Soil drying and soil structure

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Motivation

Soil structure is not static - shrinkage under drainage and drying

Image data can provide additional insight into this process

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Aims and scientific questions

How does the the soil pore network properties change under drying?

What implications do the changes have on soil aeration and hydraulic properties?

Methods – Soil sampling

8 undisturbed soil columns in aluminium cylinders

Ø = 68 mm, h = 60 mm

each two from topsoil (app. 4 to 10 cm depth) from

- Krusenberg
- Nåntuna
- Ultuna, close to Hammerbyallén
- Ultuna, close to Ramförsök

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Soil properties

location	abbreviation	sand	silt	clay	SOC
Nåntuna	NA	0.826	0.075	0.099	0.01
Ultuna / Hammerby allé	HA	0.593	0.175	0.232	0.012
Krusenberg	KB	0.339	0.324	0.337	0.014
Ultuna / RAM 1956	RA	0.117	0.376	0.507	0.012

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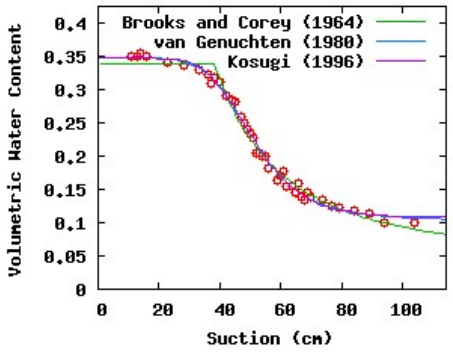
Methods – Water retention measurements (credits to Ana Mingot!!)

Columns were first saturated from bottom,

Then put on the sandbed to pressure steps

h = 1, 15, 50, 100, 300, 600 cm tension

(counting from bottom of column)



After equilibrium was reached, column was X-rayed.

Eventually, column was oven-dried (105 ℃) and X-rayed a last time

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Methods – X-ray imaging and image analyses

Each X-ray image had a voxel size of 0.12 mm (visible pores are macropores)

The columns' gray values were calibrated using SoilJ

The images at different water potentials were aligned,

using Elastix and an Euler transform (rigid transform)

Changes in pore morphology with water content were quantified

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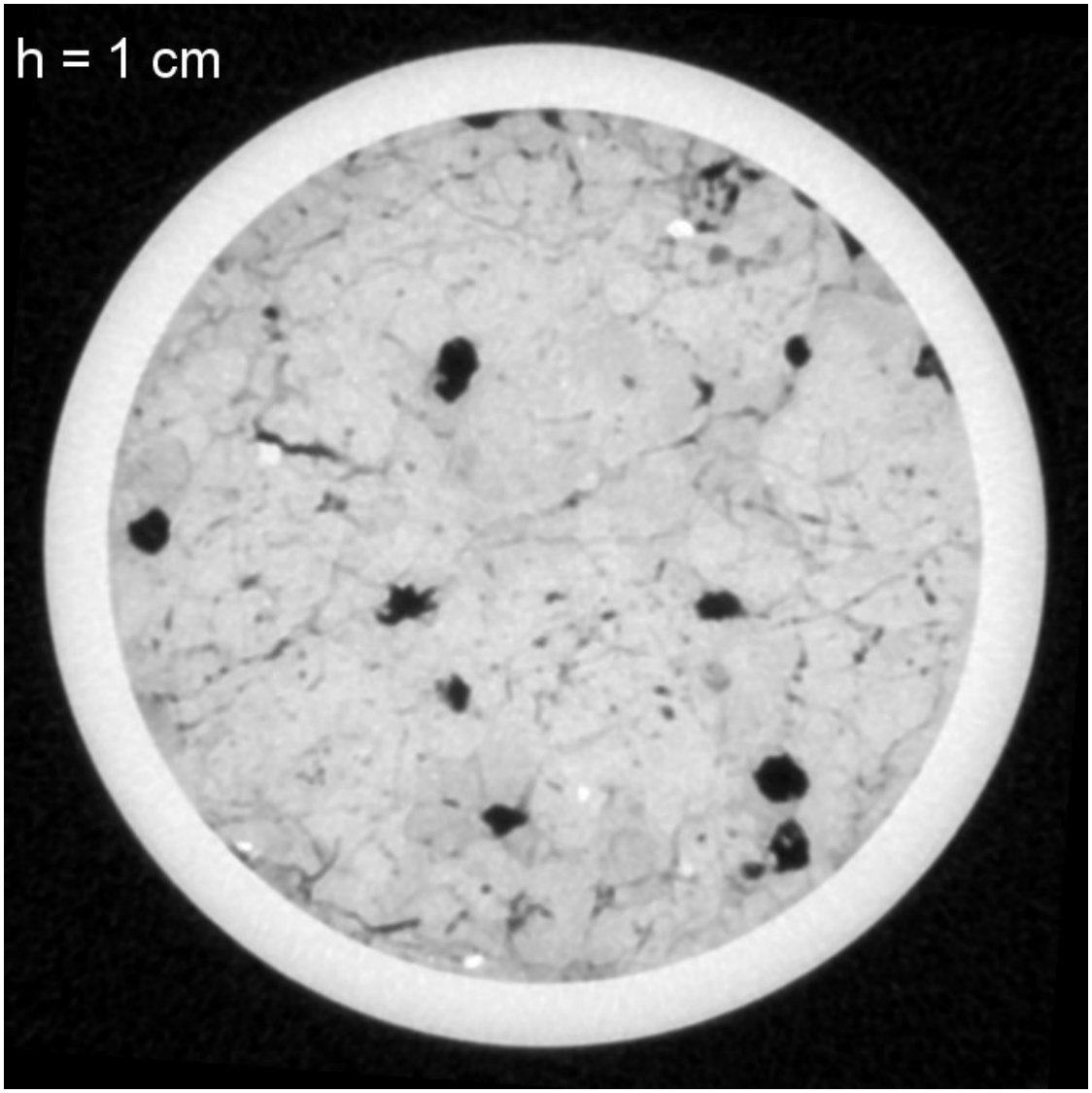
Results

Example Column:

Krusenberg 1



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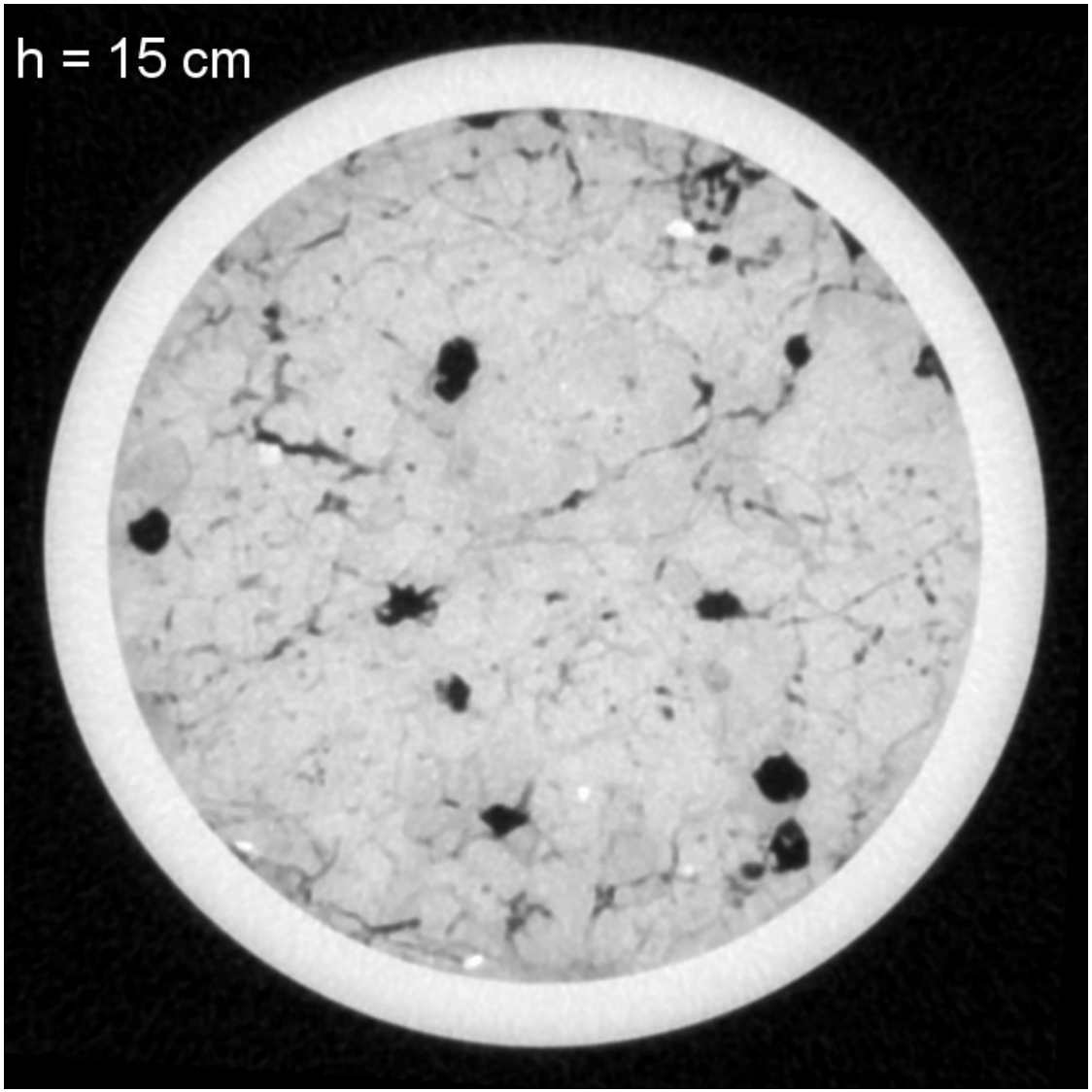
Results

