Estimating excess ice using industrial computed tomography scanning and comparison with established methods

Mahya Roustaei[1], Joel Pumple[1], Jordan Harvey[1] and Duane Froese[1]

[1]Department of Earth and Atmospheric Sciences, University of Alberta, Edmonton, Canada

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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

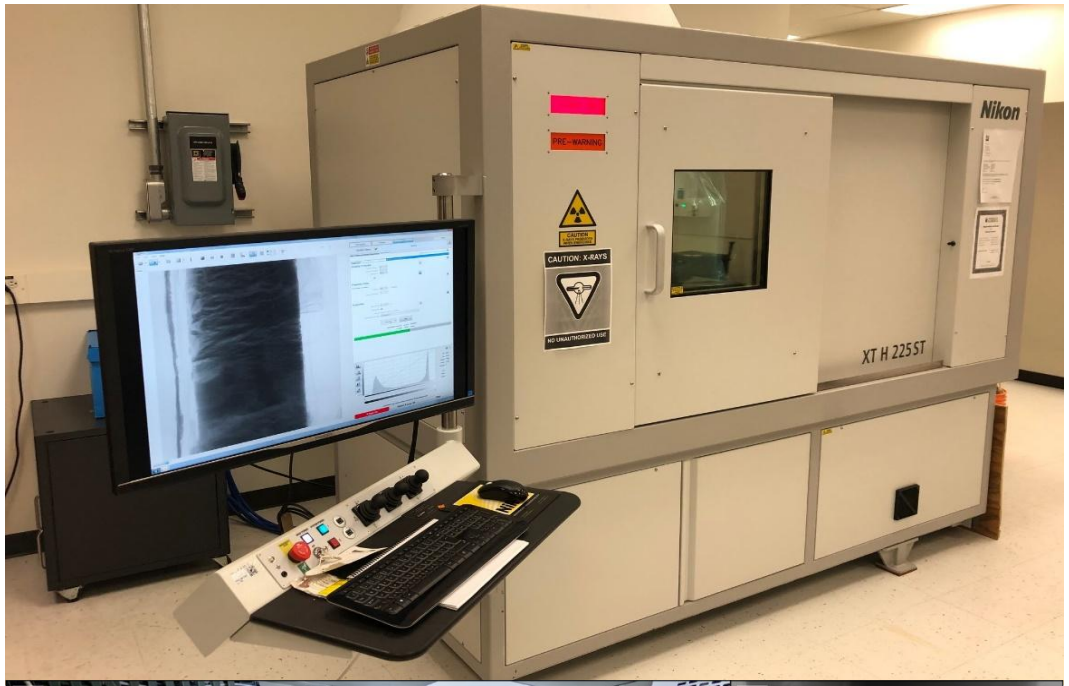
Questions

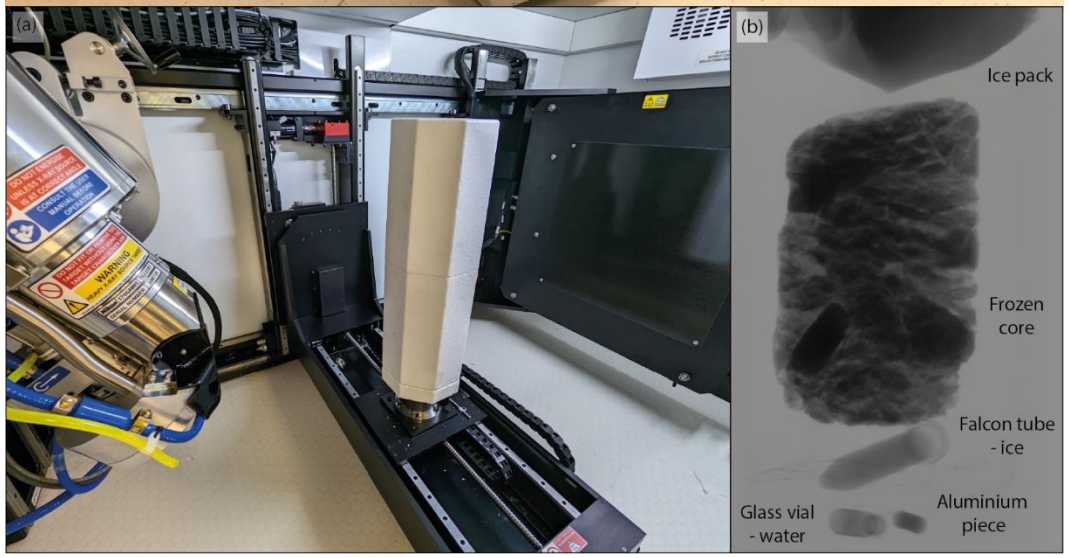
- What is excess ice?
- Why is it important?
- What is the problem this study wants to address?

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 (GeoTek)c

Non-destructive method



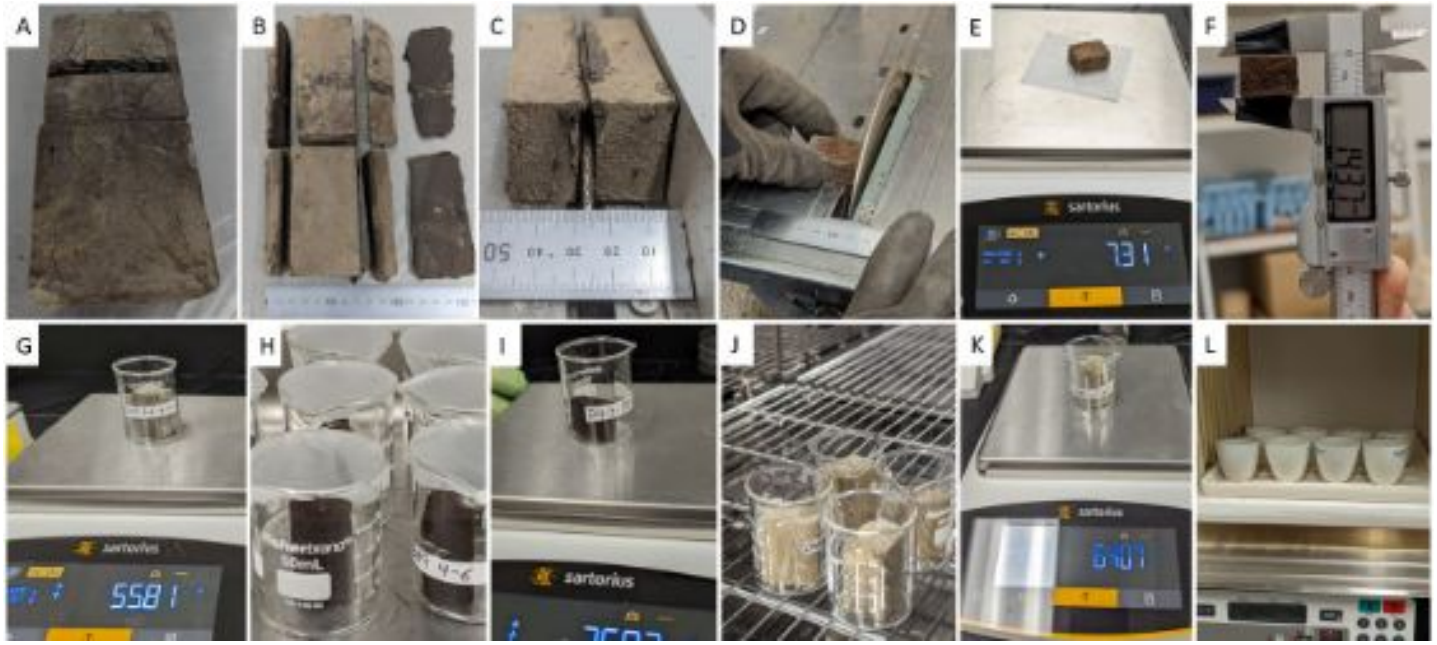


Nikon XT H 225 ST

- 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

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

Material

BH20B-337

Ice-poor inorganic sandy silts.

