Permafrost core characterization using gamma ray attenuation and industrial computed tomography scanning

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Context

The collection of permafrost cores is expensive and time consuming and can sometimes represent a one-time opportunity. Making sample storage, perp and subsampling critical steps. Non-destructive data collection methods can help streamline the subsampling and analysis stage resulting in better use of the limited material.

Permafrost ArChives Science (PACS) Lab

A physical and digital **archival facility** for the characterization and analysis of permafrost materials.

Permafrost **core processing** laboratory;

- Core scanning (Mag Sus, gamma density, optical properties) for ice and thermal properties
- Nikon Industrial CT Scanner (cryostructures, ice, gas and sediment contents – <0.1 mm resolution)

Analytical labs;

- Water isotopes (2 Picarros 2130 isotope analyzers), grain size analyzer and elemental analyzer
- HEPA filtered clean labs for genomic and biogeochemical sampling and extractions
- Test facility– heave cells in walk-in freezer for long-term experimental studies (in construction)
- Affiliated analytical labs at the U of A (ICP-MS-metals, organic chemistry, contaminants)

Destructive methods

Core processing – PACS lab cutting room

- Cores were processed in the PACS lab cutting room held at -10C°.
- All cores cut in half along their long axes with half core kept as archive and the other used as working half.
- The cores were then subsampled for multiple analyses as seen in the image above.

Cuboid method – bulk density

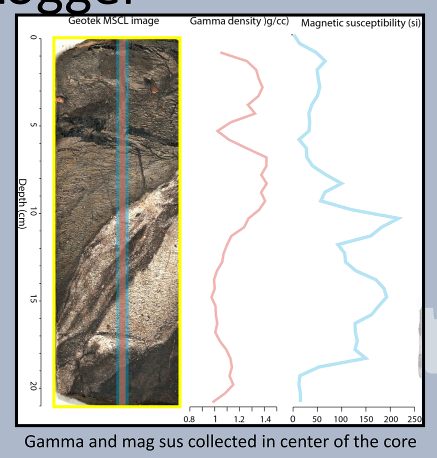
- Cuboid method uses carefully cut cubes measured with digital calipers along with a high precision scale to collect bulk density measurements from frozen material.

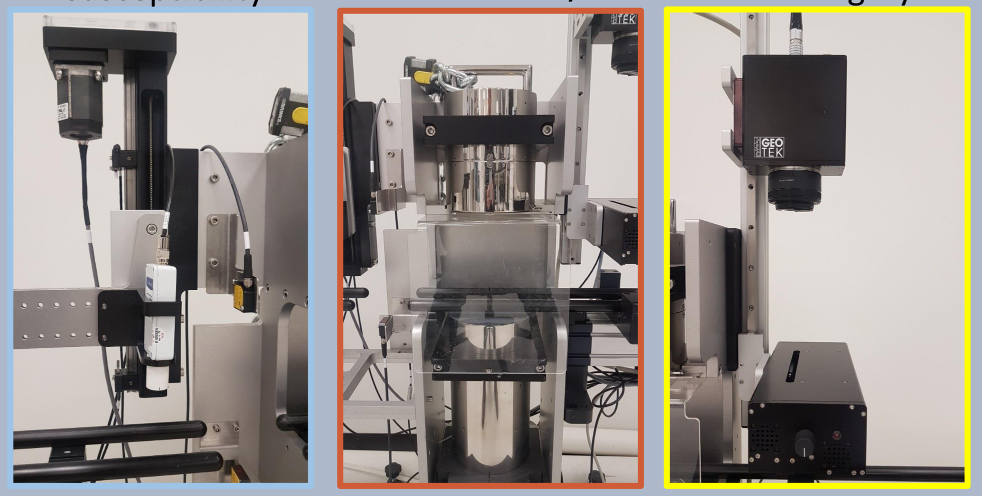
Non-destructive methods

Nikon XT H 225 ST Micro CT

- The **Nikon XT H 225 ST Micro CT** has a 225 kV, 225 W maximum power source able to carry out high power scans with high resolution.
- Greater image detail compared to typical medical scanner.
- To minimize temperature lose all scanned cores were placed inside and insulated styrofoam container during the scans.
- The scans times were ~ 45 minutes
- Temperature of the outside of the core ramped from -25C° to -10C° over the course of the scan.
- Internal temperature of the core stayed relatively constant.
- All scans were helical scans
- All scans had an effective pixel size of ~60um
- Reconstructed file size of ~20-35 GB.

