



Non-destructive characterization of permafrost physical properties using industrial computed tomography

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PermafrostNet
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Recent permafrost landslide, In the central Mackenzie Valley Foothills
Credit: **Alexandre Chiasson** (June 2021)

Video from Brendan O'Neill, GSC Ottawa

Questions

- What is excess ice?
- Why is it important?
- What is the problem this study wants to address?

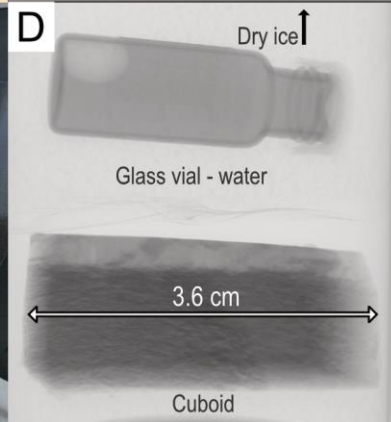
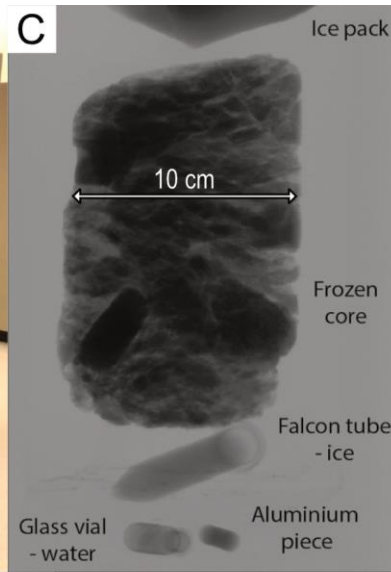
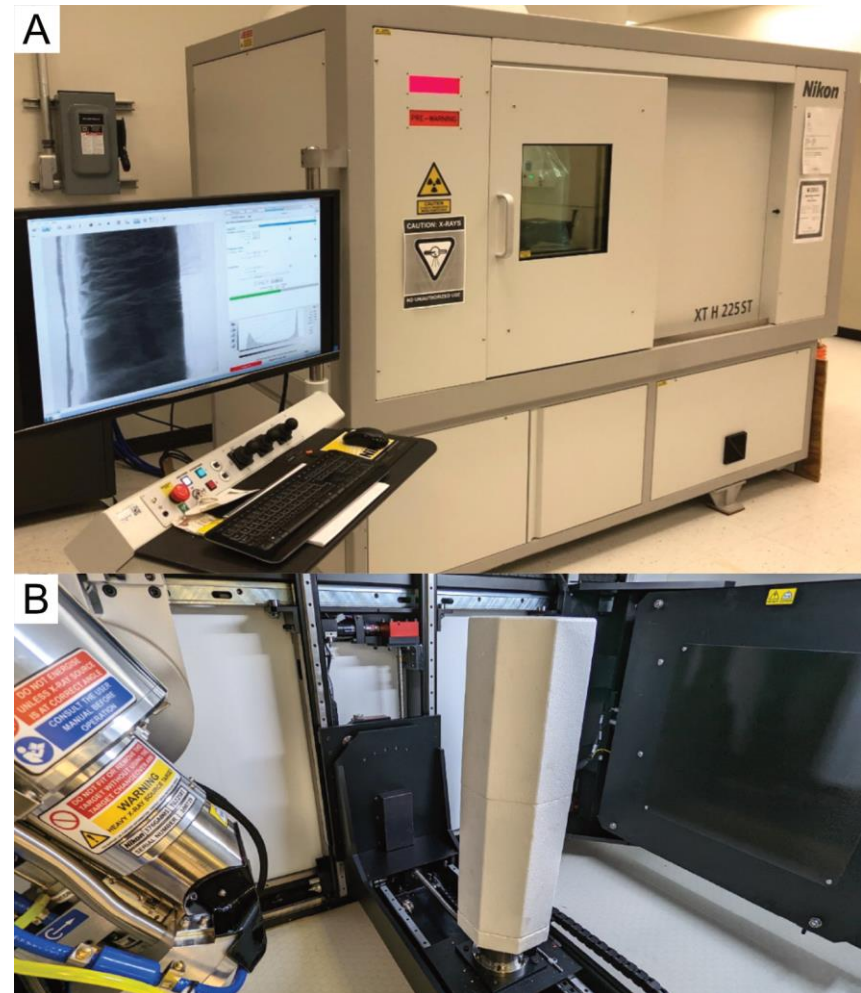


OBJECTIVE

- Use high-resolution Industrial computed tomography (CT) scanning to image a range of permafrost cores
- Use image analysis and estimate the pore ice and excess ice contents *non-destructively*
- Present a systematic quantitative comparison between the laboratory-measured (destructive method) and the CT image analysis.
- Present a comparison between the CT-derived composition of permafrost cores and a recent new non-destructive method (MSCL)

Non-destructive method

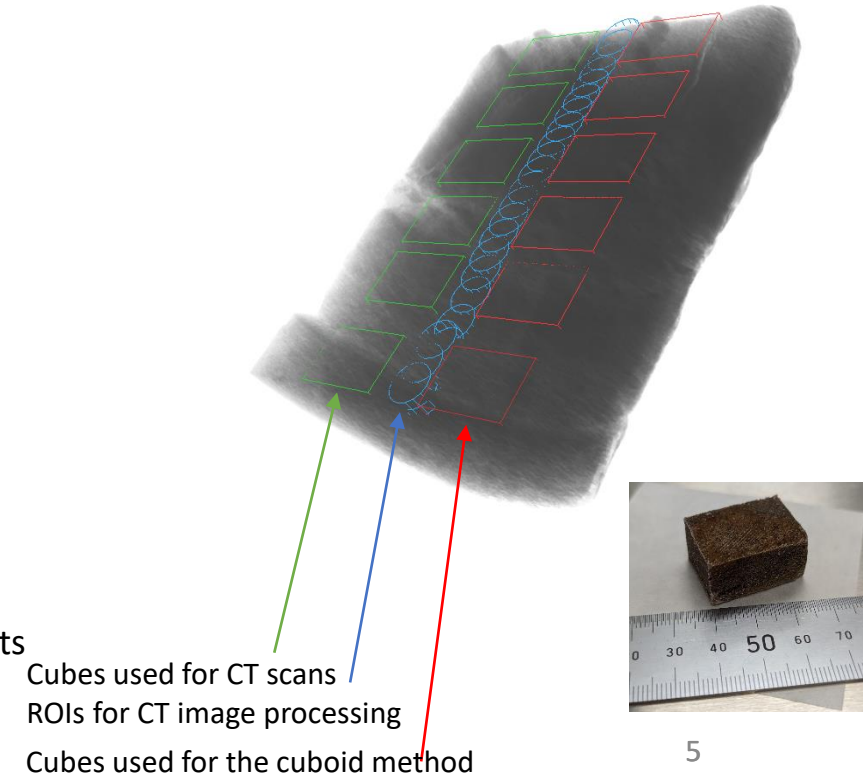
Nikon XT H 225 ST



- Superior x-ray penetration (225 kv peak voltage)
- Better resolution (10 cm core ~60 um pixel size)
- Does not require a dedicated room to operate
- Cheaper to maintain and operate