BH18-211

Micro-lenticular organic sandy silts with large ice layer

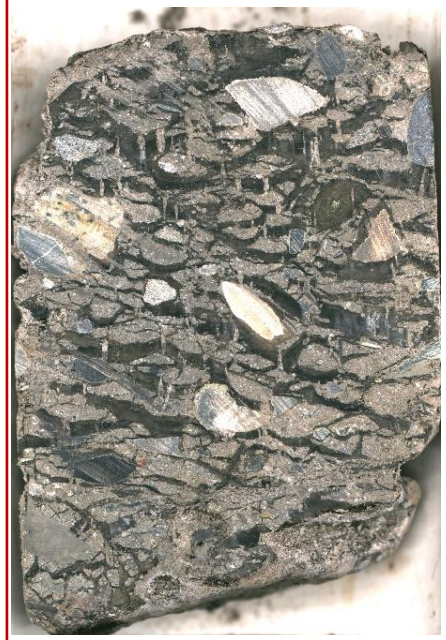
DH13-589

Ice-rich peat

BH12F-138

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

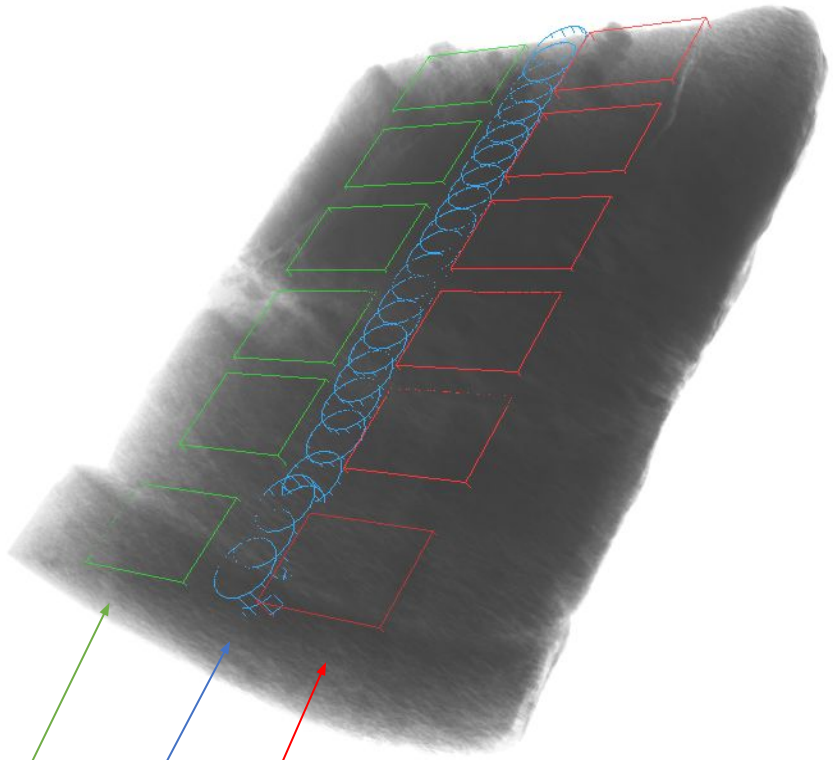
BS19-3-6



Ice rich diamict

BH18-211

Micro-lenticular organic sandy silts with large ice layer



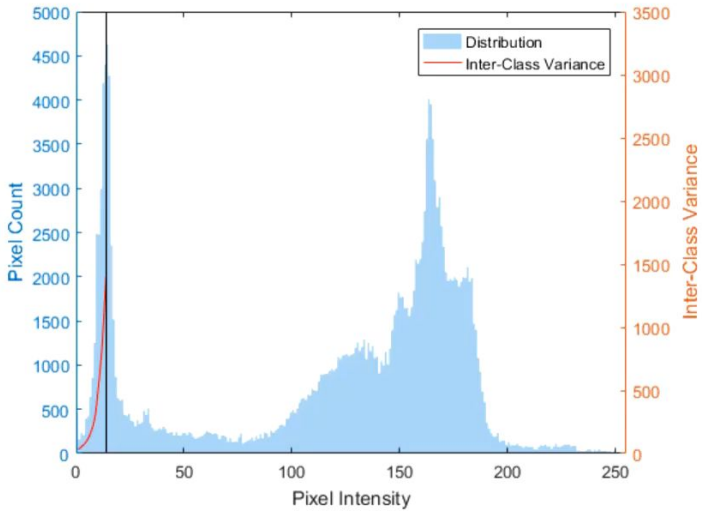
Cubes used for the cuboid method

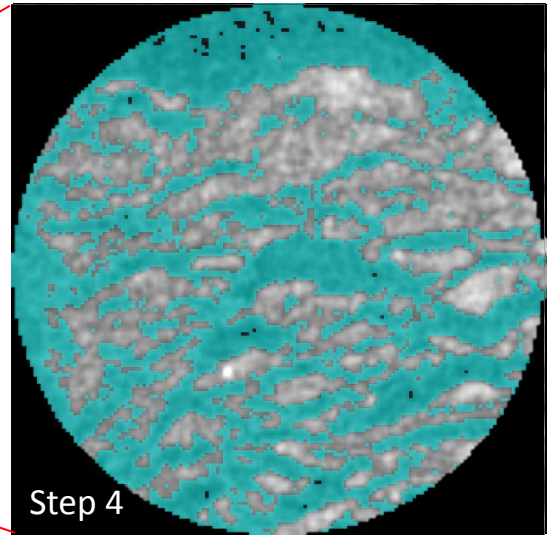
ROIs for CT image processing

Cubes used for CT scans

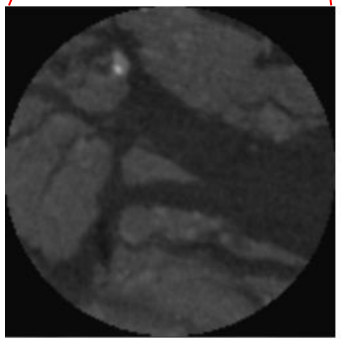
Otsu's method (automatic imagery classification)