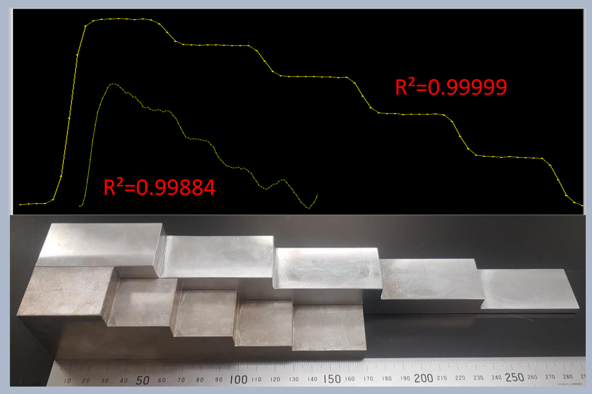
GEOTEK Multi Sensor Core Logger



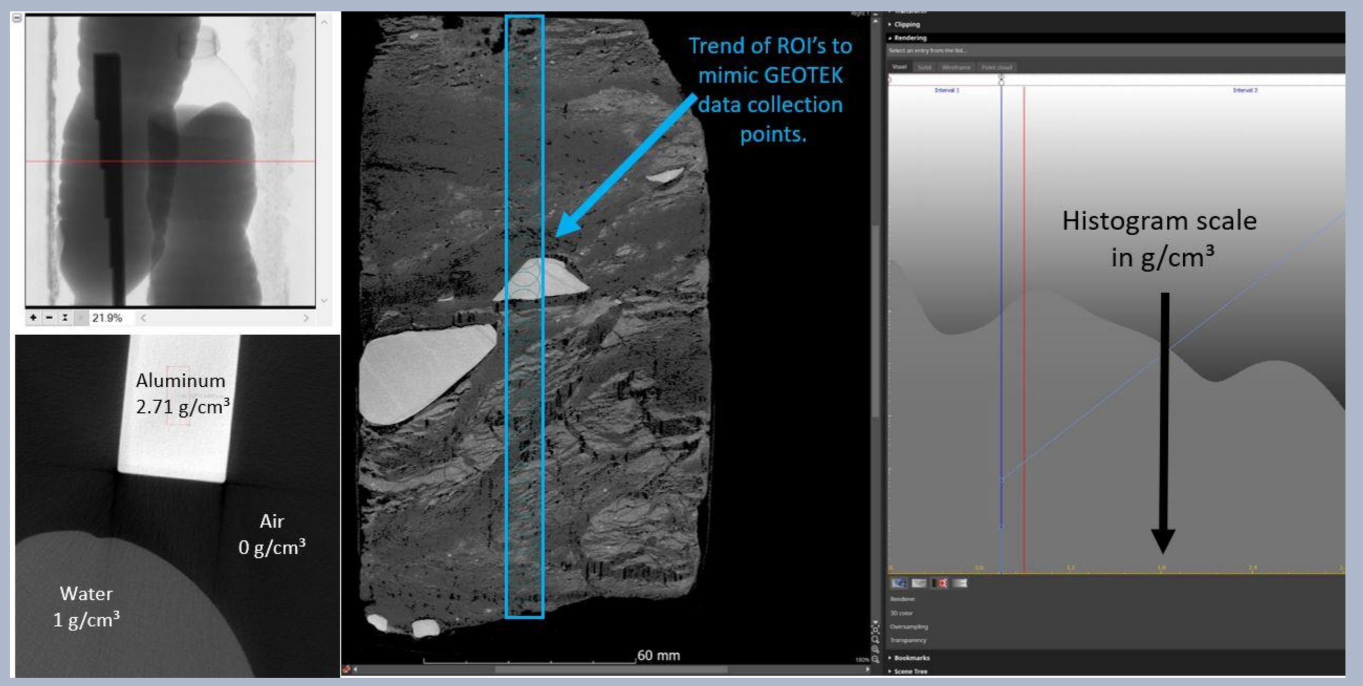


- We use three of the offered sensors on the **GEOTEK Multi Sensor Core logger.**
- The camera for capturing high resolution core images allowing for detailed cyostratigraphic analysis.
- The Gamma Density sensor which uses Cs 137 in a shielded container as a fixed source of gamma radiation.
- The magnetic susceptibility data was collected using the point sensor but the data is not presented on this poster.
- The source emits gamma radiation through the material and into the shielded detector.
- The bulk density is calculated (g/cm³) based on attenuated radiation.
- A 25 cm core takes ~20 minutes to scan using a 5 second sensor count at a 0.5 cm resolution.
- We found that having the core at a stable -25C° in a near by chest freezer resulted in minimal thaw.

