Potential of combined neutron and X-ray imaging to quantify local carbon contents in soil

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Motivation and aim

Mapping the

3-D distribution of organic material in soil

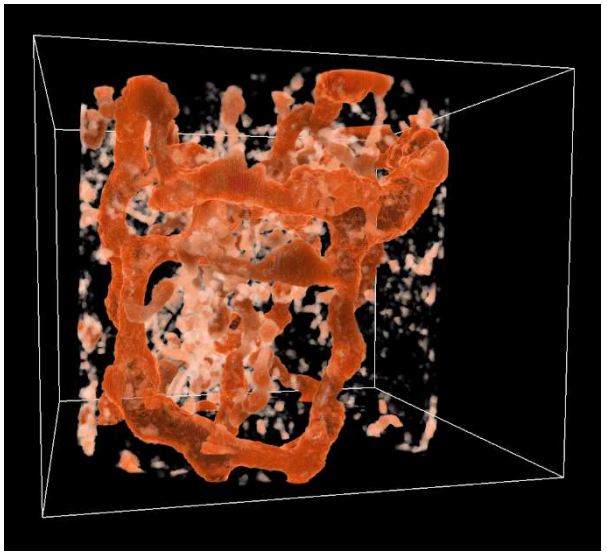
at a sub-image resolution scale

is required to understand the relationship between

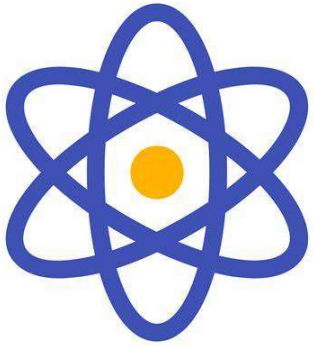
soil structure and soil function

Combined X-ray and neutron imaging

has potential to deliver such maps



Theory



X-rays interact with atoms' electron clouds

-- > attenuation is appr. linear to material density

Neutrons interact with atoms' nuclei

-- > strong interaction with specific isotopes,
e.g. protium (H) (ok, rather: reasonable interaction)

Theory

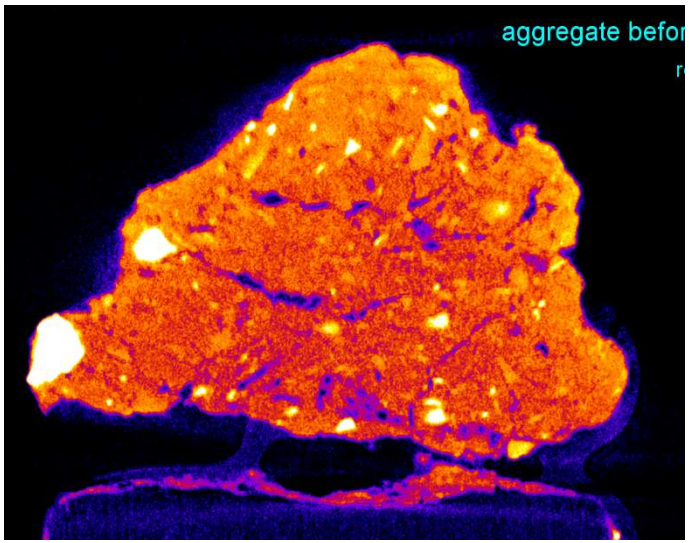
Soil is relatively free of strongly interaction isotopes
like for boron or cadmium isotopes

Soil organic material consists to a large part of H
-- > neutron scattering may be used

However:

Soils may contain H-bearing minerals

Soils contain crystal and adhesive H2O



Theory

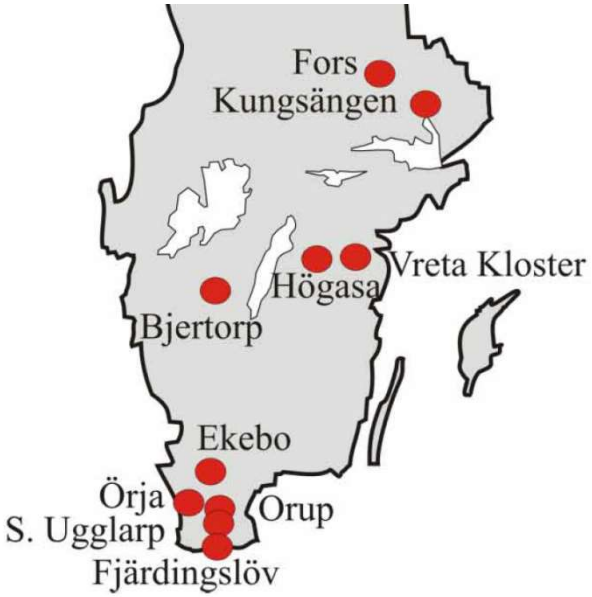
If soil is dried at a specific temperature and the mineralogy is known, the H content associated with the mineral phase may be estimated