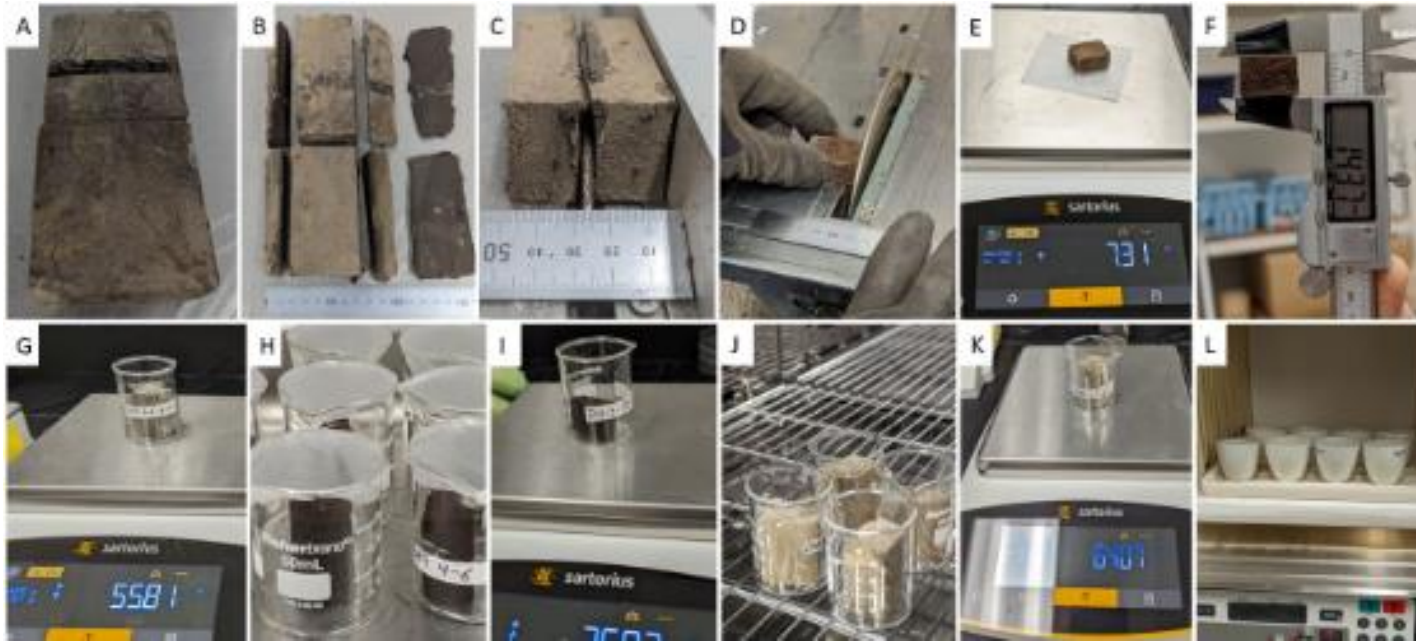
Micro-lenticular organic sandy silts
with large ice layer
BH18-211



Cubes used for CT scans
ROIs for CT image processing
Cubes used for the cuboid method

Destructive method

Cuboid Method (VIC, GMC, EIC, EMC, ρ , ρ_s)



VIC: Volumetric Ice Content

EIC: Excess Ice Content

GMC: Gravimetric moisture content

EMC: Excess moisture content

ρ : Bulk density

ρ_s : Density of sediments

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Ice-poor inorganic sandy silts.

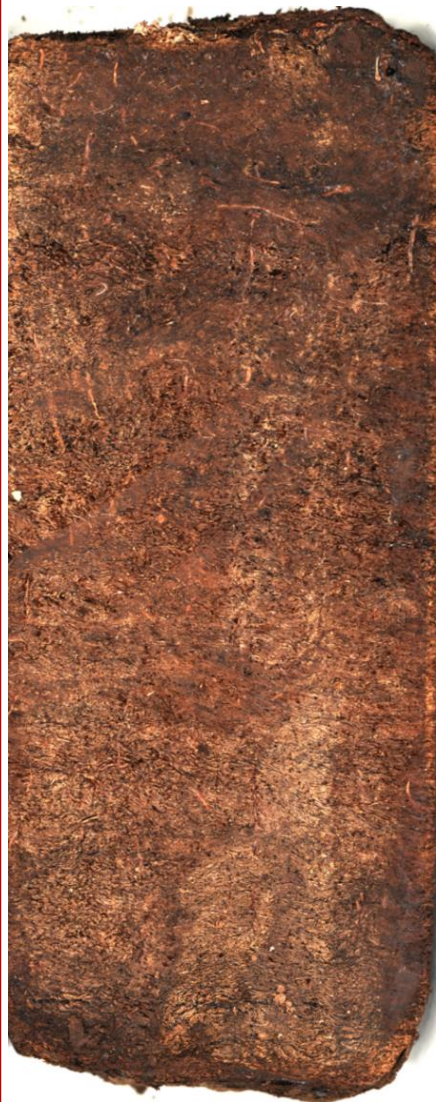
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Micro-lenticular organic sandy silts with large ice layer