Column:

Krusenberg 1



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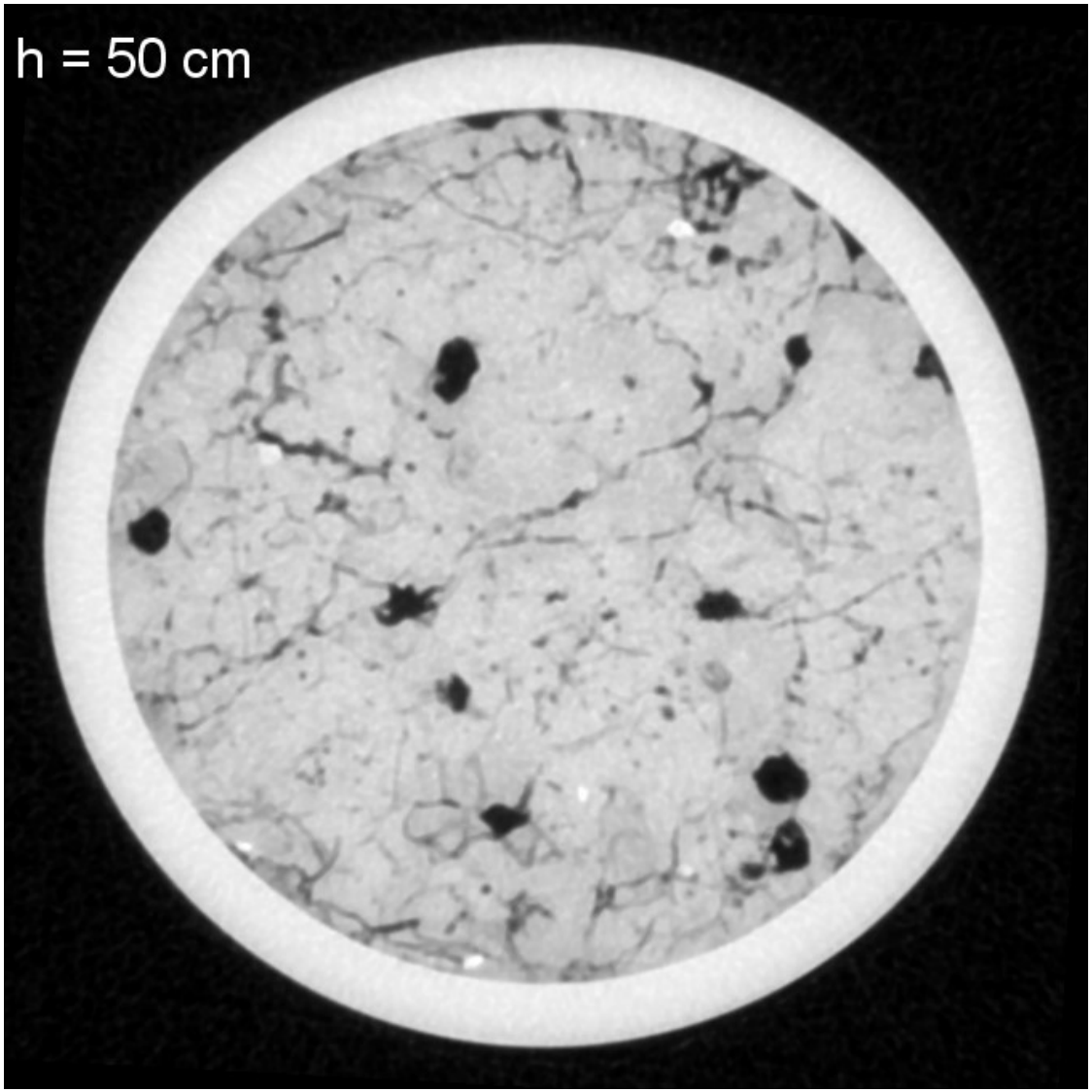
Results

Column:

Krusenberg 1



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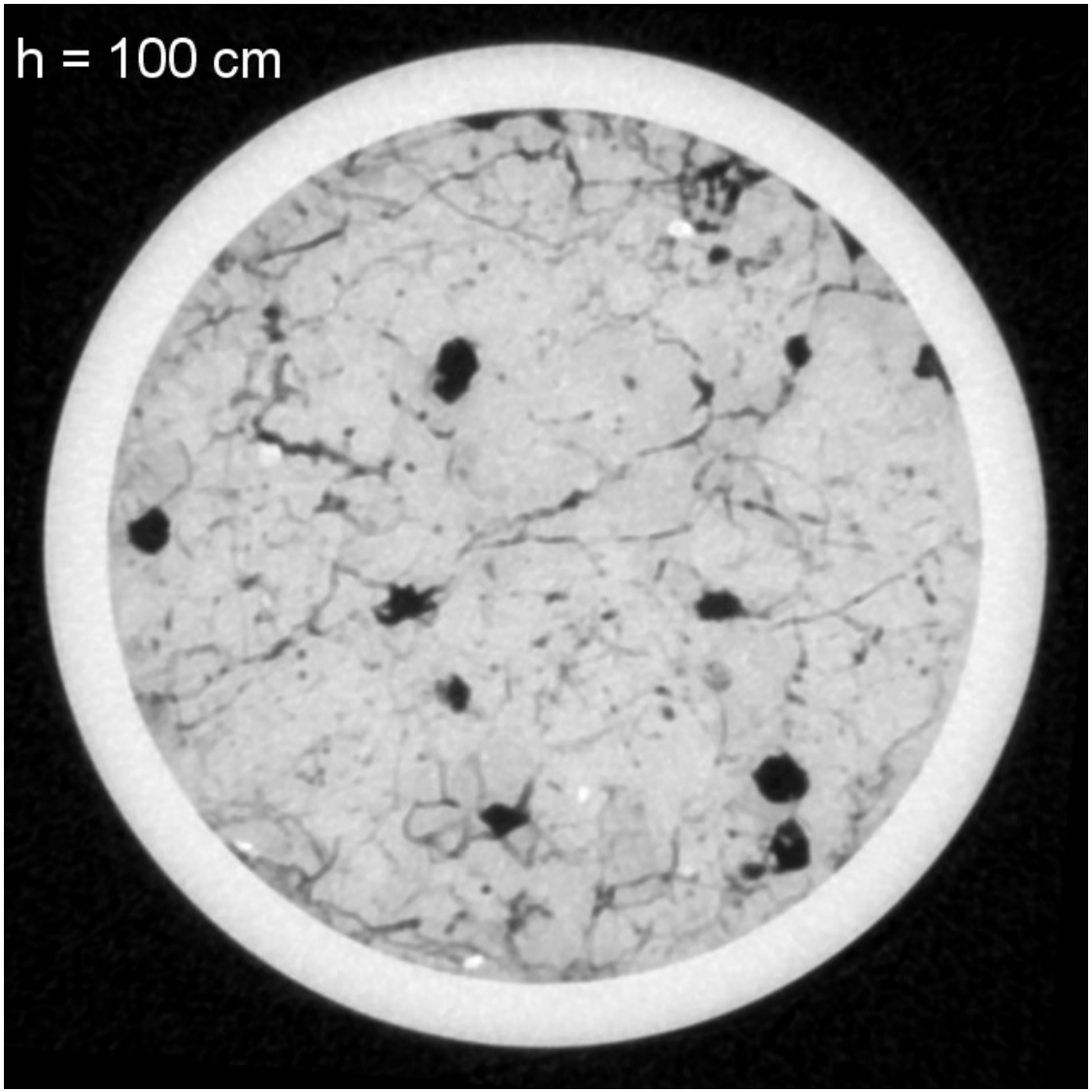
Results