-- > neutron beam attenuation relates quantitatively to organic matter content (even for partial volume voxels) if soil mineralogy is spatially homogeneous

Materials

Soil collected from six long-term field experiments in

Sweden, with varying minerals and organic matter contents



low high

organic matter content

Materials

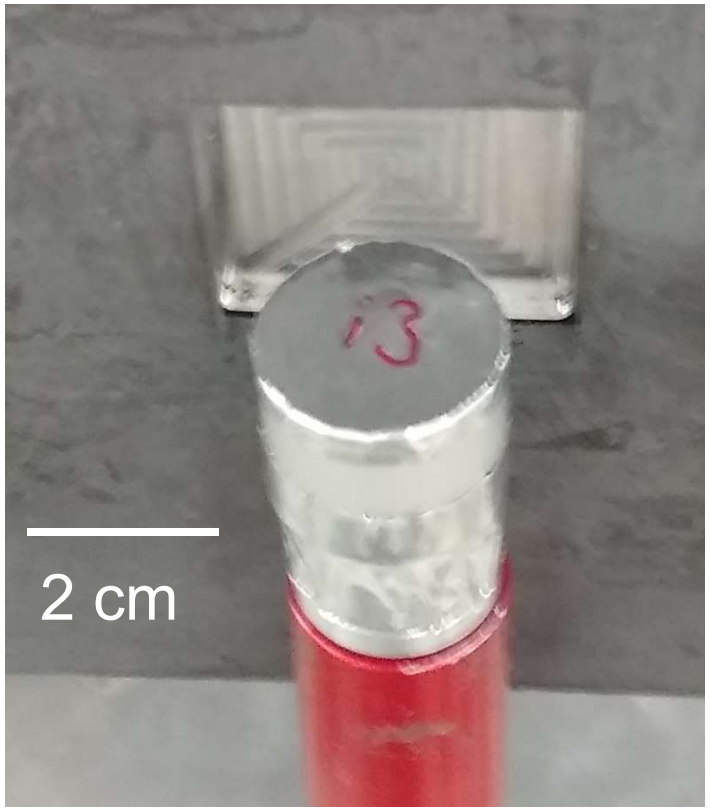
In addition, beauty clay powder (for facial masks) was used

and mixed with different amounts of saw dust (organic matter!)

+

Materials two types of samples

Clay powder or sieved soil for 2-D radiography



Soil aggregates, pebbles, plant seeds, plastics, quartzsand, etc. for 3-D imaging

Methods

Neutron TOF radiography at IMAT / ISIS
(2709 TOF channels, exposure time: 1 h)

Neutron white beam attenuation imaging at IMAT / ISIS

courtesy of Genoveva Burca

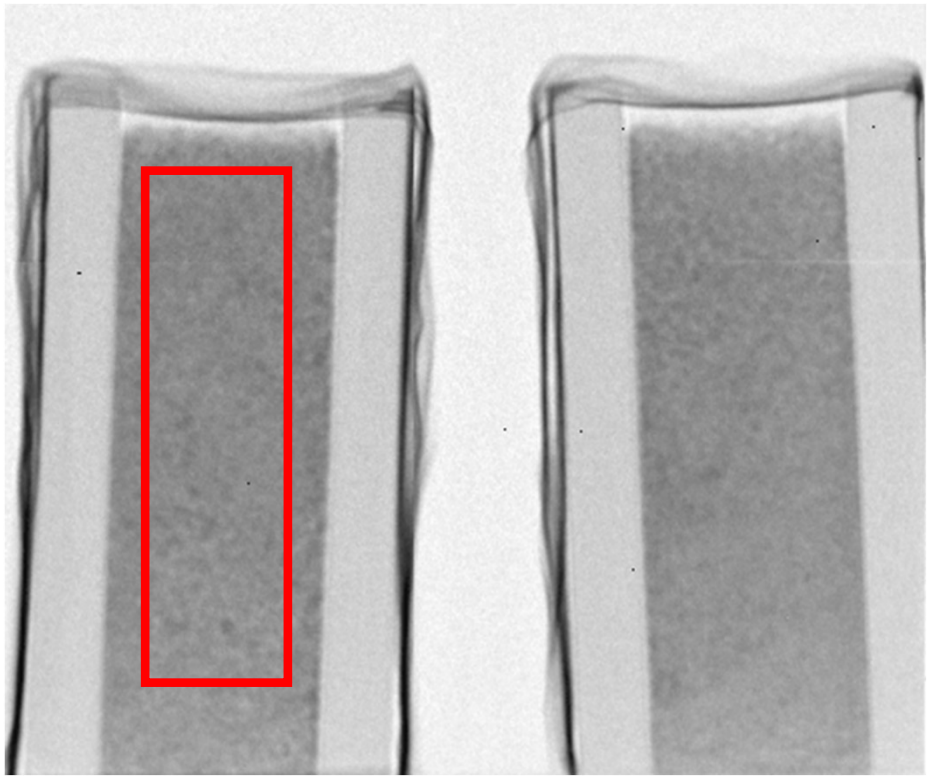
142 radiographs with TOF resolution (2709 channels)
exposure time 45 minutes, i.e. acquisition time: 5 days