An example image thresholded

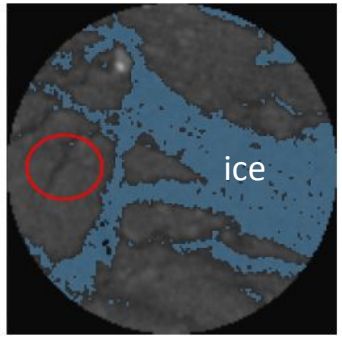




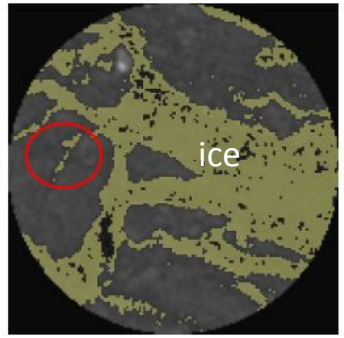
Blue area (Excess ice + pore ice)



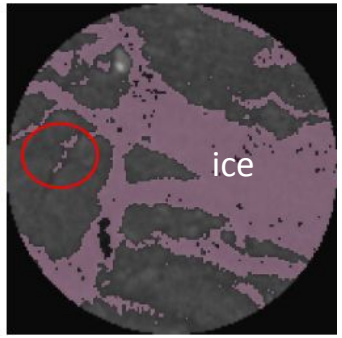
Step 1



Step 2



Step 3



Step 4

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