Column:

Krusenberg 1



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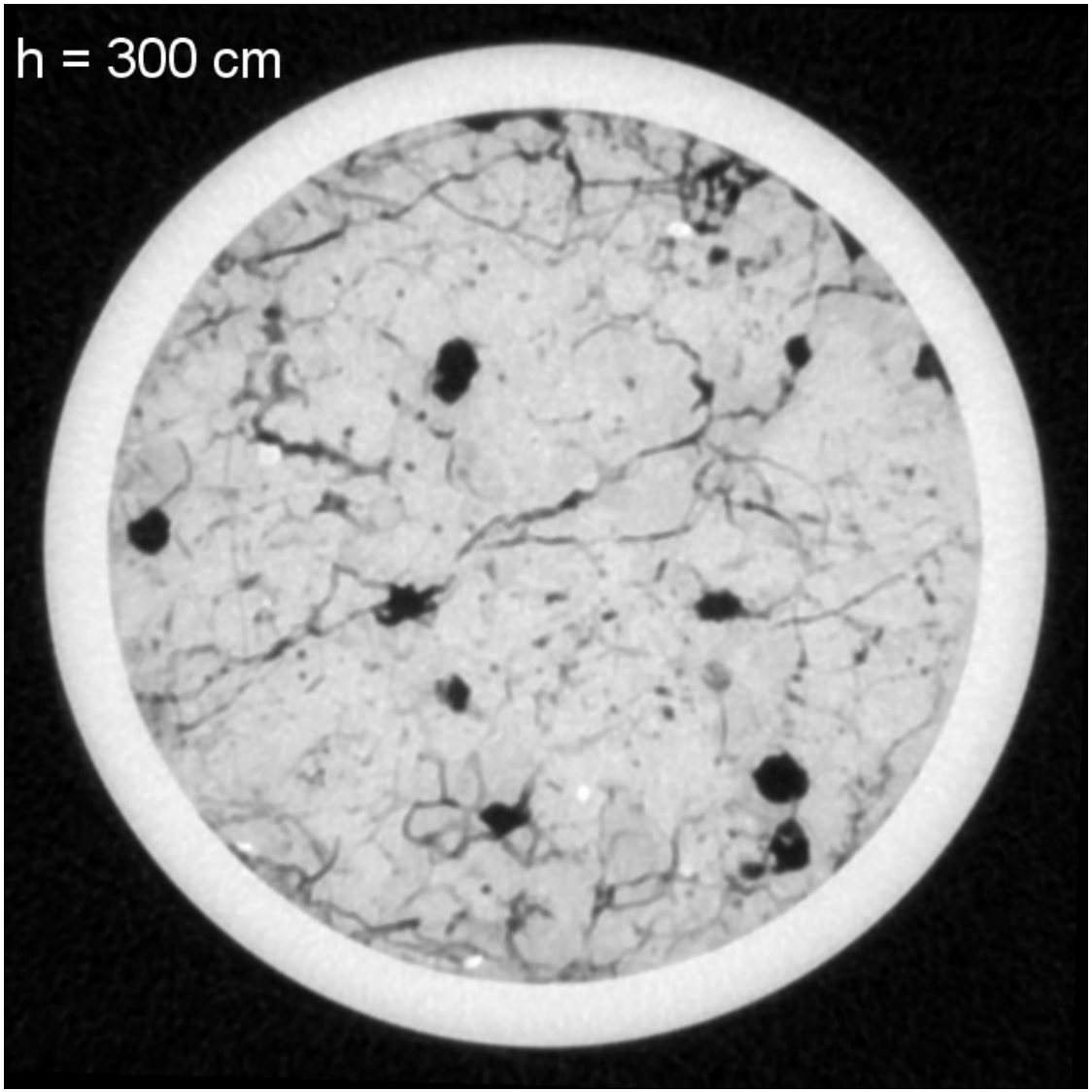

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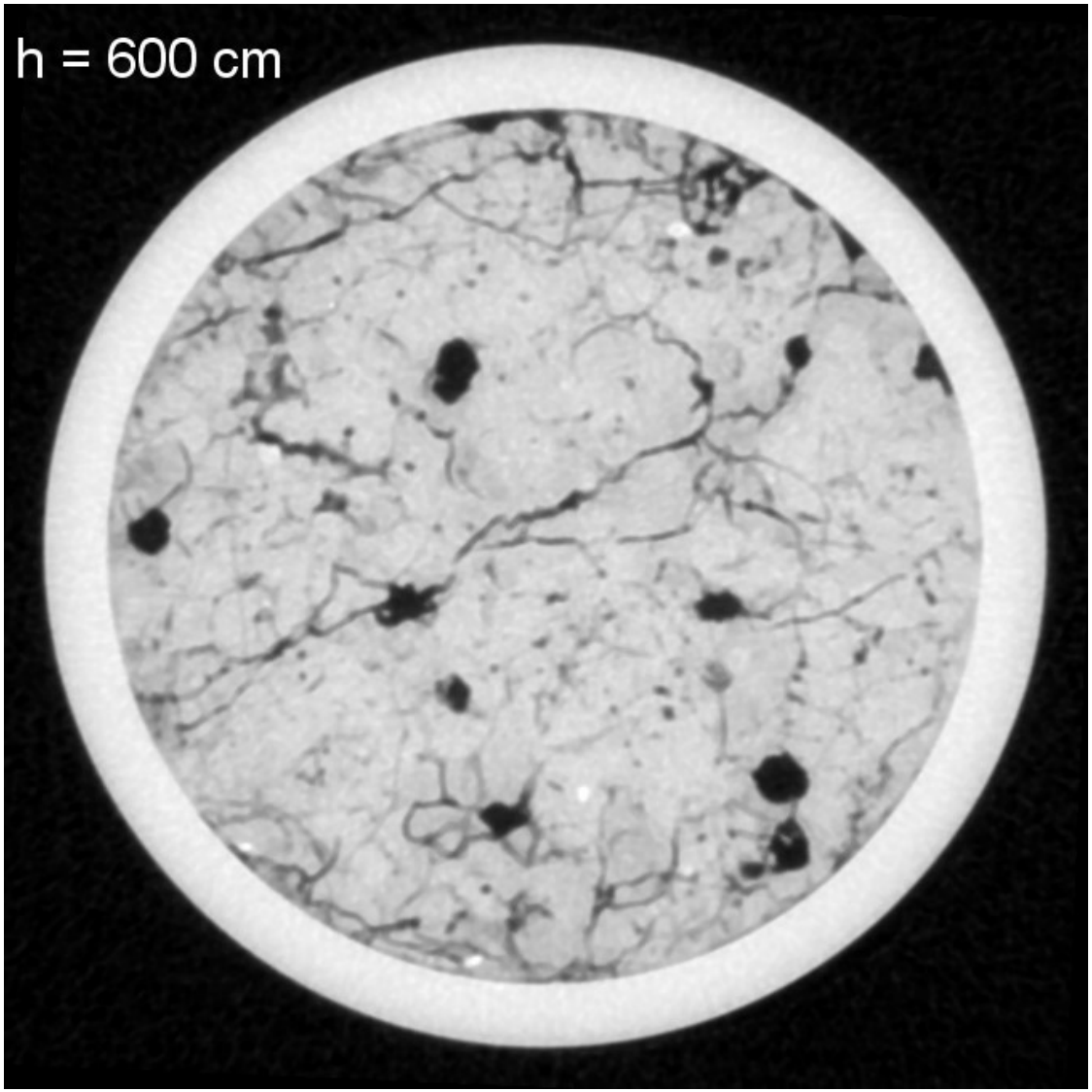