X-ray attenuation imaging at I12 / Diamond

courtesy of Oxana Magdysyuk

2-D data evaluation

2-D neutron radiography



neutron white beam

attenuation was measured in

regions of interest

(size indicated by red box)

3-D data evaluation

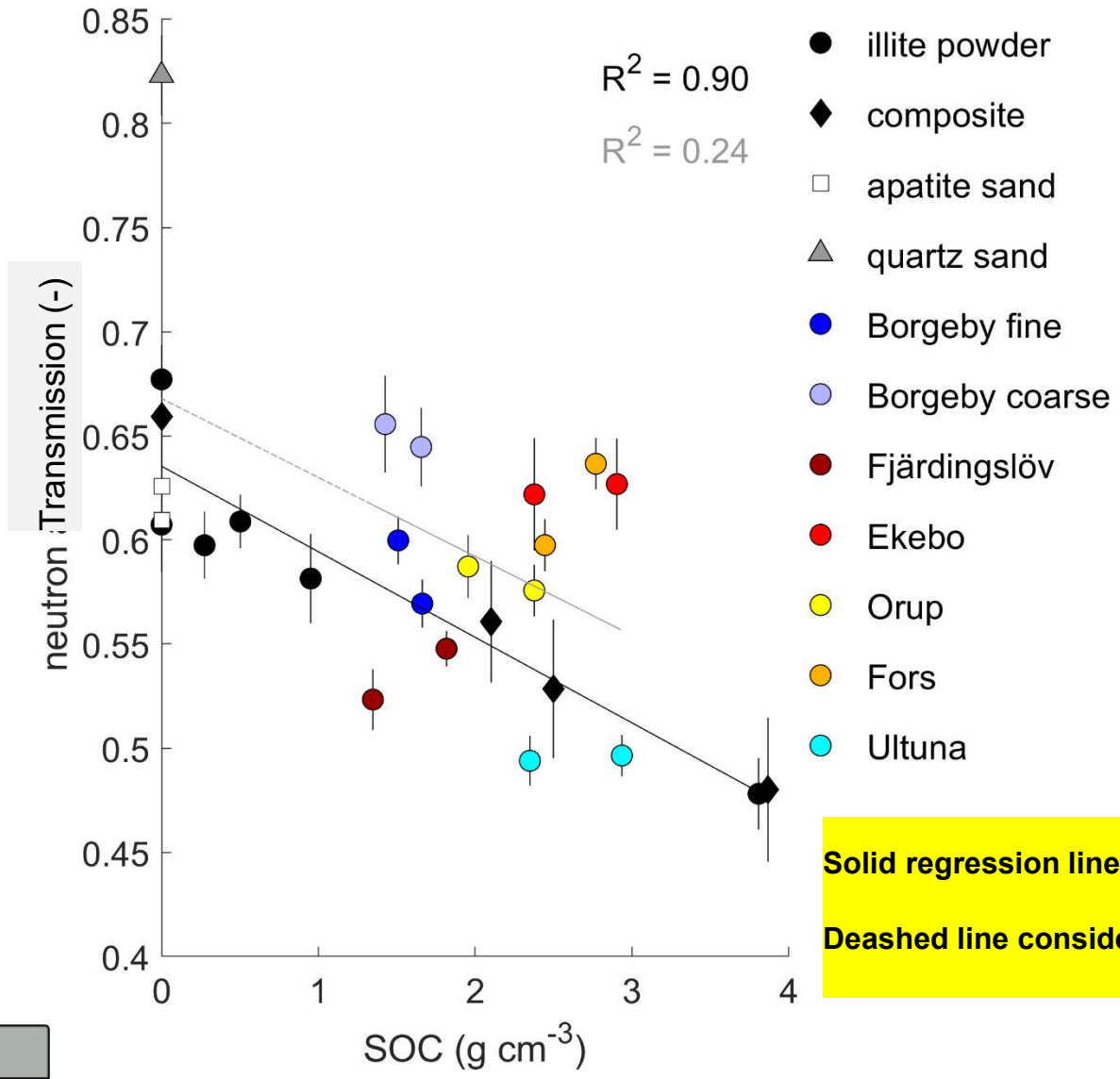
Combined 3-D (white-beam) neutron and X-ray imaging