Material

DH13-589



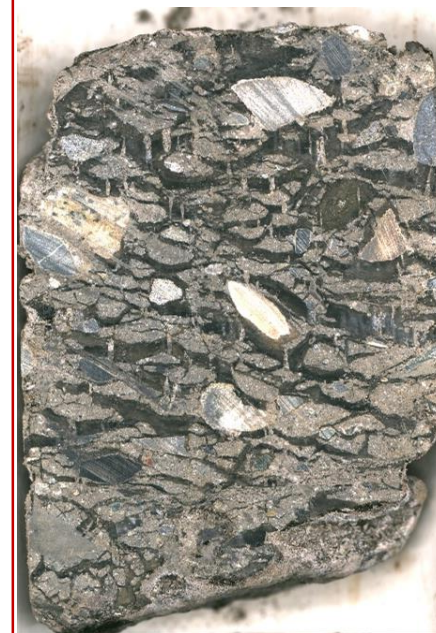
Ice-rich peat

BH12F-138



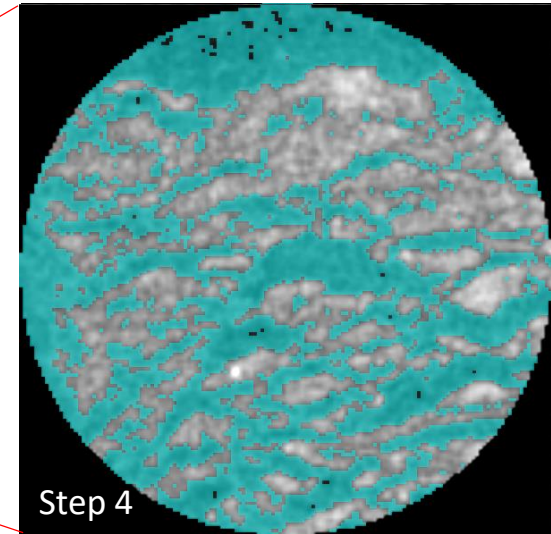
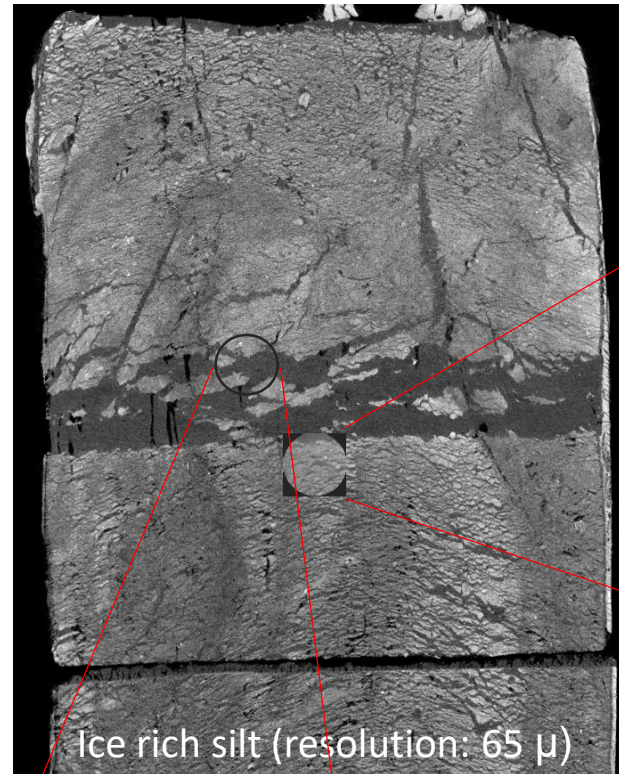
Sharp transition between ice-rich sandy silty peat and inorganic ice-poor silts

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Ice rich diamict

Otsu's method (automatic imagery classification)



Blue area (Excess ice + pore ice)

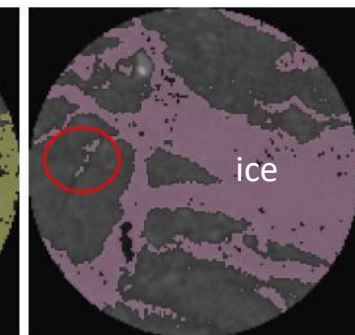
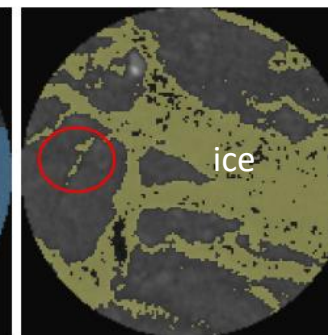
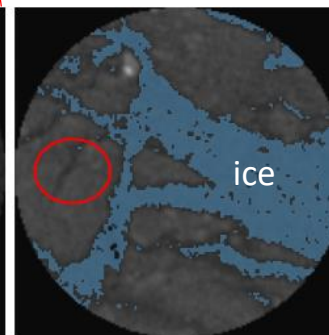
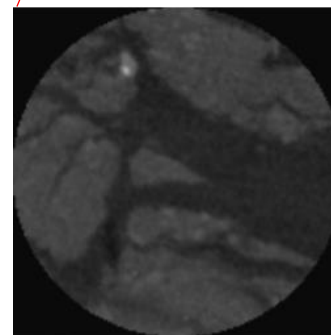
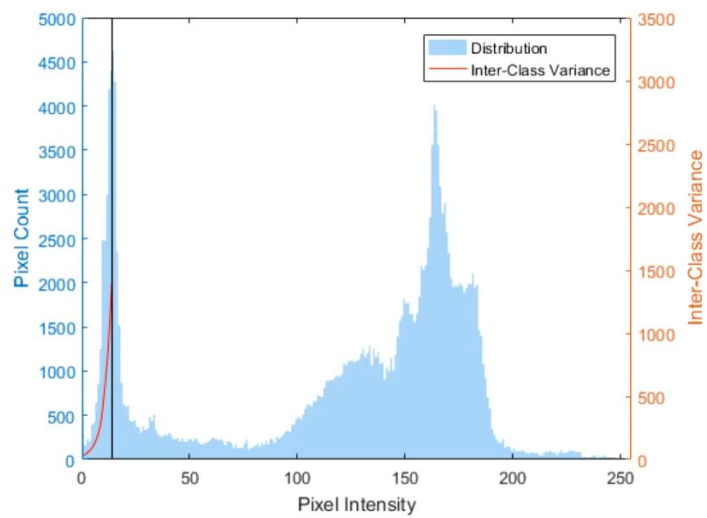