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Results

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Krusenberg 1

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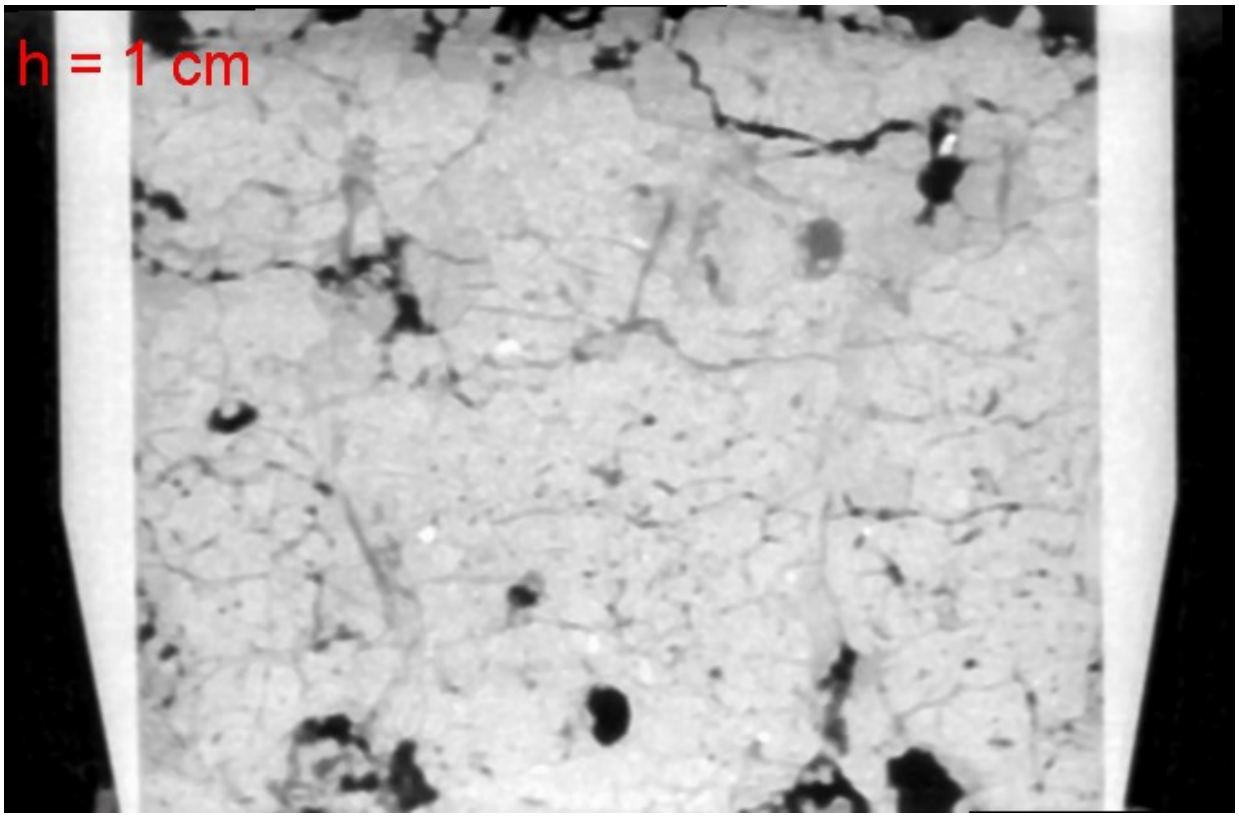
Krusenberg 1



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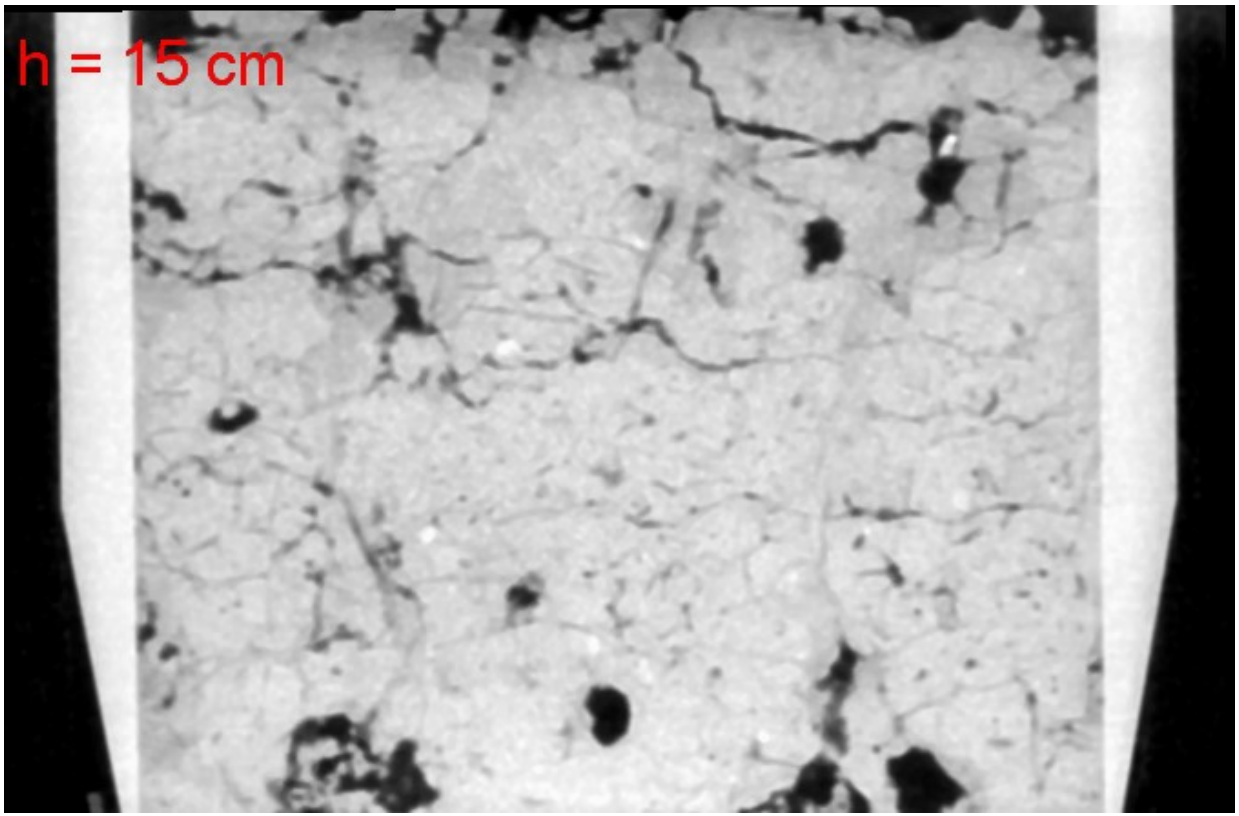

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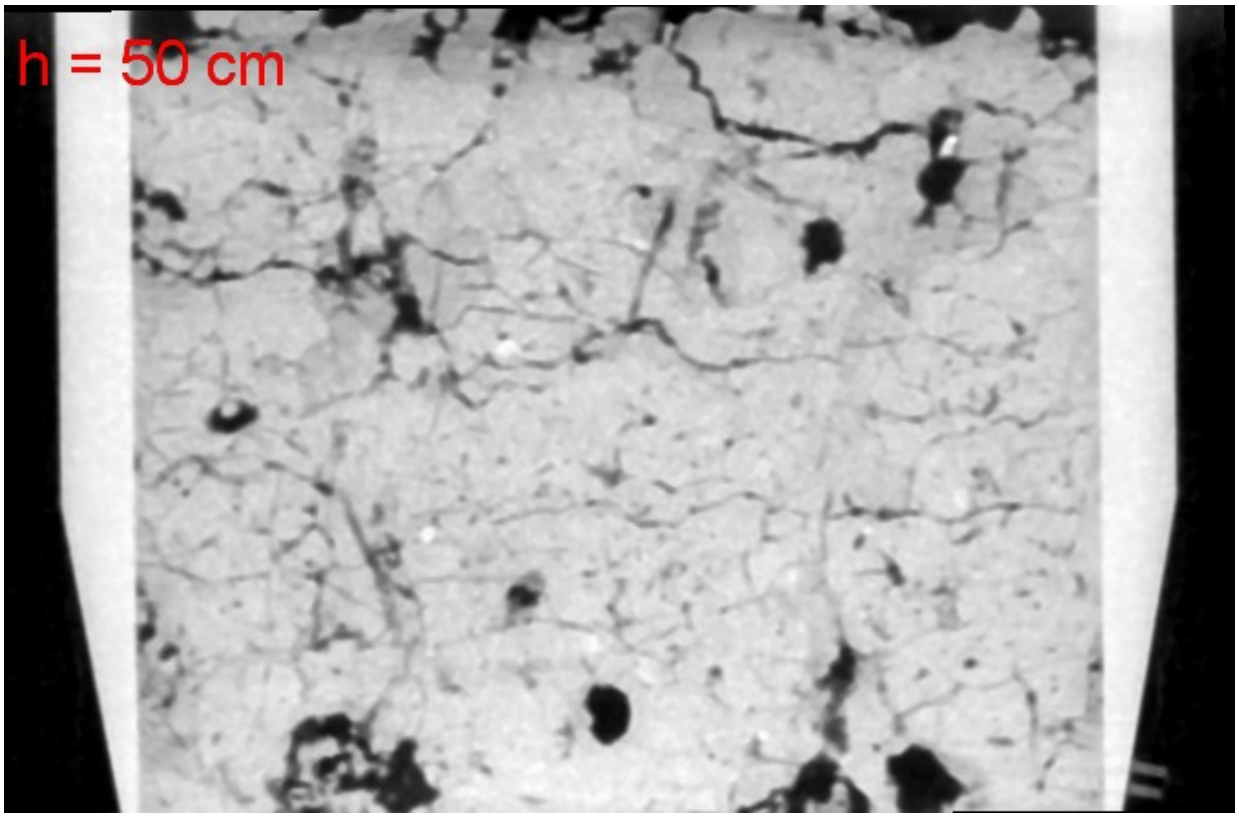
Krusenberg 1