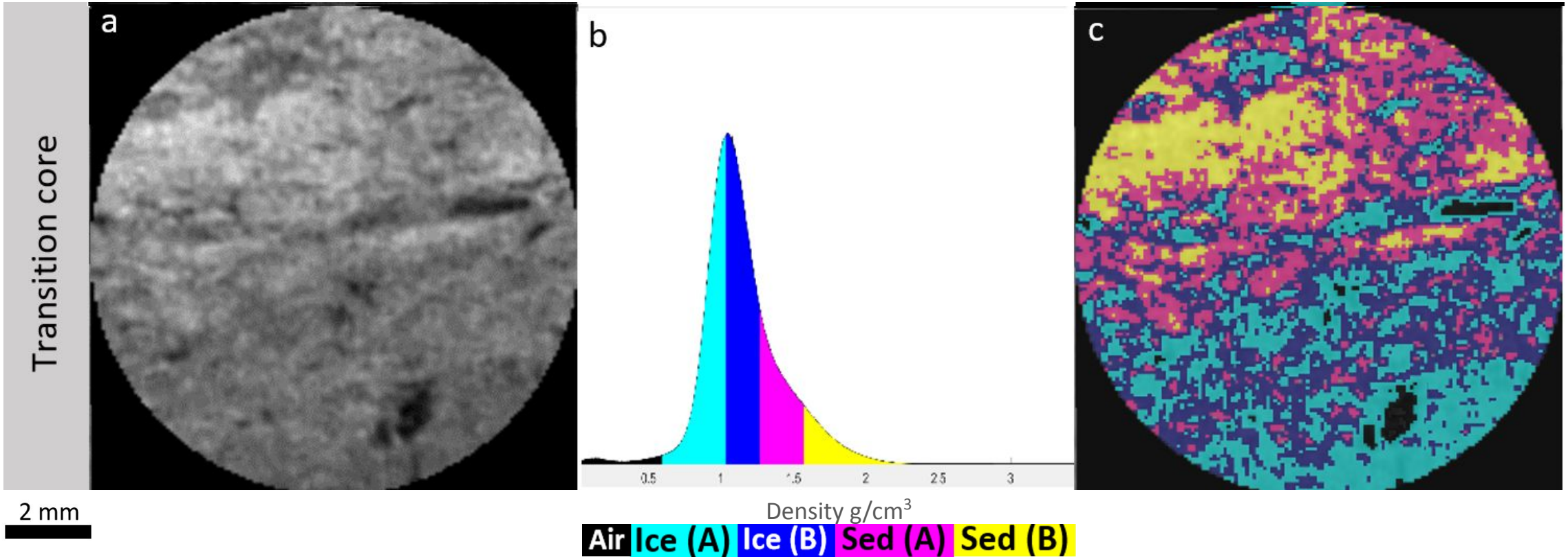


Image segmentation results
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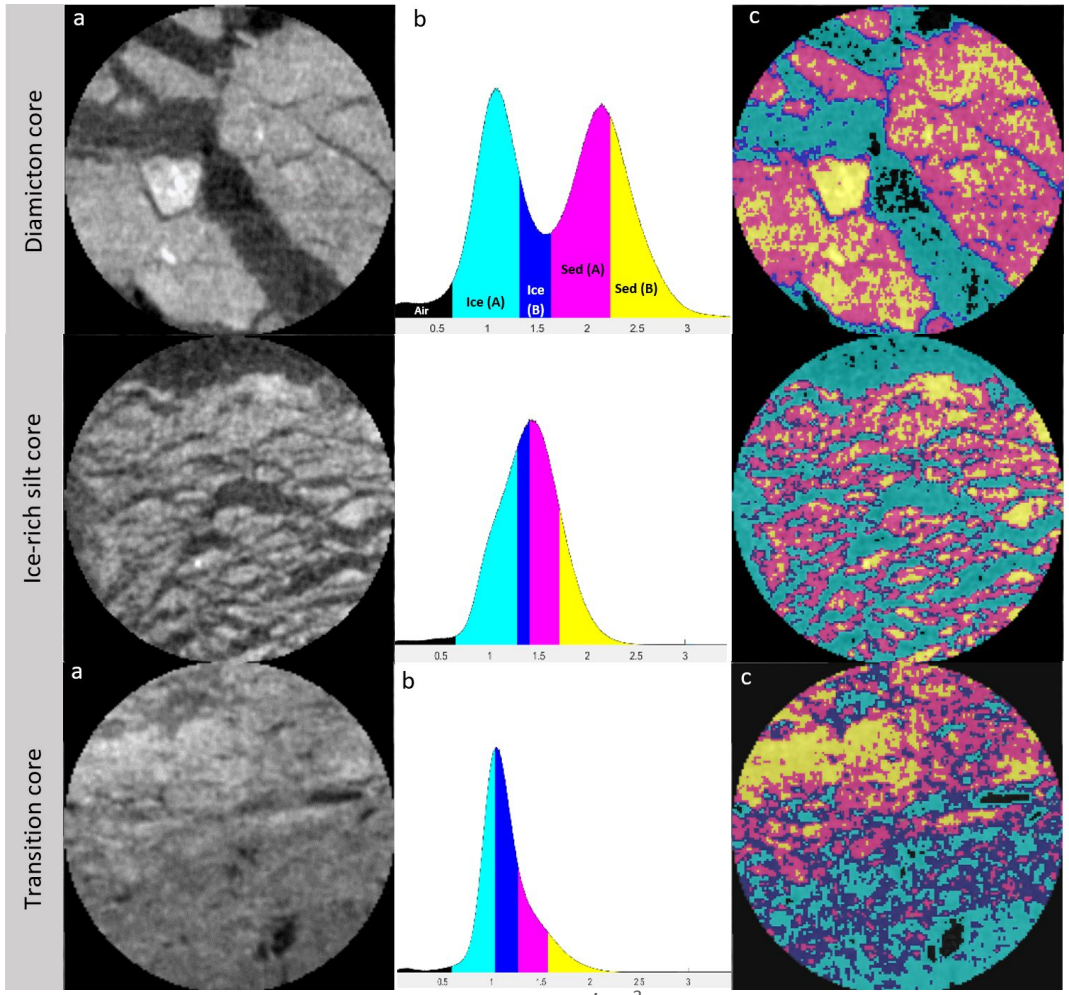
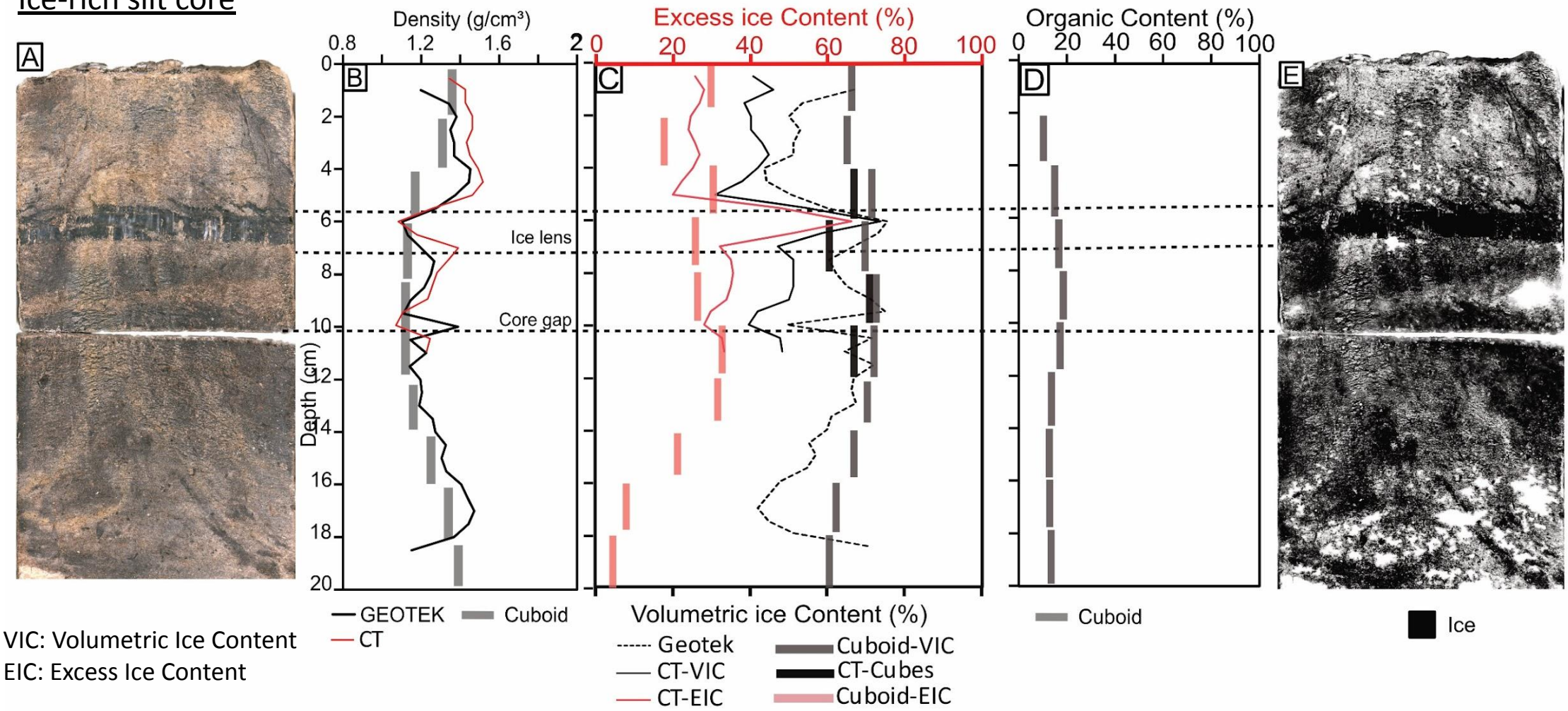
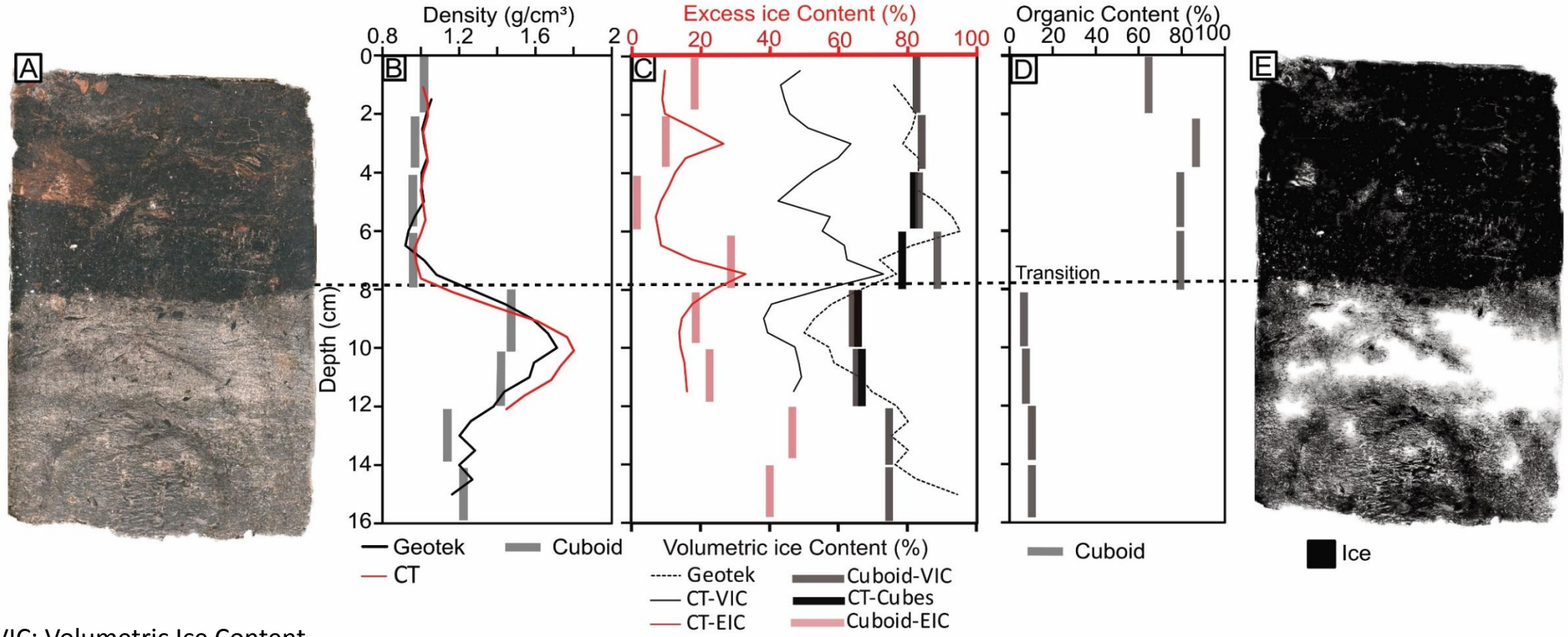