Image segmentation results
a) Before b) After c) Histogram

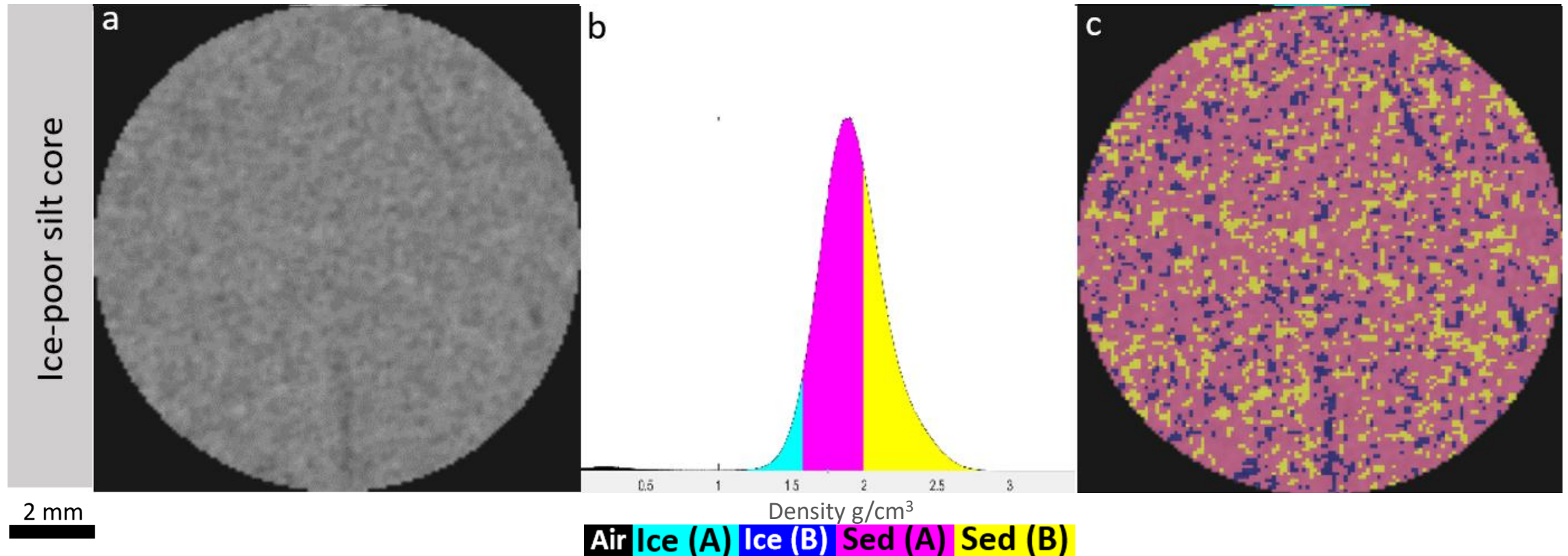


Image segmentation results

a) Before b) After c) Histogram