Cross-registration of neutron and X-ray images done with the software Elastix (Klein and Staring, 2010)

Klein, S., M. Staring, K. Murphy, M. A Viergever and J. P W Pluim. 2010. Elastix: A Toolbox for Intensity-Based Medical Image Registration.

IEEE Transactions on Medical Imaging 29: 196-205. doi:10.1109/TMI.2009.2035616.

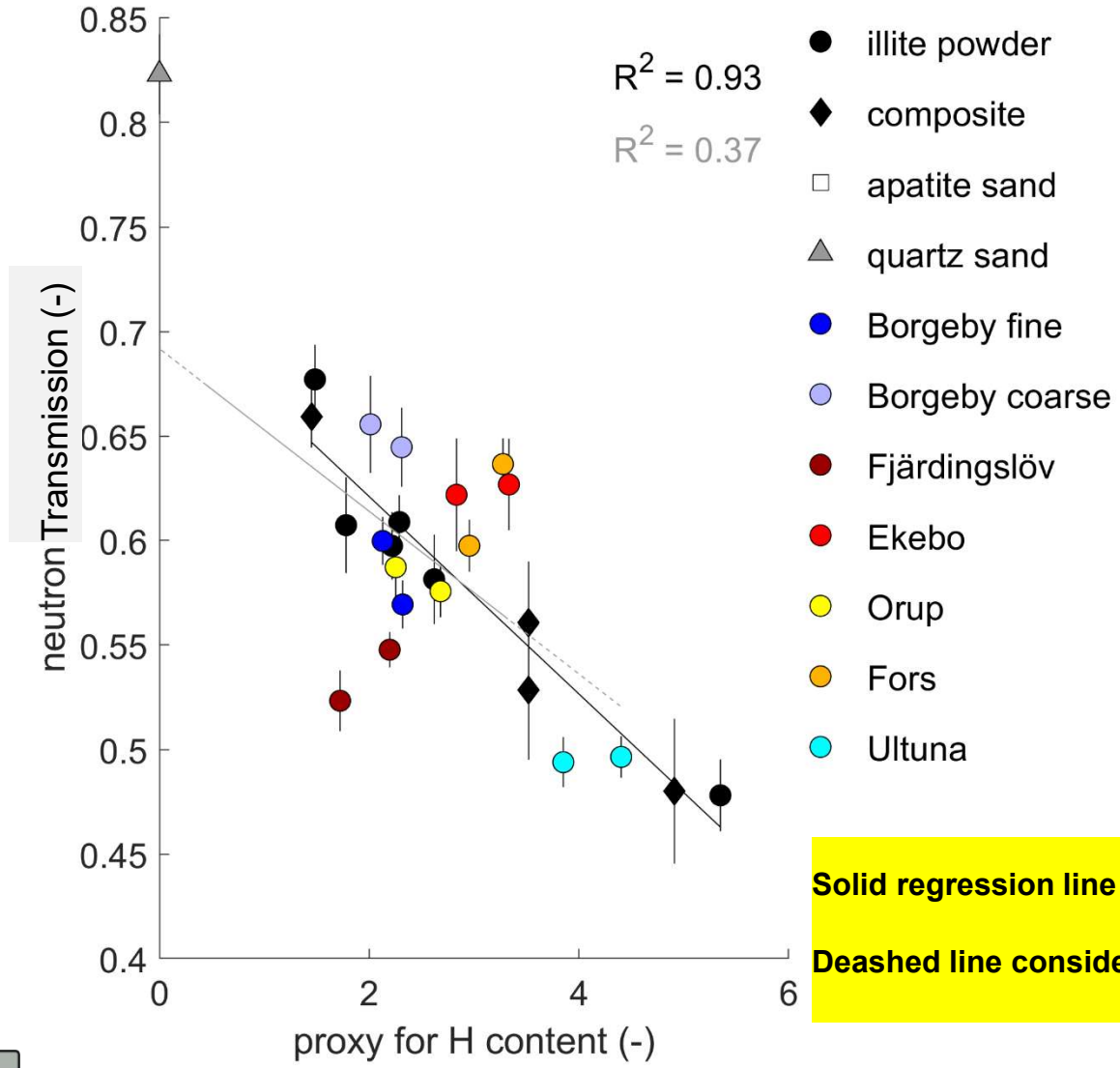
Results 2-D white beam radiography



Solid regression line only considers samples with illite

Deashed line considered all data points

Results 2-D white beam radiography



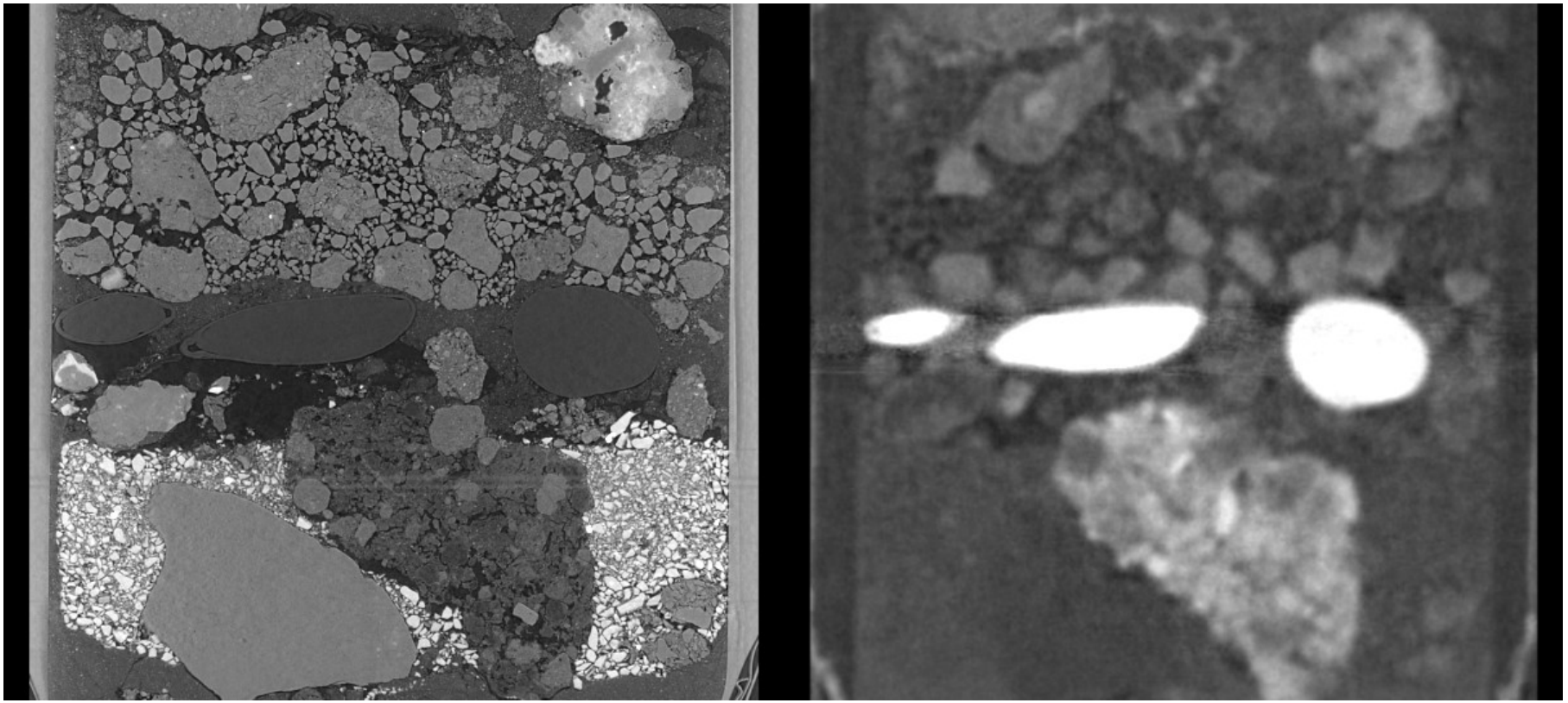
Solid regression line only considers samples with illite