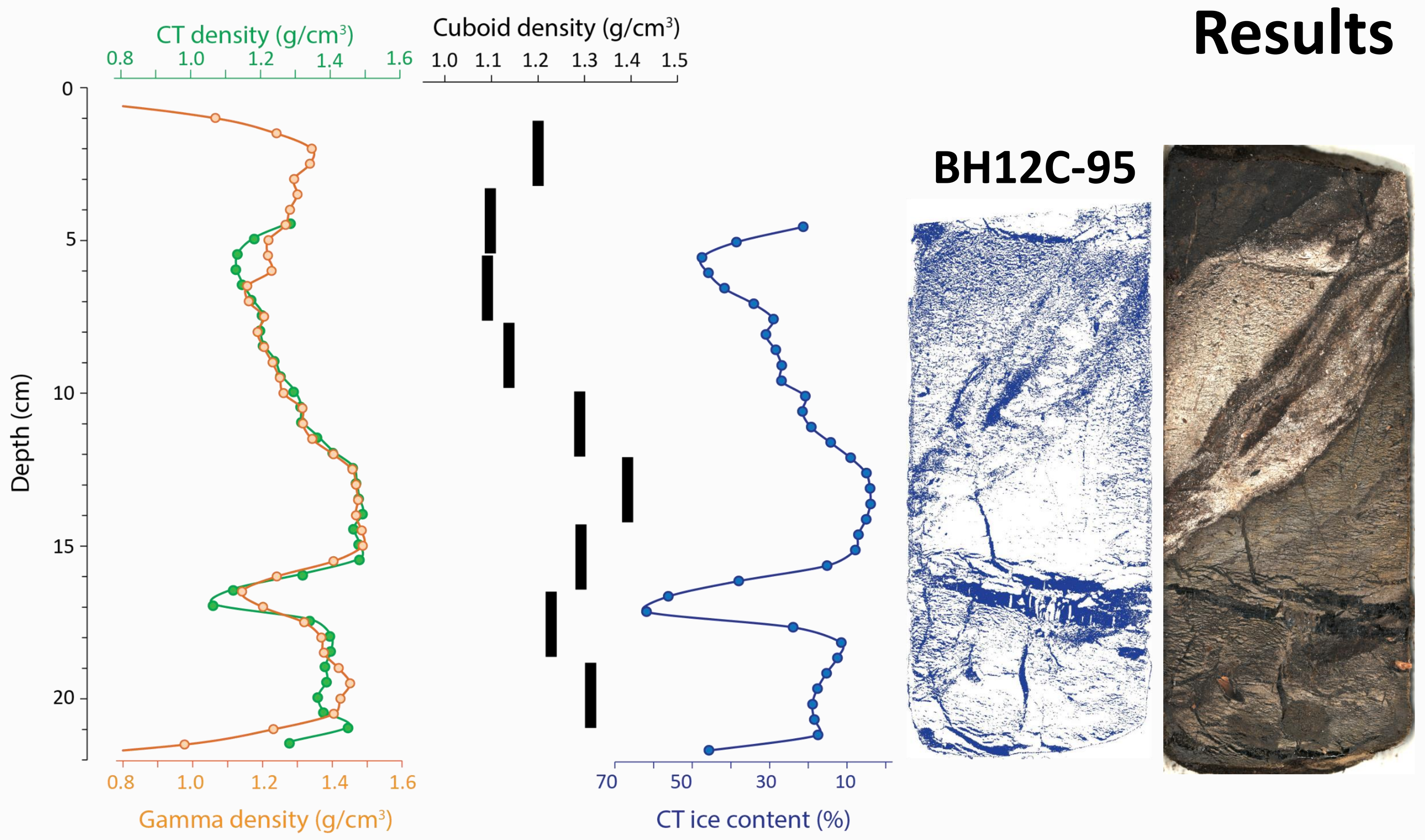
Calibration and comparison

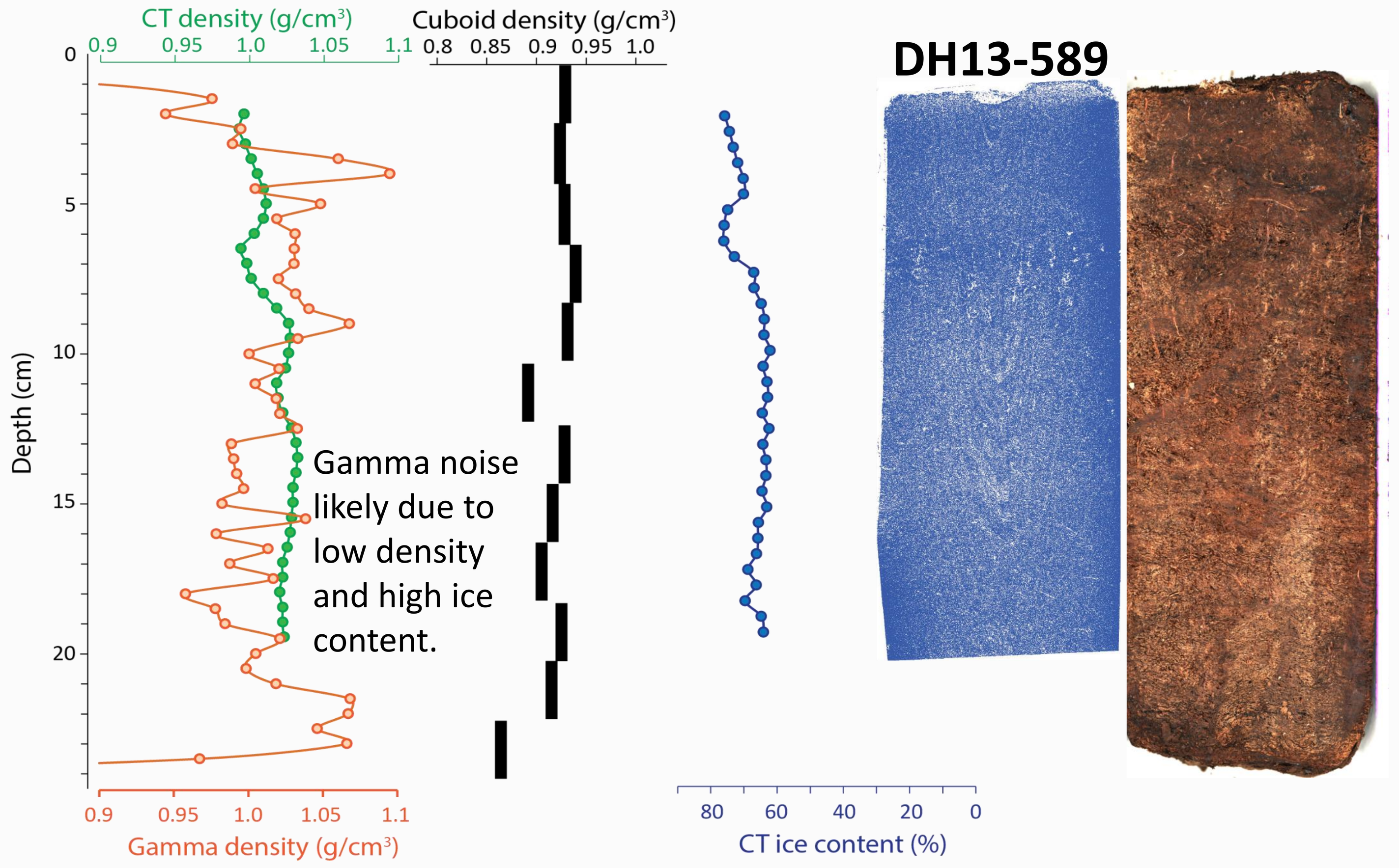


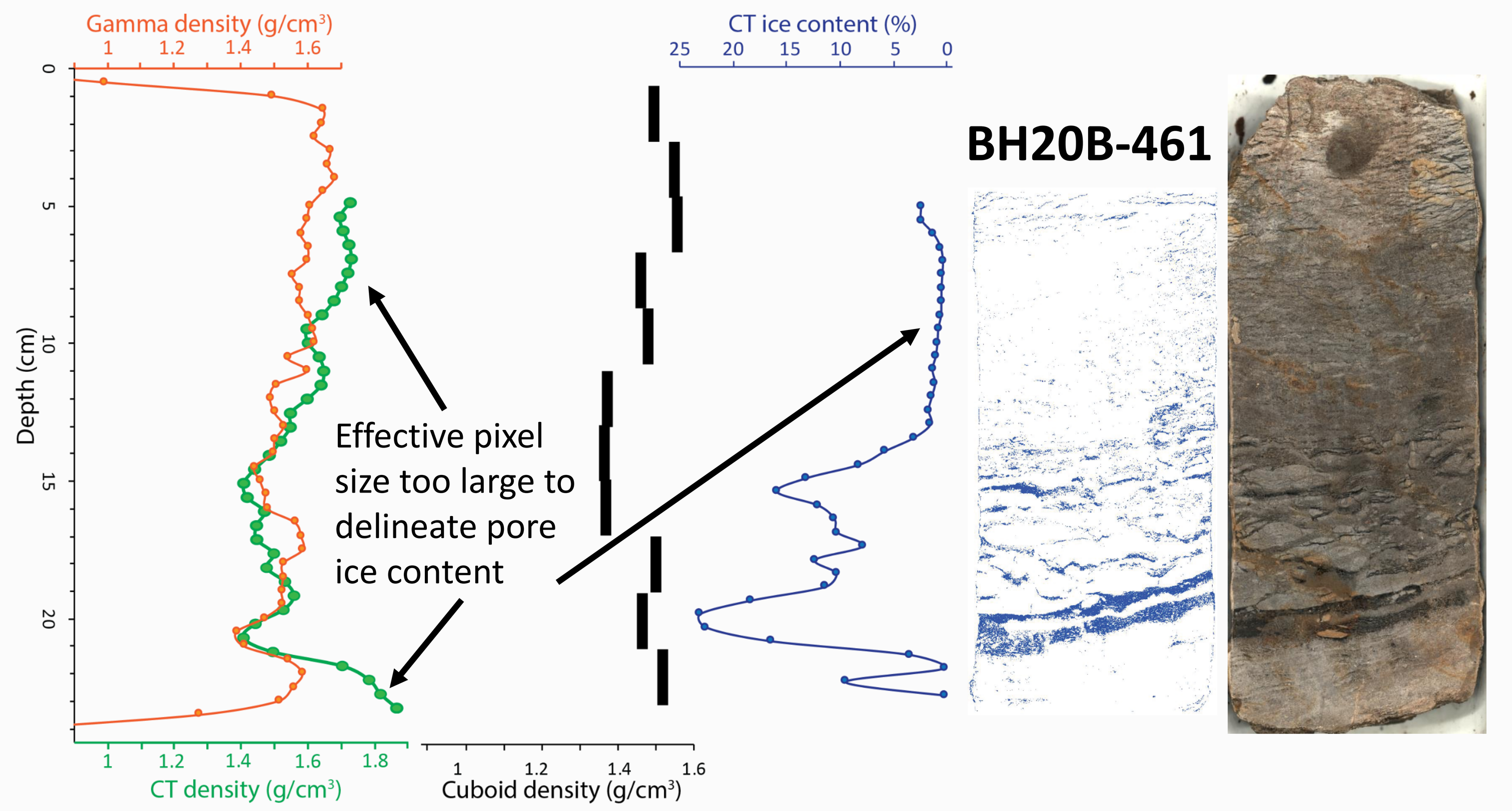
- GEOTEK and the Nikon CT use stepped piece of aluminum for calibration.
- We designed our own piece based on the supplied GEOTEK piece but with longer steps resulting in accurate and reproducible calibration curves and 50% less run time for the calibration run.
- The CT Scanner produces linear attenuation units
- Nikon CT Pro 3D (a software provided with the scanner), converts Linear attenuation units directly to g/cm³.
- The blue highlighted region in the center image below shows the location of ROIs in CT scan to overlap GEOTEK data collection locations.