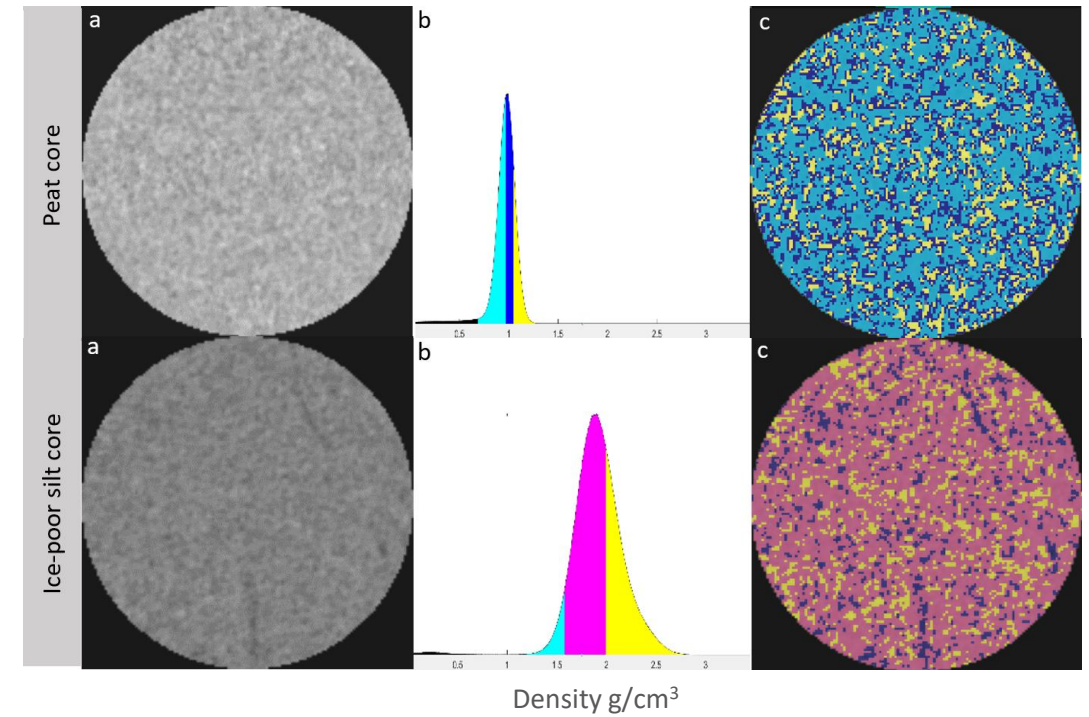
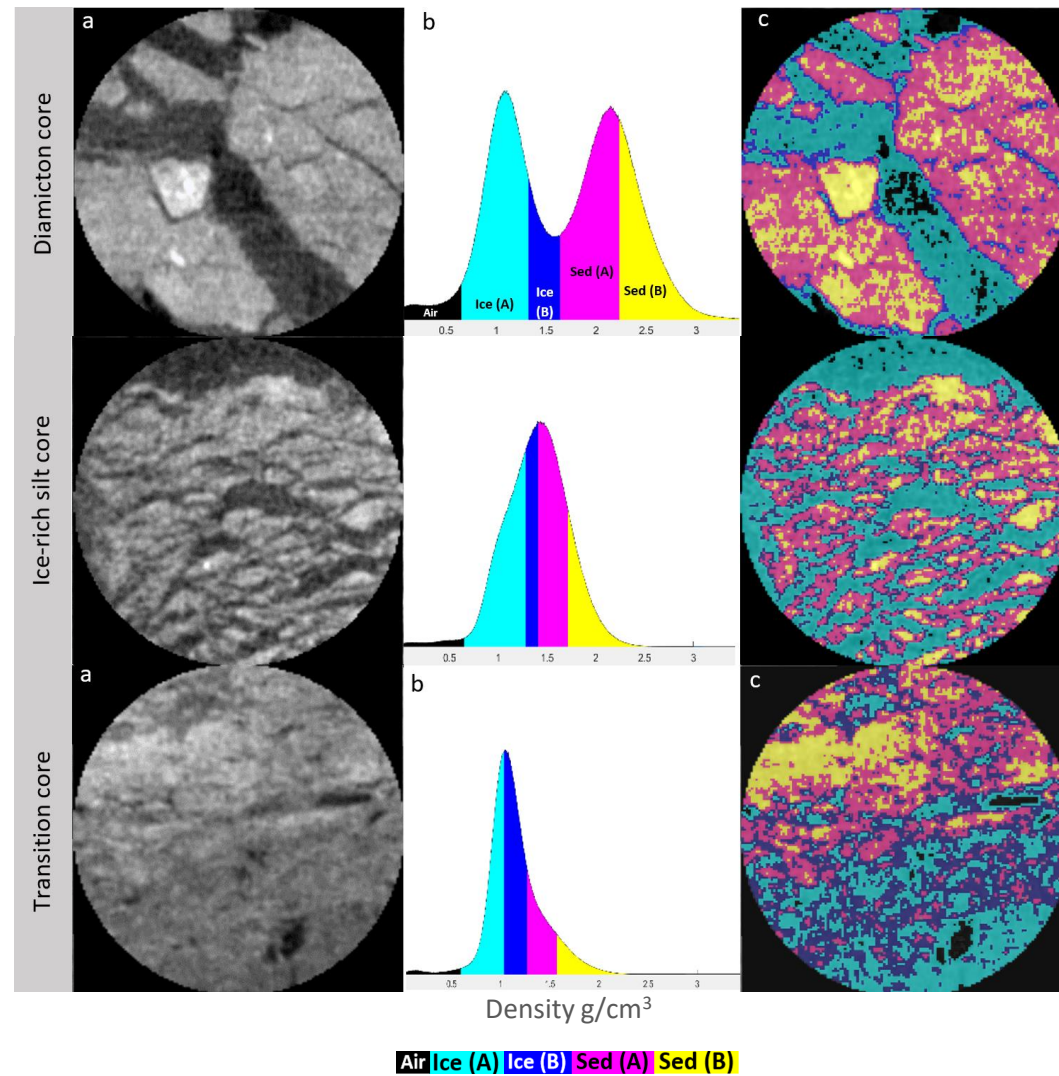
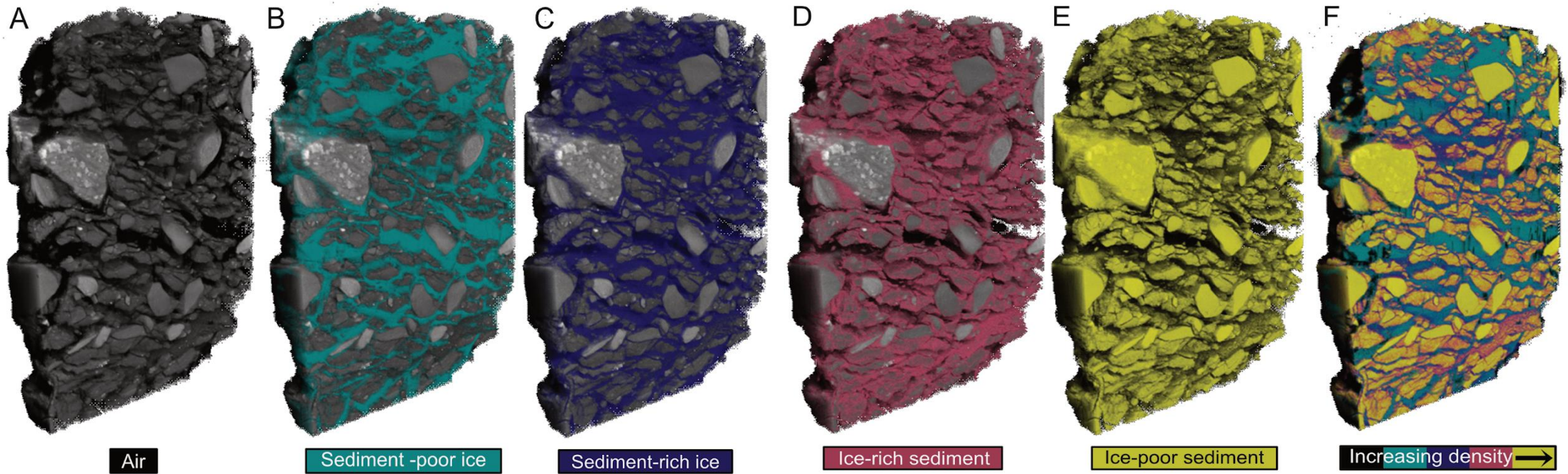
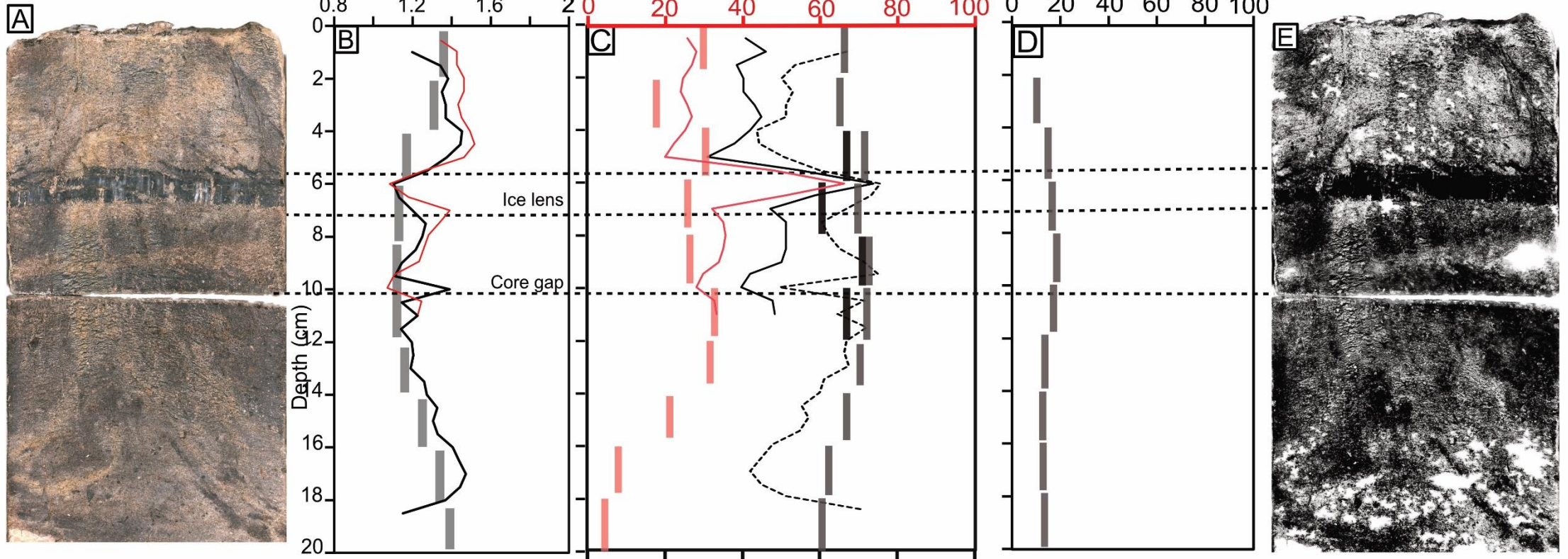