Ice-rich silt core



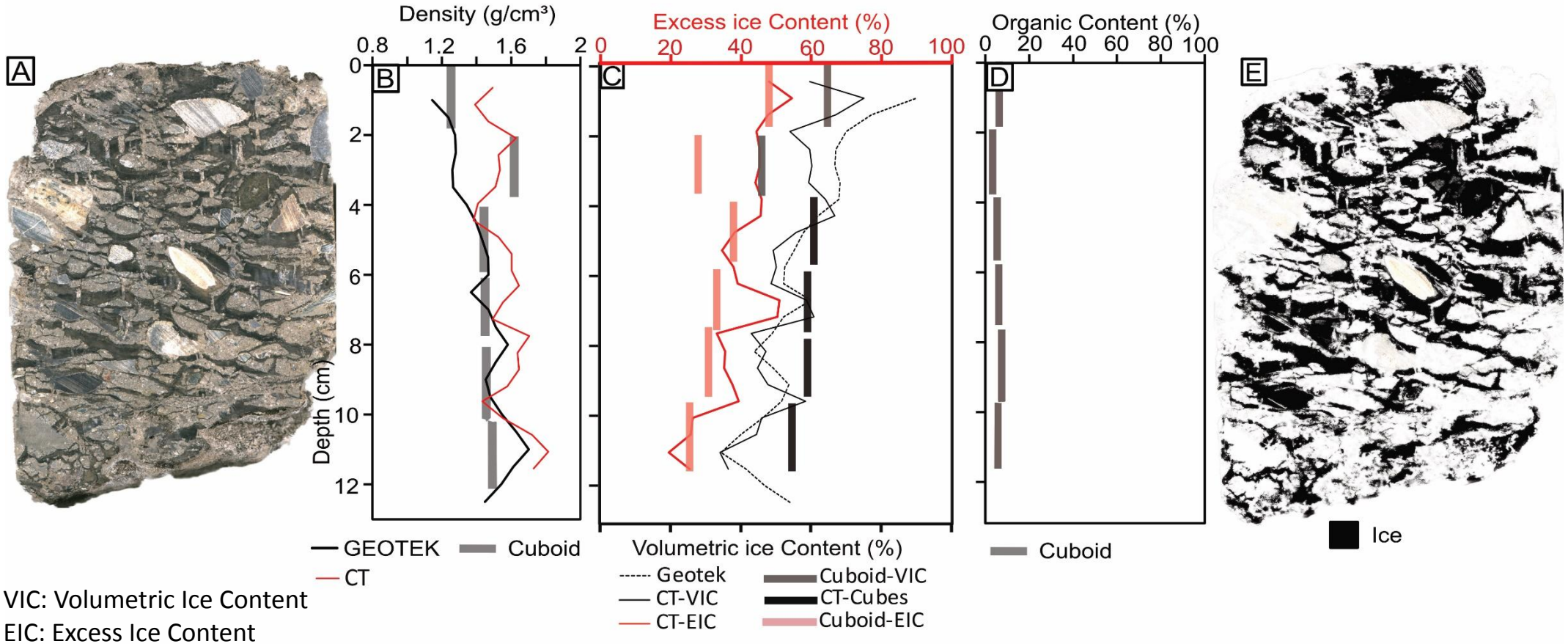
VIC: Volumetric Ice Content
EIC: Excess Ice Content

