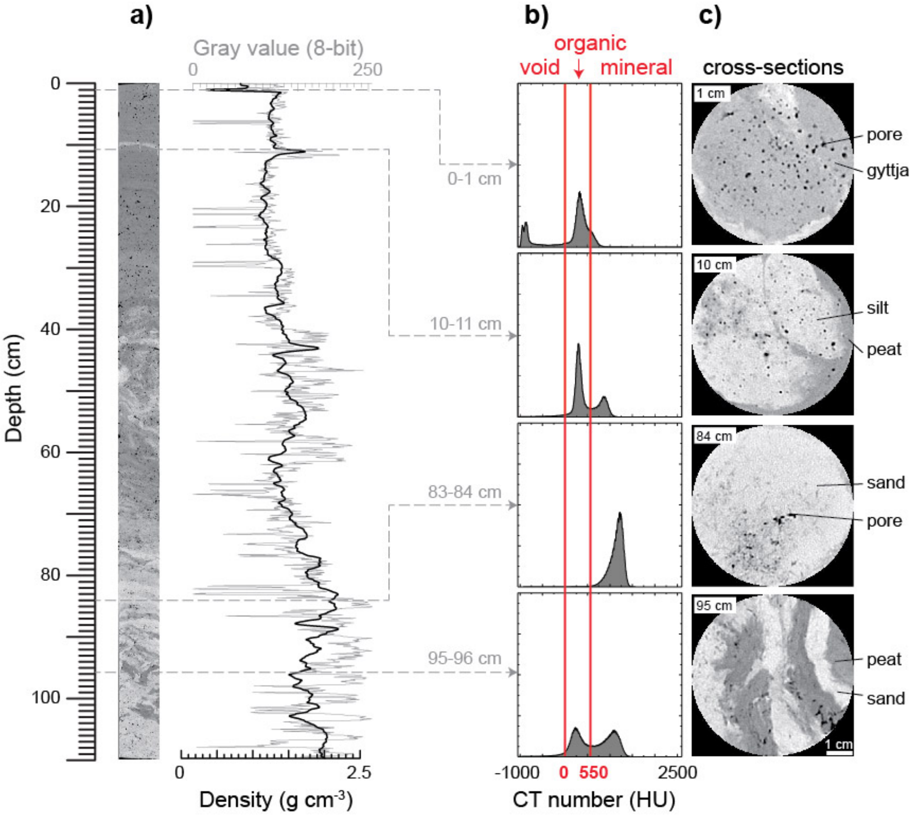

Figure S2: Computed tomography (CT) scanning of a lake sediment core. (a) CT-scan 2D image, grayscale profile extracted from the 2D image, and density profile inferred from the whole core (3D). (b) Frequency histograms of selected 1-cm intervals (1,058,090 voxels) used to differentiate voids (air/water), organic material (gyttja/peat) and mineral material (silt/sand) based on their CT-number range. (c) Cross-section (6.7-cm diameter x 0.6-mm thickness) images on top or at the base of the intervals in (b), where distinct sediment fractions can be identified.