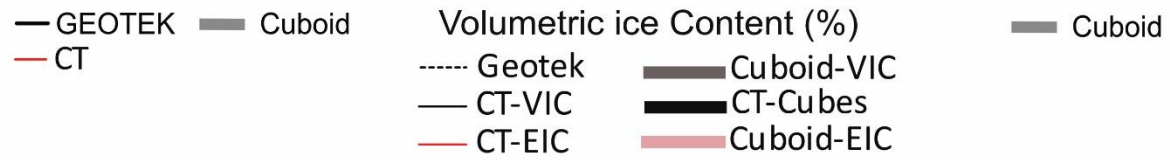
Image segmentation results of the diamict core



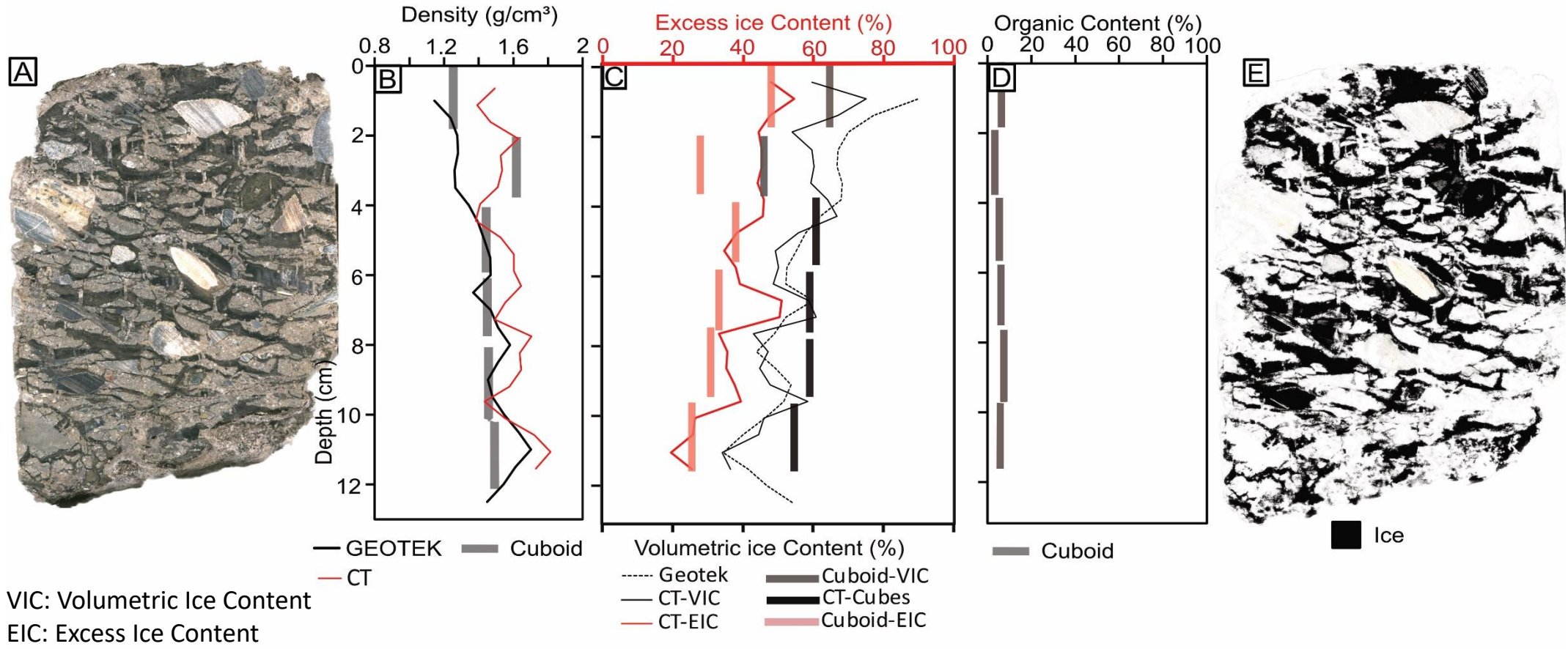
Ice-rich silt core