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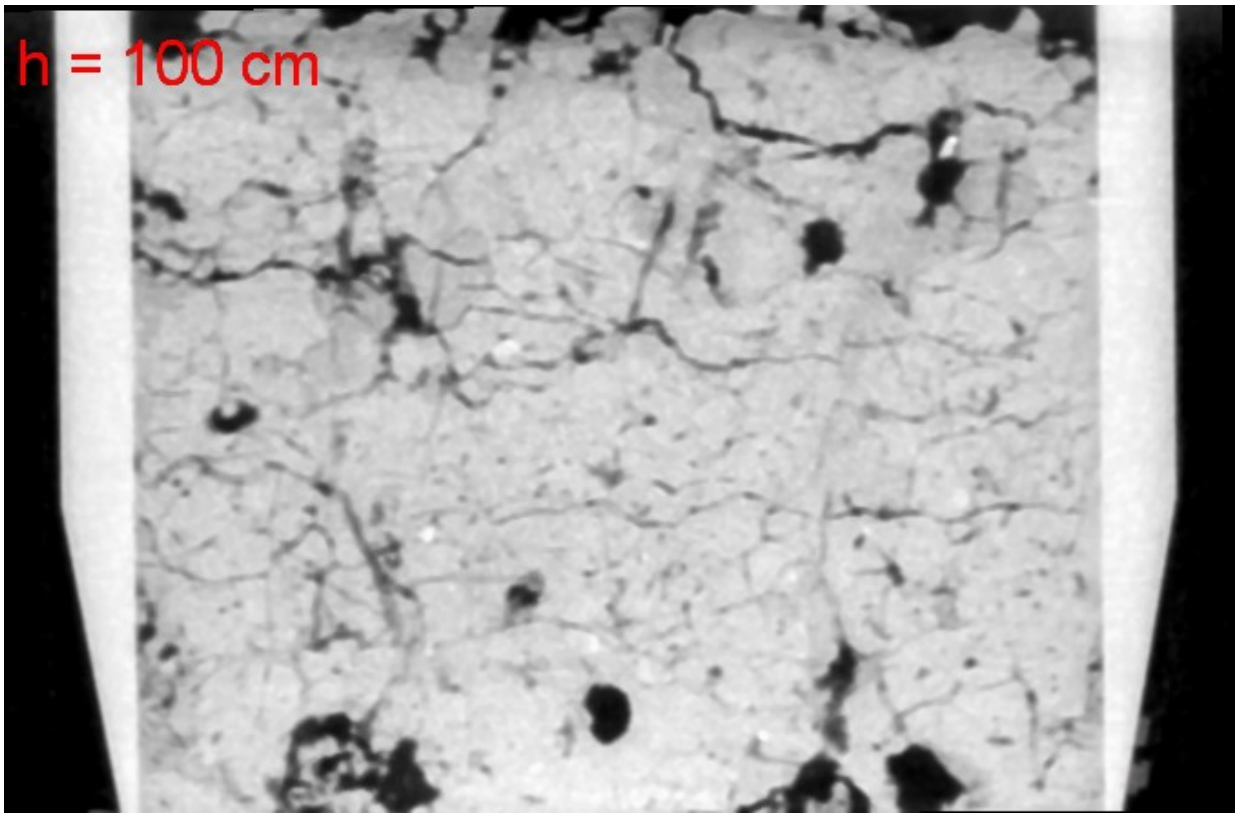

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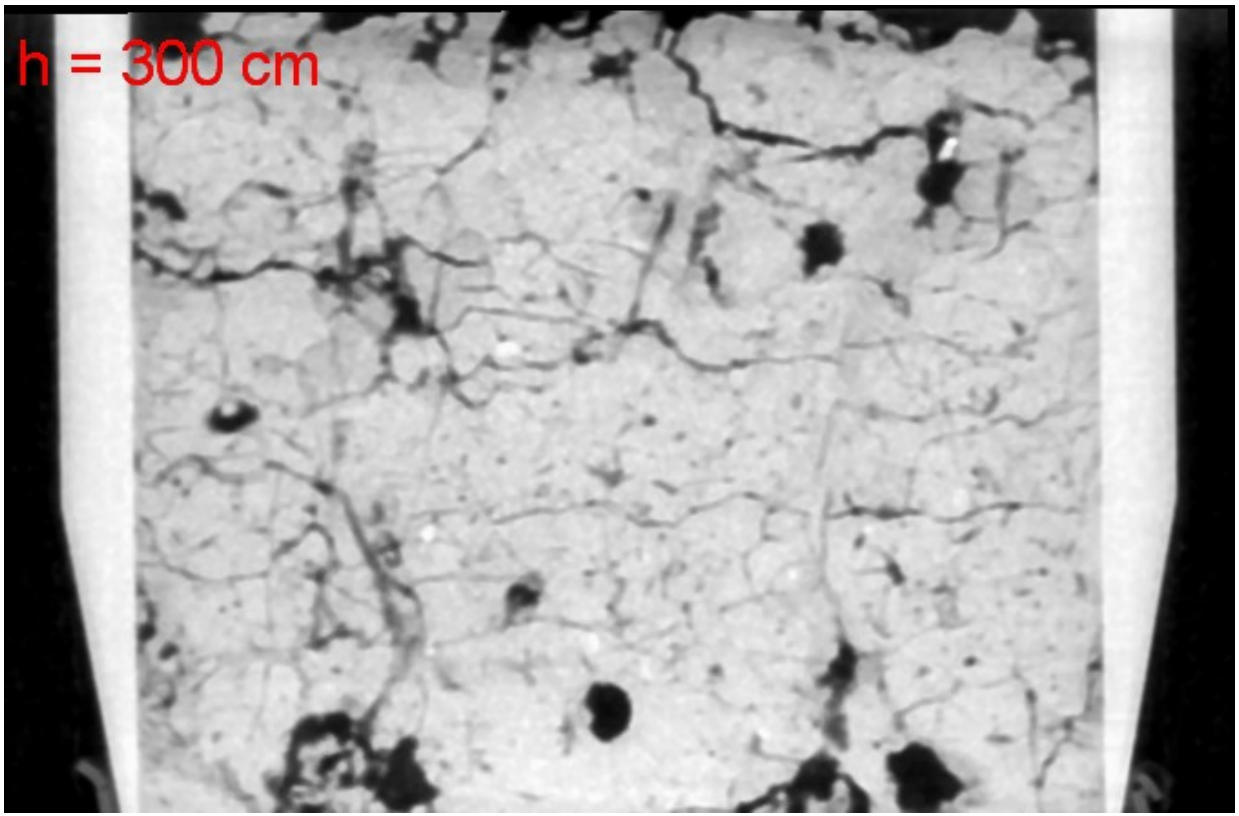