Transition core

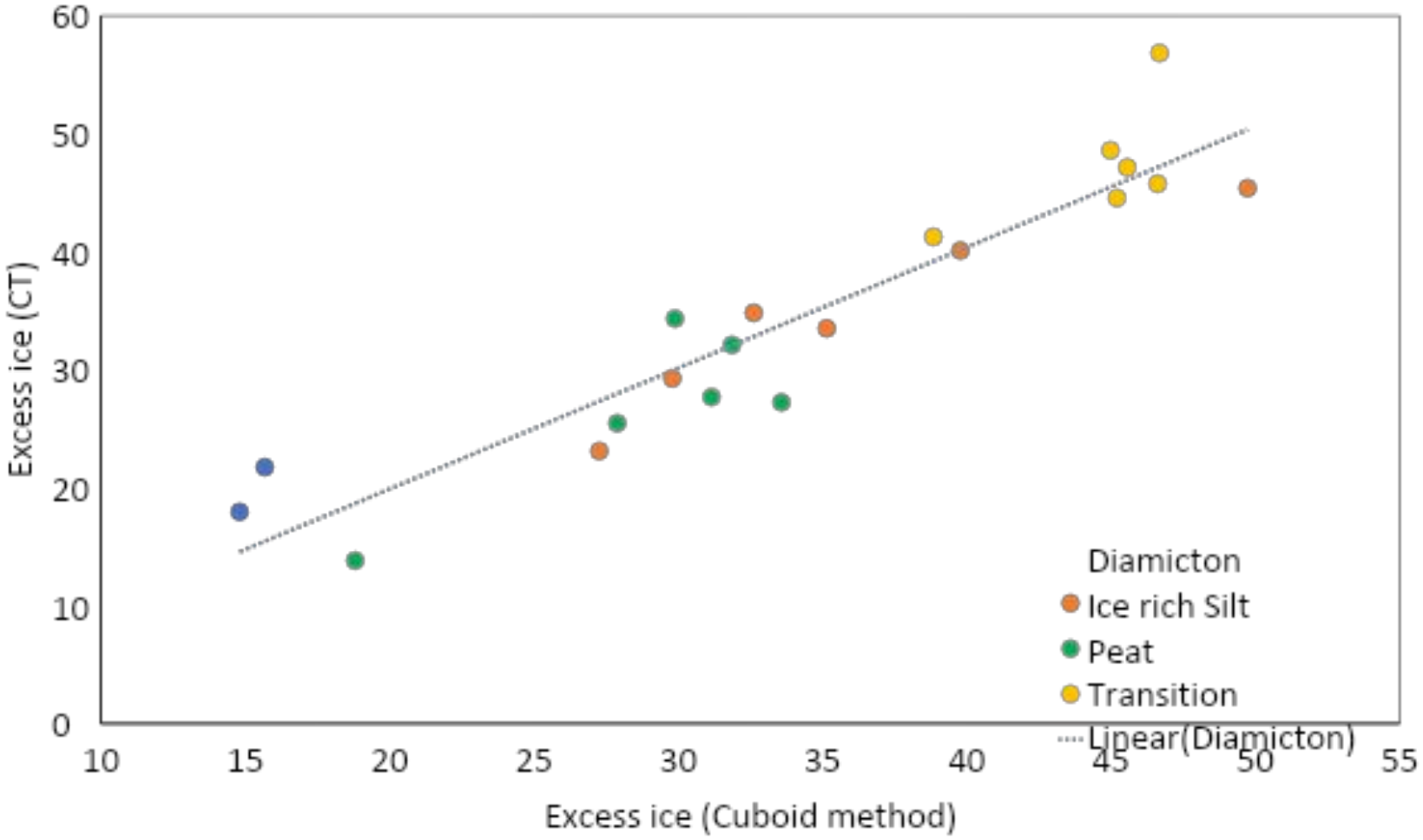


VIC: Volumetric Ice Content
EIC: Excess Ice Content

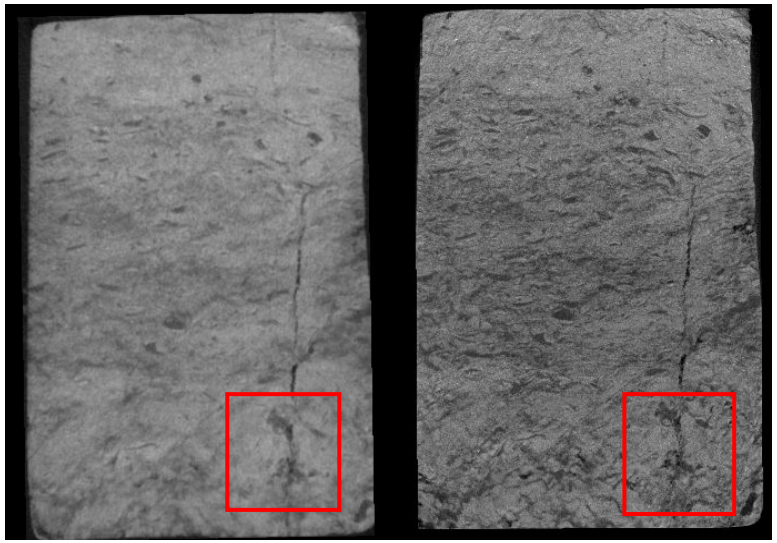
Diamicton core



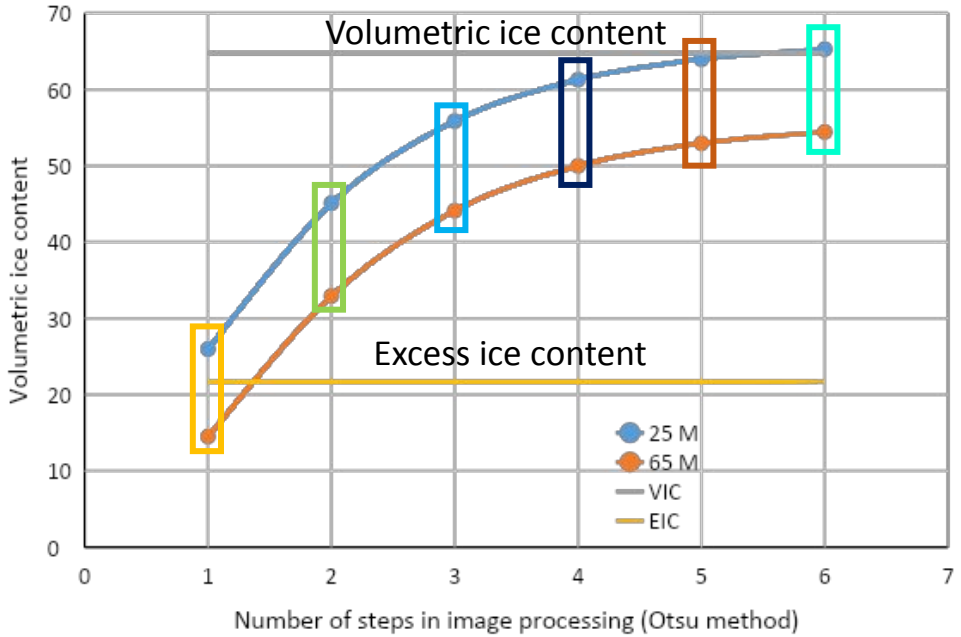
VIC: Volumetric Ice Content
EIC: Excess Ice Content


Excess ice (CT)
Excess ice (Cuboid method)
0
10
20
30
40
50
60
10
15
20
25
30
35
40
45
50
55
Diamicton
Ice rich Silt
Peat
Transition
Linear(Diamicton)

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

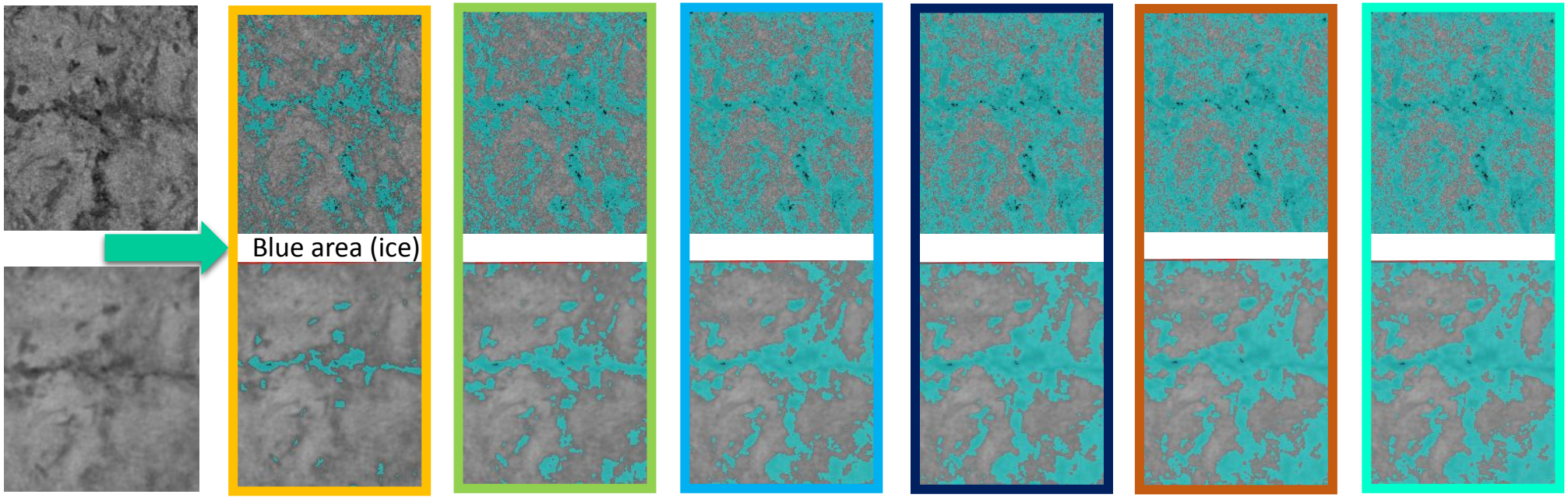


CT images of a cube from the transition core in two different resolutions 65 um (left), 25 um (right)