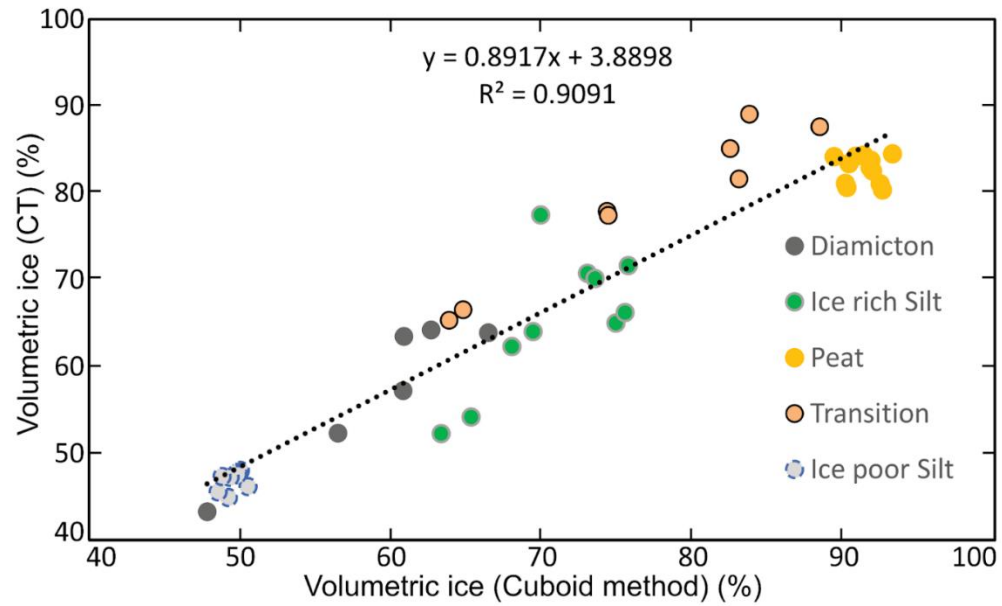
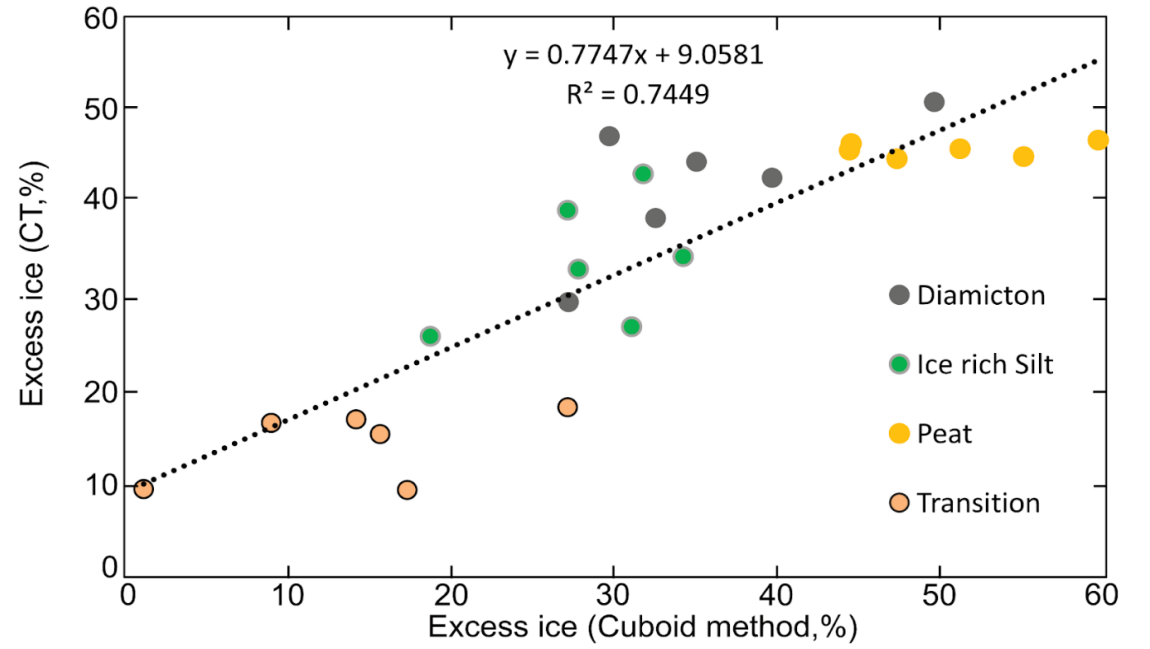
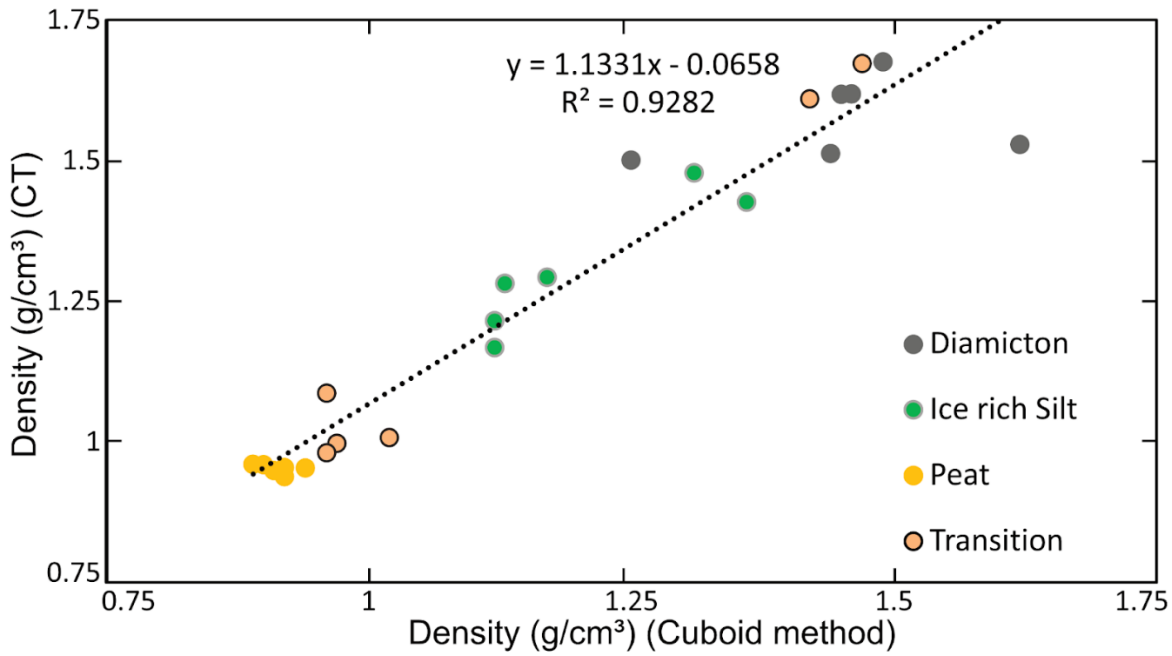
VIC: Volumetric Ice Content
 EIC: Excess Ice Content