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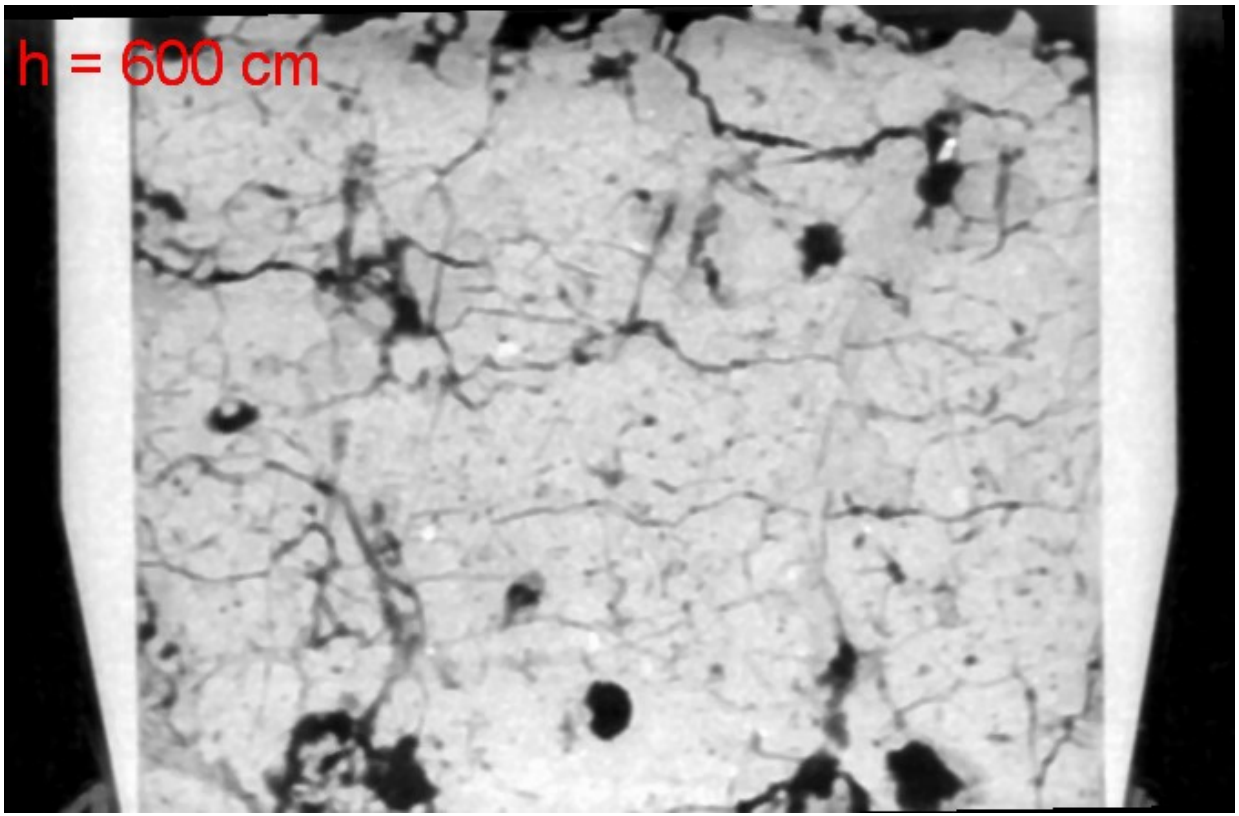

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Results

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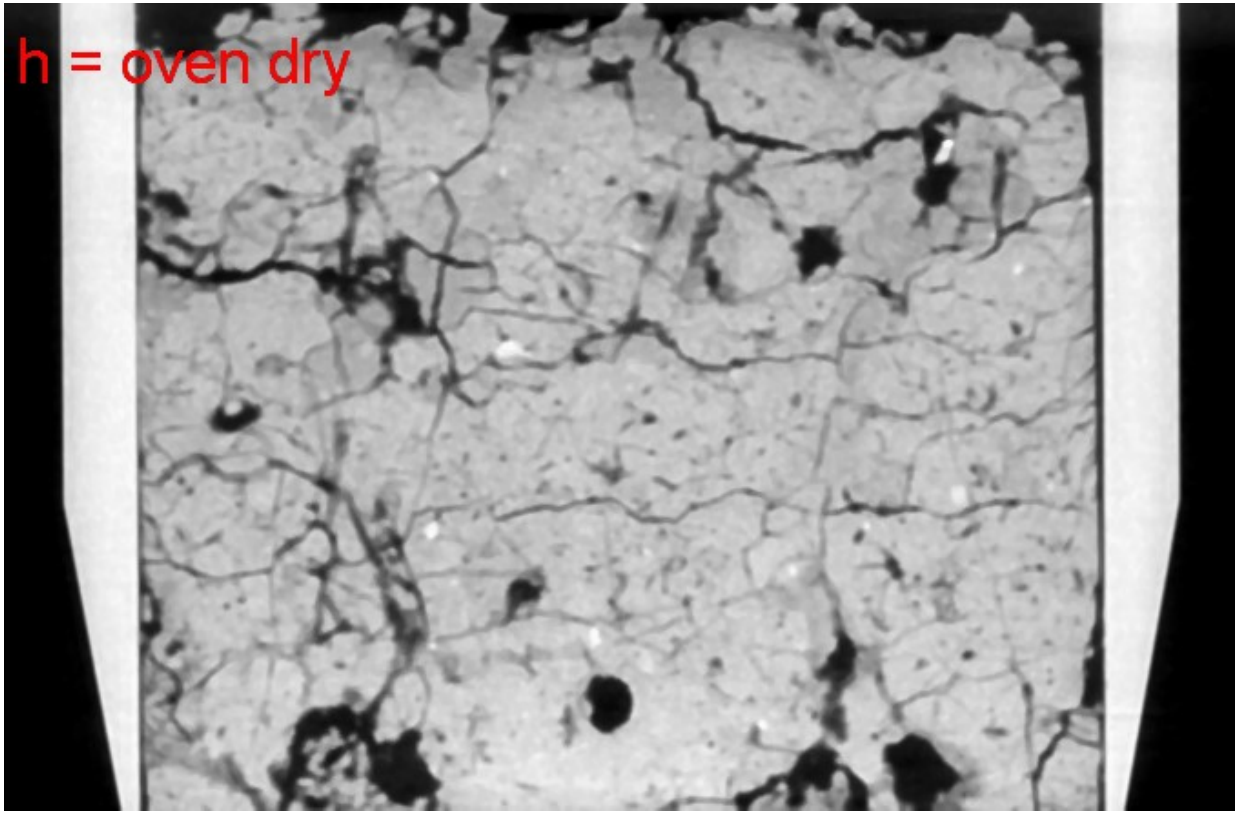
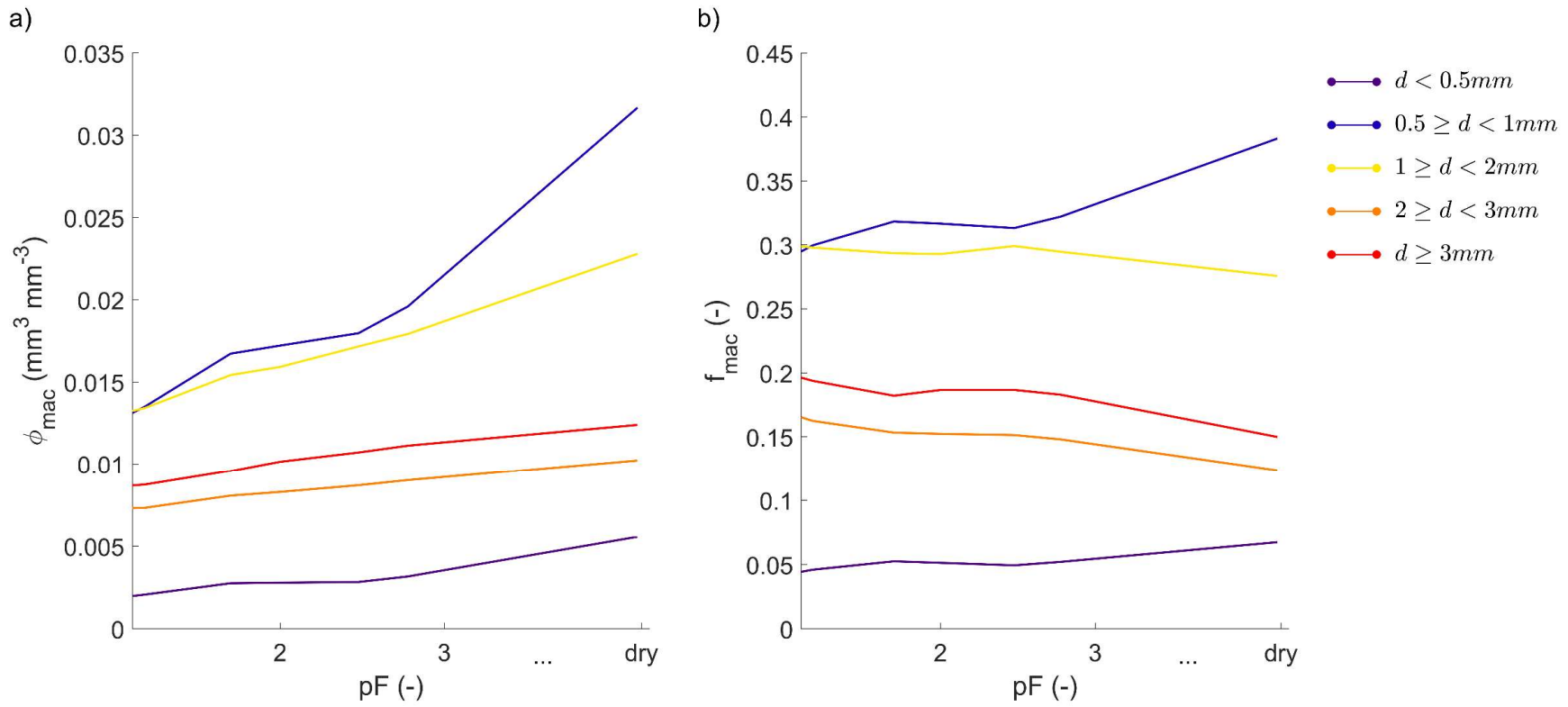
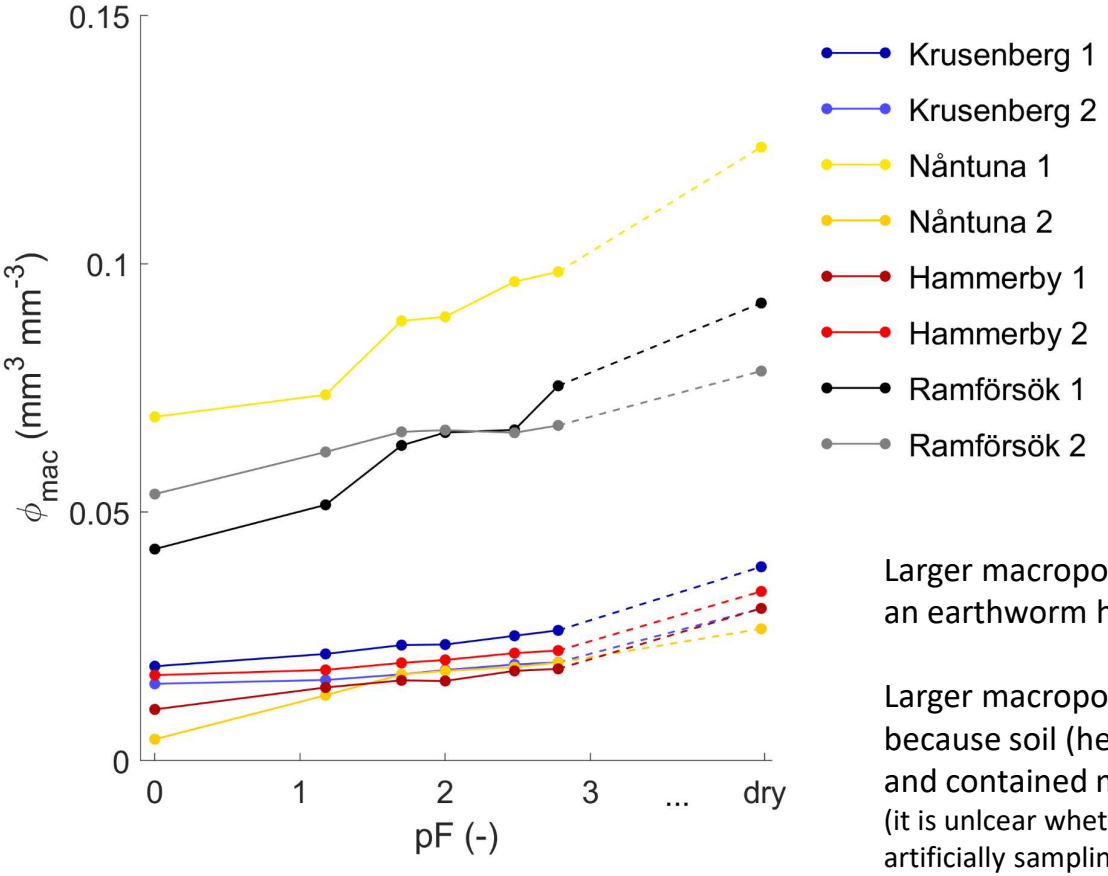