25 um

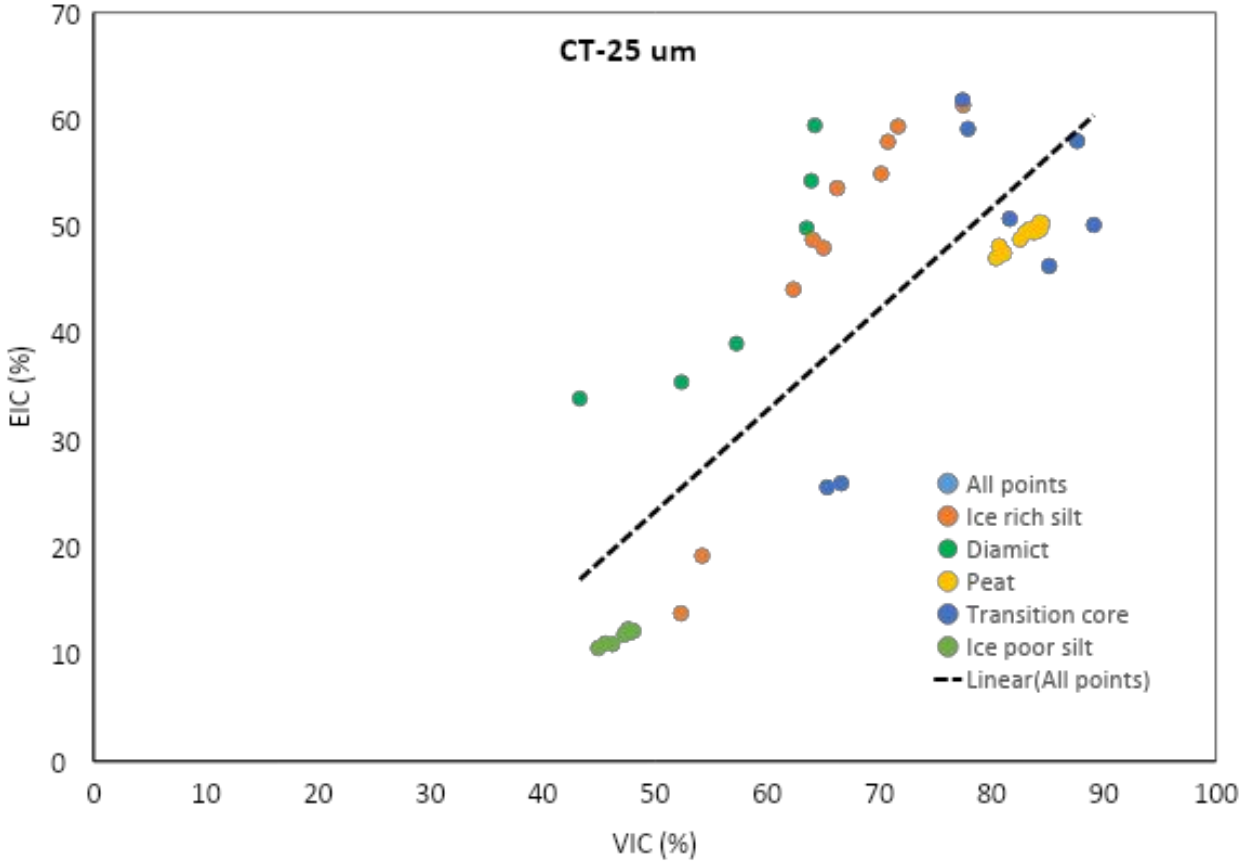
65 um

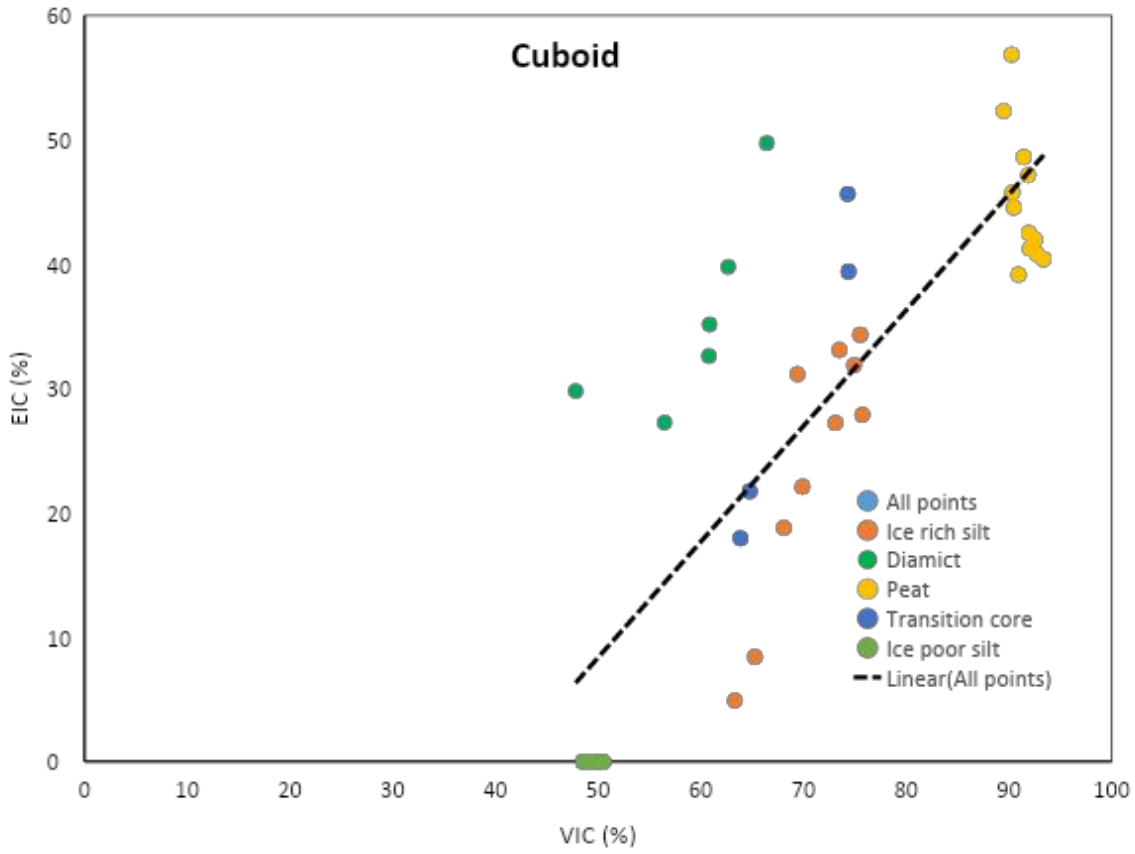


Next Steps

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

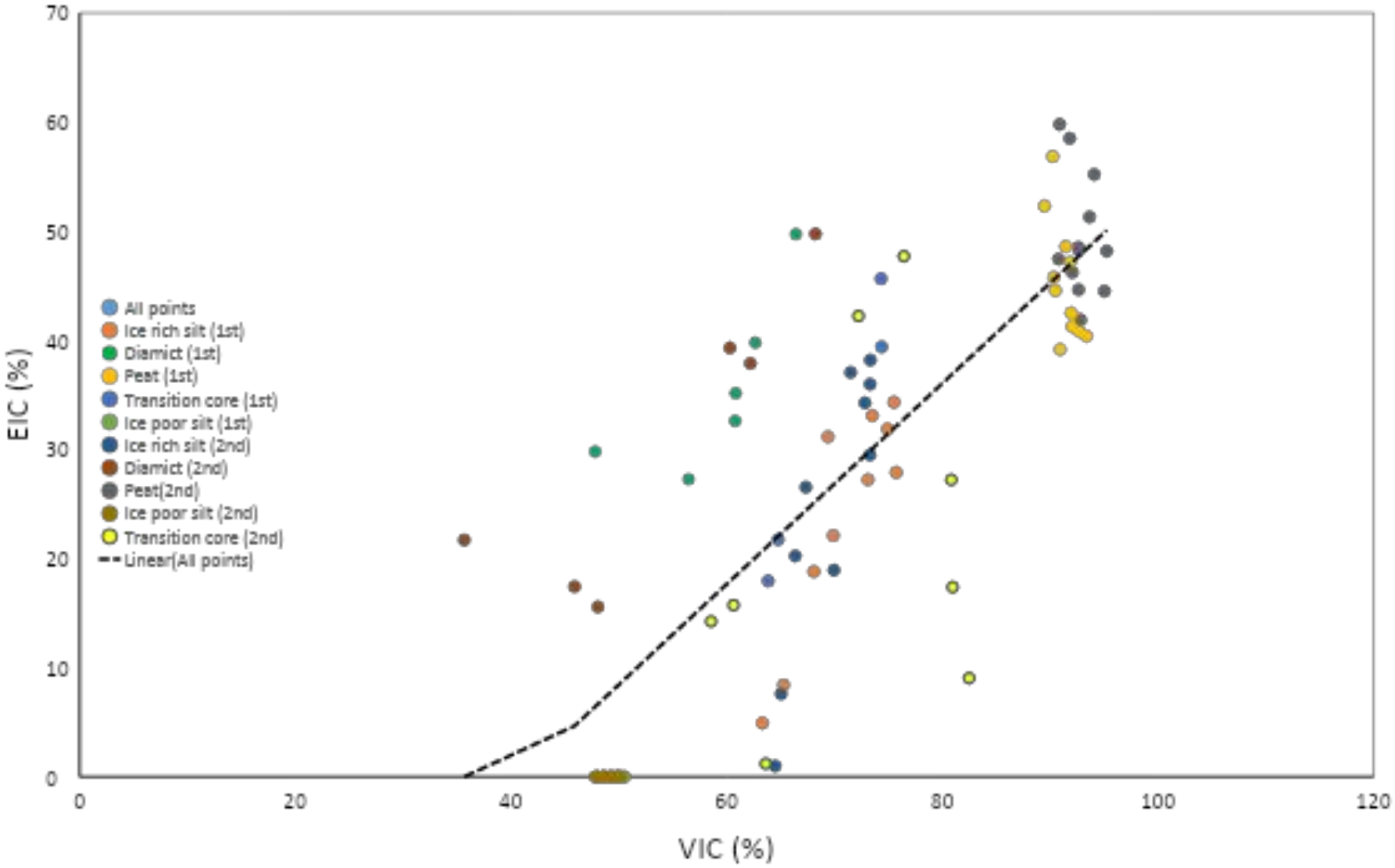
Correlations