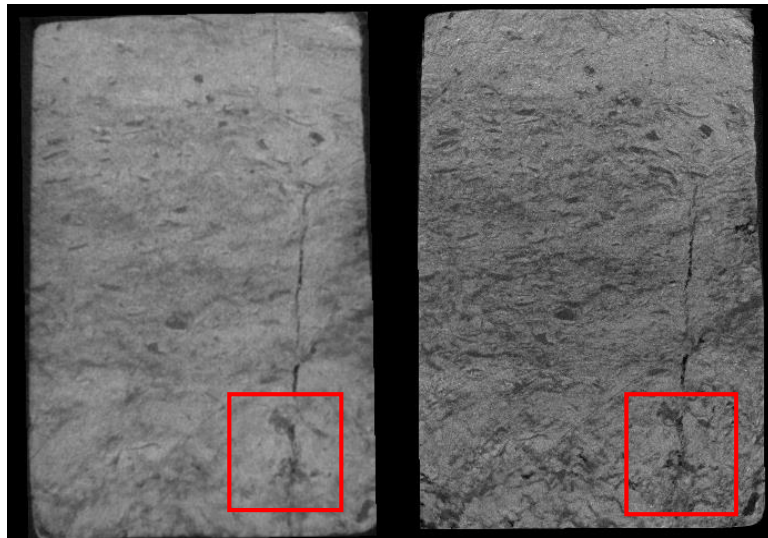
Diamicton core



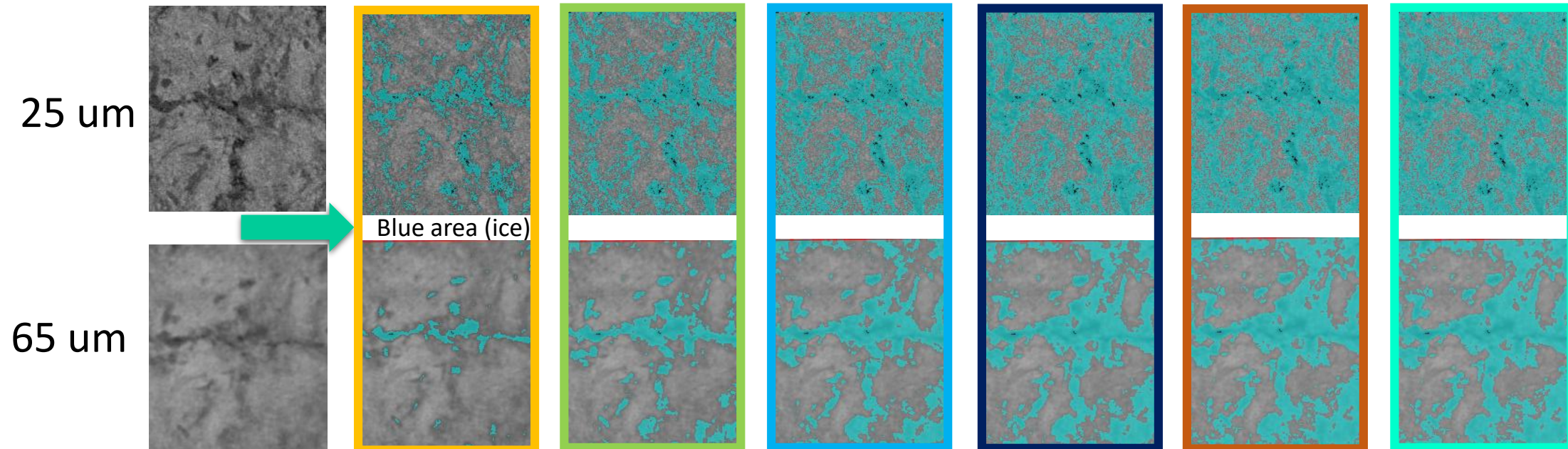
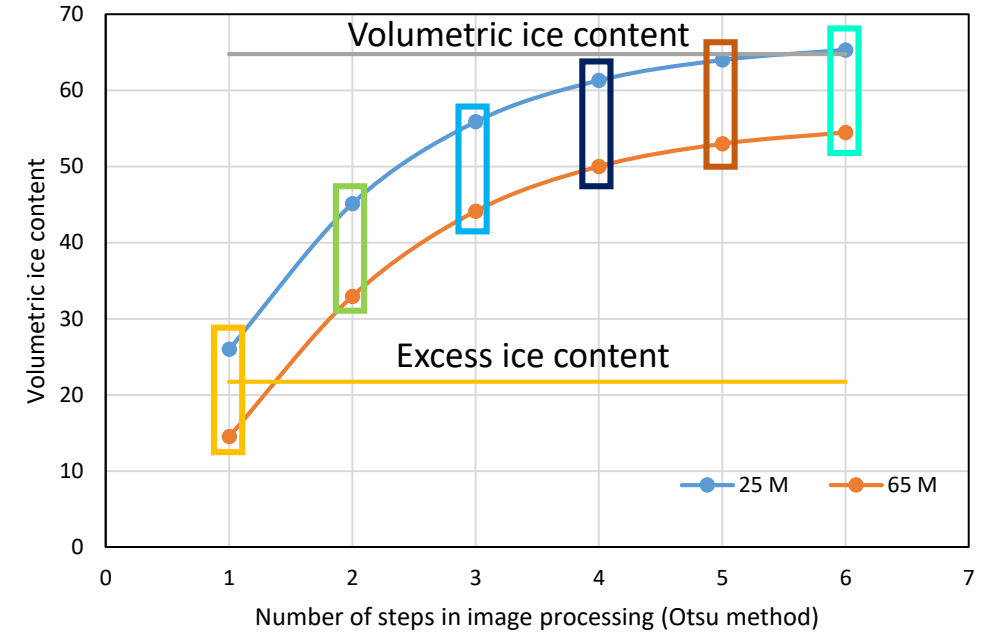
Comparison



CT Resolution – 65 μm (core) vs 25 μm (cube)



CT images of a cube from the transition core in two different resolutions 65 μm (left), 25 μm (right)



Conclusion

- Application of high-resolution CT
- Strong agreement between ND and D methods
- A sensitivity analysis of resolution

Next Steps

- Extract a correlation between VIC, EIC, GMC
- Apply it to the available permafrost database

Sediment type

Density

GMC

VIC

Excess ice



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Thank you

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