Average volume change of visible pores of different diameter



Visible porosity and fraction of pores with different diameters
Smallest macropores gain most volume!

Porosity of individual samples



Larger macroporosity in Nåntuna 1 because an earthworm had been caught in the sample

Larger macroporosity in the Ramförsök samples because soil (heavy clay) was strongly aggregated and contained many visible interaggregate pores
(it is unlcear whether the latter were created during artificially sampling)

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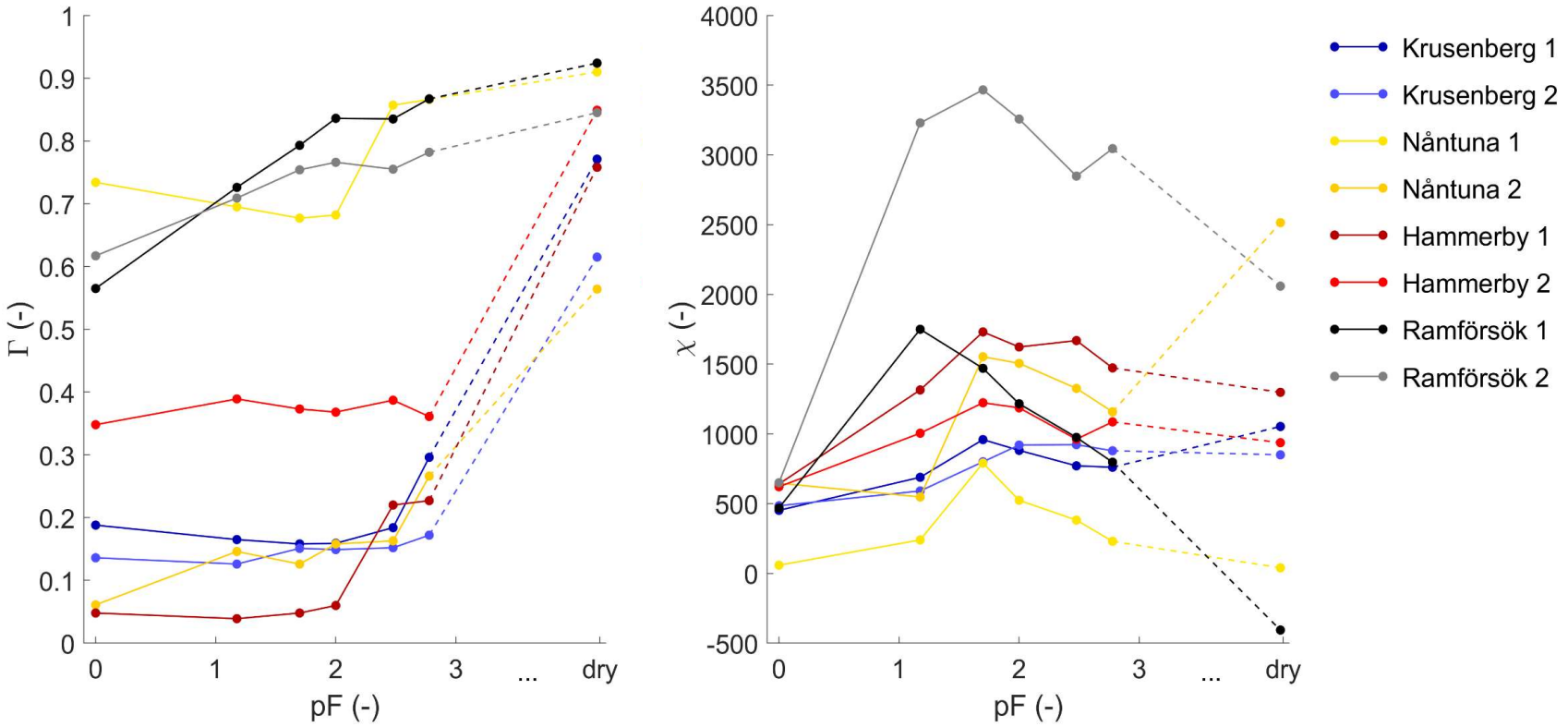
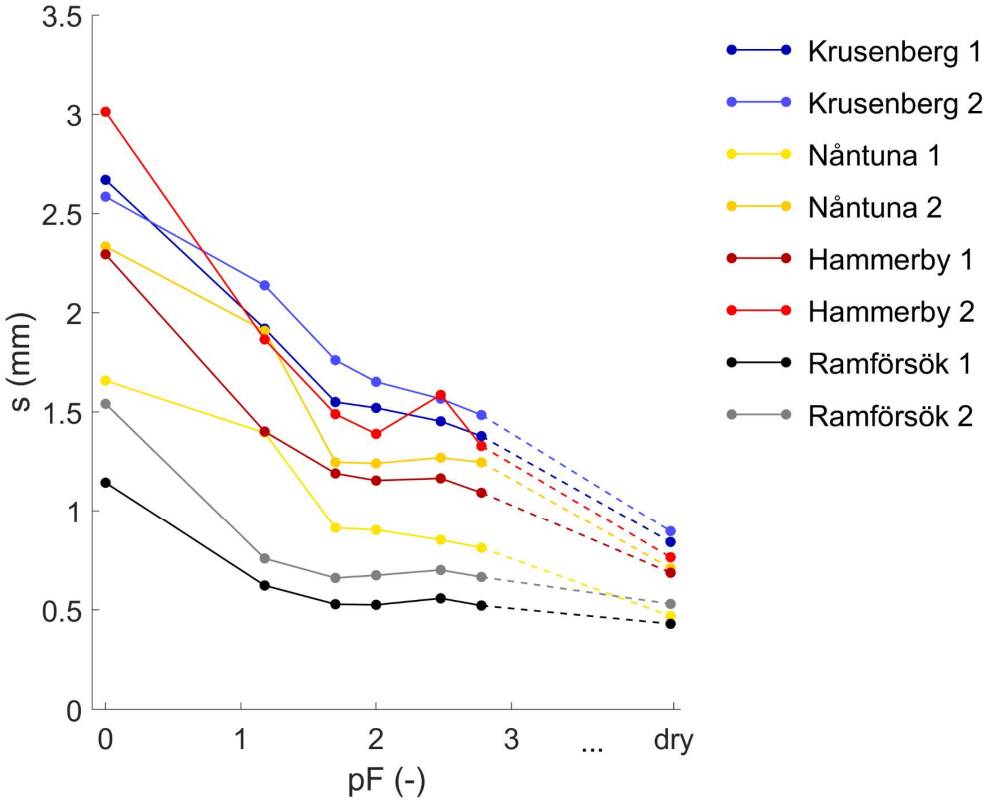
Pore connectivity