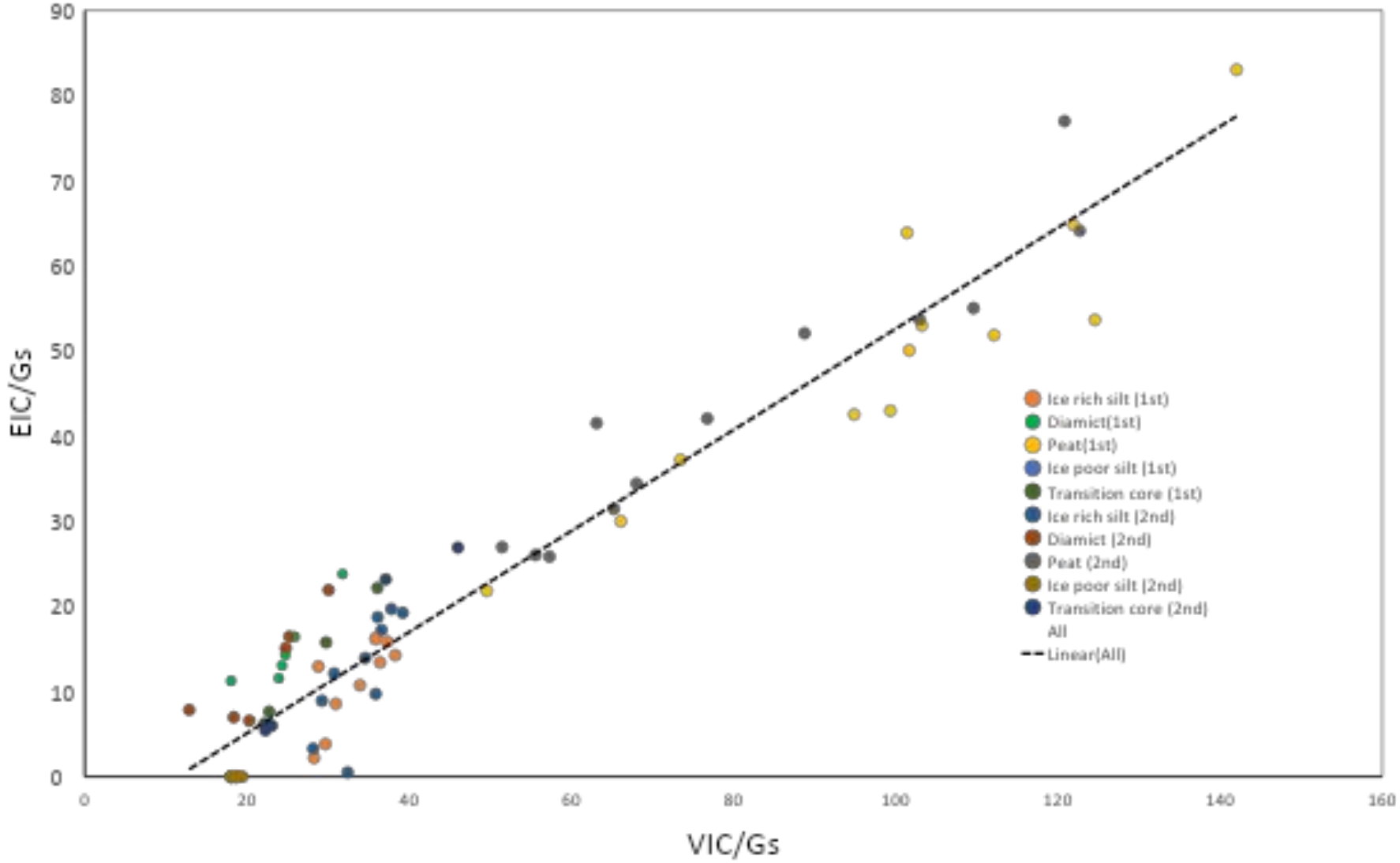
Correlations

Cuboid



Correlations

Cuboid



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Prof. Duane Froese
Joel Pumple, MSc.
Jordan Harvey, MSc.

Thank you

mroustae@ualberta.ca