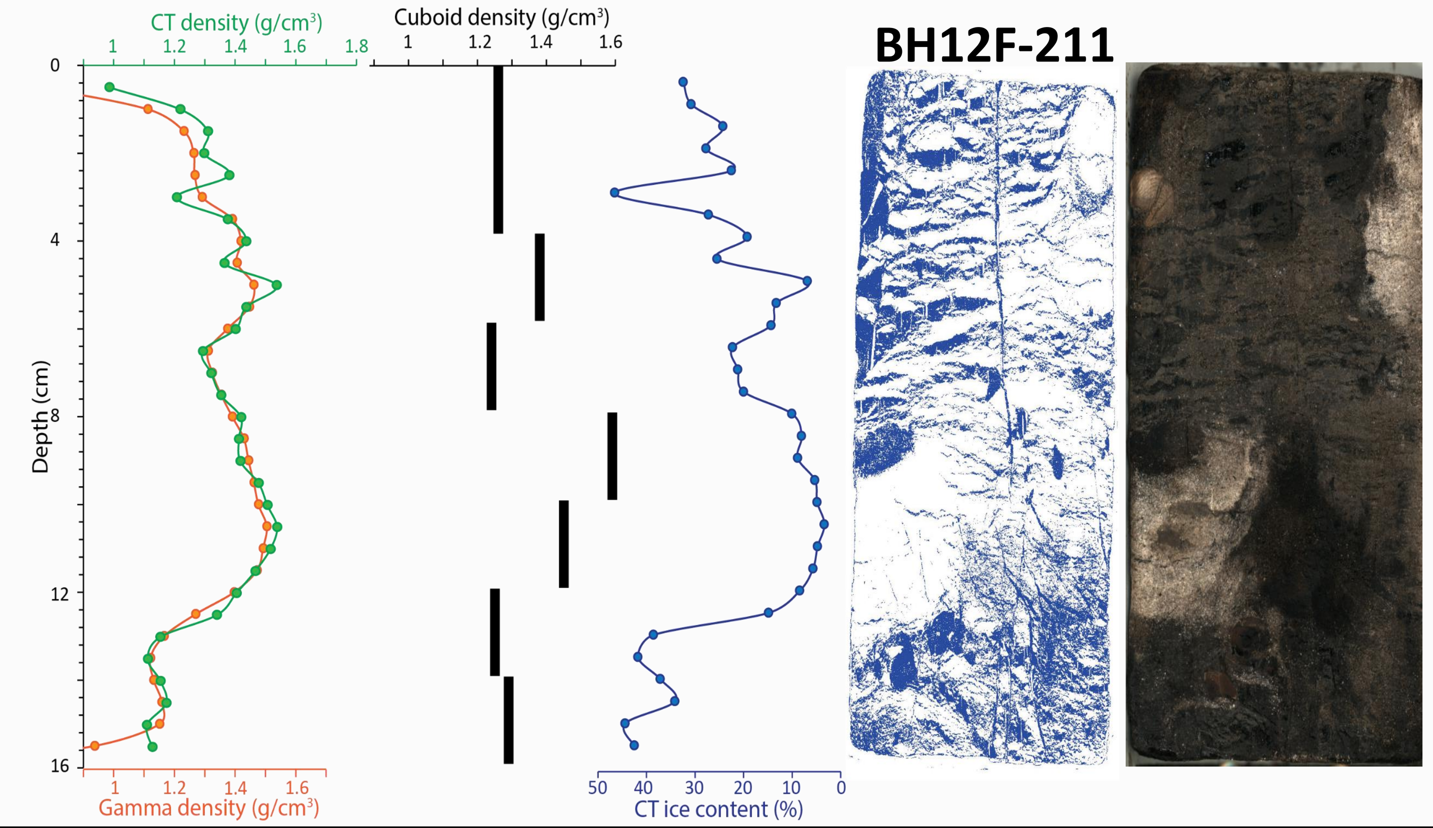


Results









	GEOTEK MSCL	Nikon Micro CT
Multiple Data Sets	+	+
Rapid Data Sets	+	-
Limited Training	+	-
Maintenance Cost	+	-
Adaptability	-	+
Whole Core Results	-	+
3 Dimensional Visual	-	+
Accurate Ice Content and Porosity	-	+
Rapid Core Imagery	+	-
Total	+++++	+++++

Conclusions & future work

Overall, the GEOTEK is a faster and cheaper method to collect bulk non-destructive density measurements relative to the CT Scanner. However, the CT Scanner can pull more data from the whole core at a user defined scale.

GEOTEK future work;
Ice-rich low-density scans to investigate frequency and consistency of gamma noise

Nikon CT scanner future work;
Decrease pixel size to capture pore ice in fine sediment and accurately delineate ice and organics

Questions? pumple@ualberta.ca

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Acknowledgements

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