Connectivity measures do not strictly improve despite that the initially visible pores become more connected because new, isolated pores become visible upon drying.

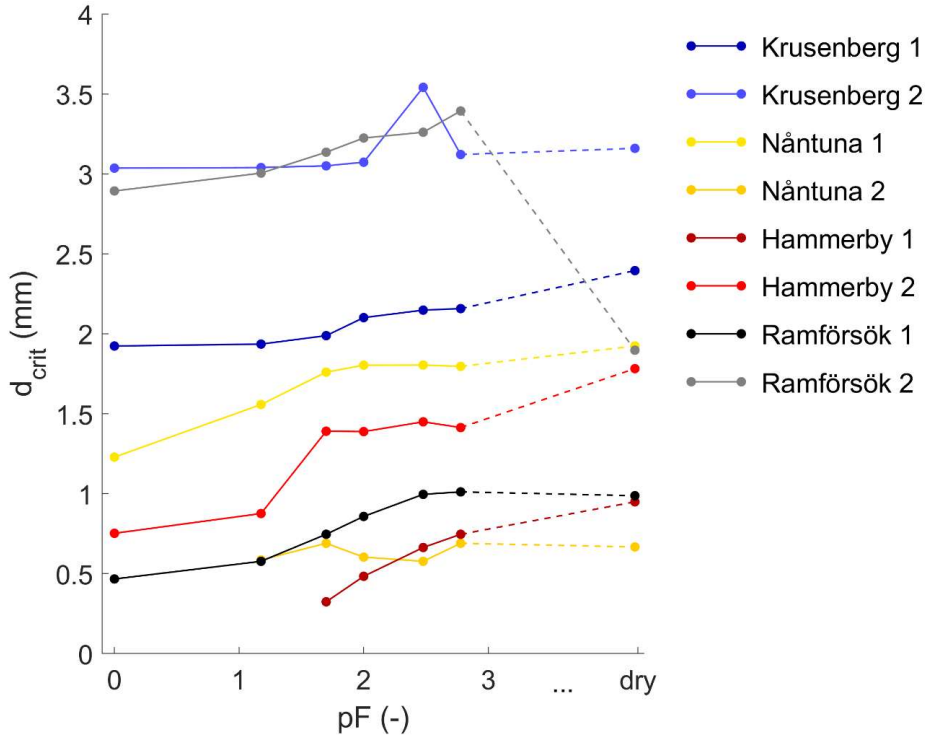
Average distance of a matrix voxel to next macropore with surface connection



Average distance to next surface connected macropore is approximately halfed, soil matrix becomes better aerated with drying

Bottleneck diameter in connection from top to bottom surface

(the bottleneck diameter is also known as critical pore diameter; its square is a proxy for Ks)



If saturated hydraulic conductivity is proportional to square of bottleneck,
it increased by up to the eight-fold during drying. In one case it decreased by a factor 2.

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Conclusions

Image derived pore morphology evolution during drying yield valuable insight

- smallest macropores gained most in volume

- majority of columns macropore network became strongly connected only above tensions of 600 cm

- while initially exisiting macropore became more connected, new unconnected pores expanded to macropores. This led to complex evolutions of the pore-connectivity measures

- the soil matrix became clearly more exposed to atmospheric air during drying

- bottleneck diameter evolution suggests that hydraulic conductivity changes non-linearily with drying, often exhibiting discrete ”jumps”

Future research will focus on the quantifitcation of the matrix deformation under drying.

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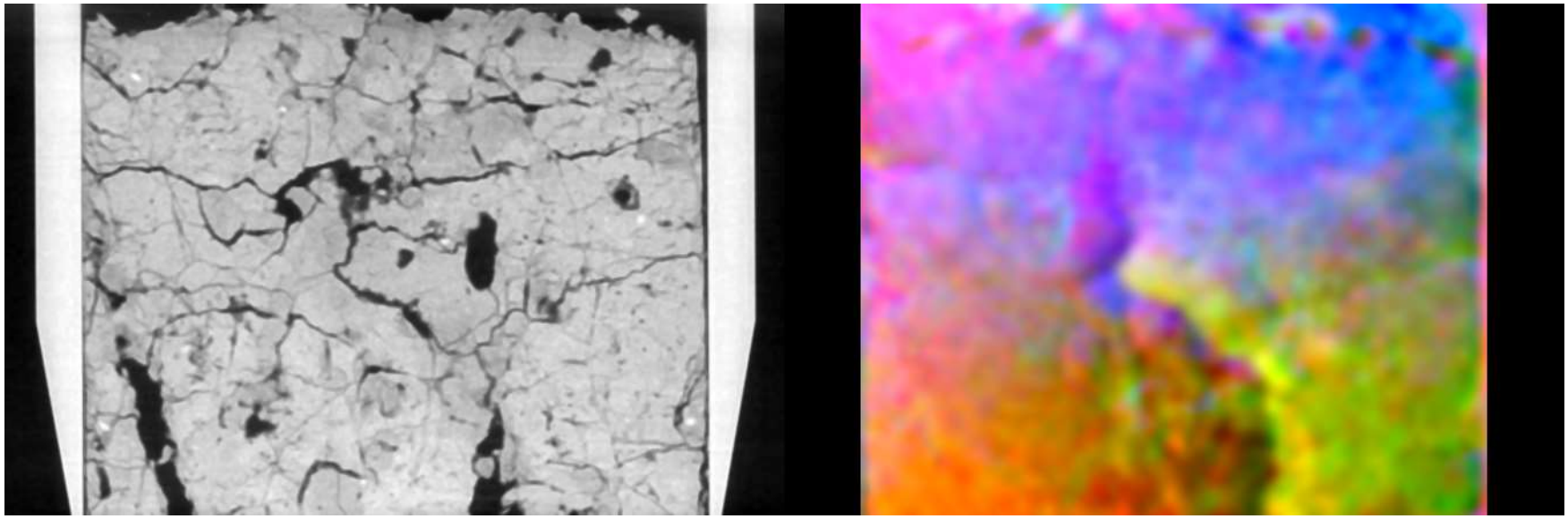

Thank you for having a look at this presentation!

Do you have questions?