Deashed line considered all data points

(Taking into account the minerology at the different sites)

Results

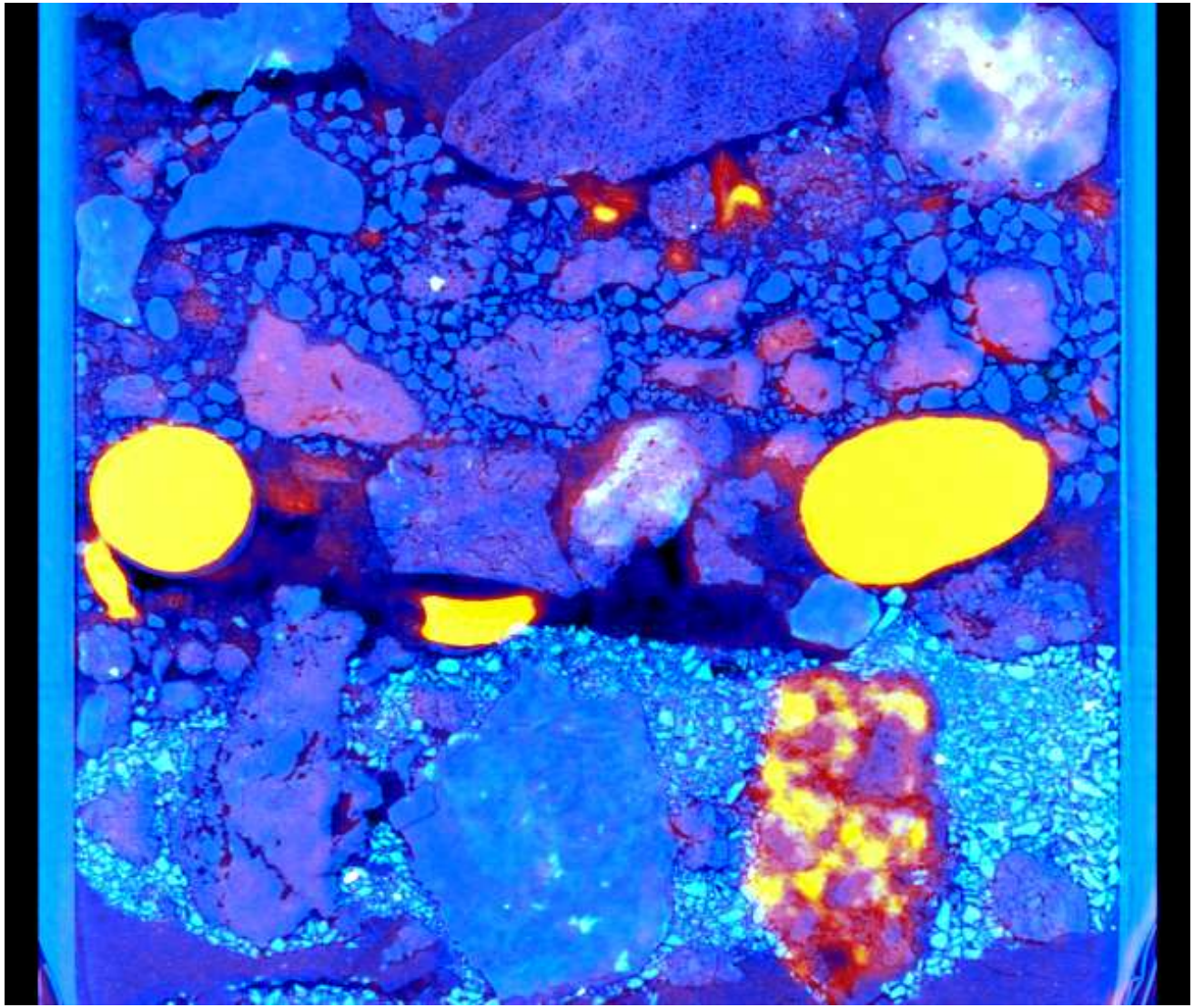
Combined 3-D neutron and X-ray white-beam imaging



X-ray

Neutron

Results Combined 3-D neutron and X-ray imaging



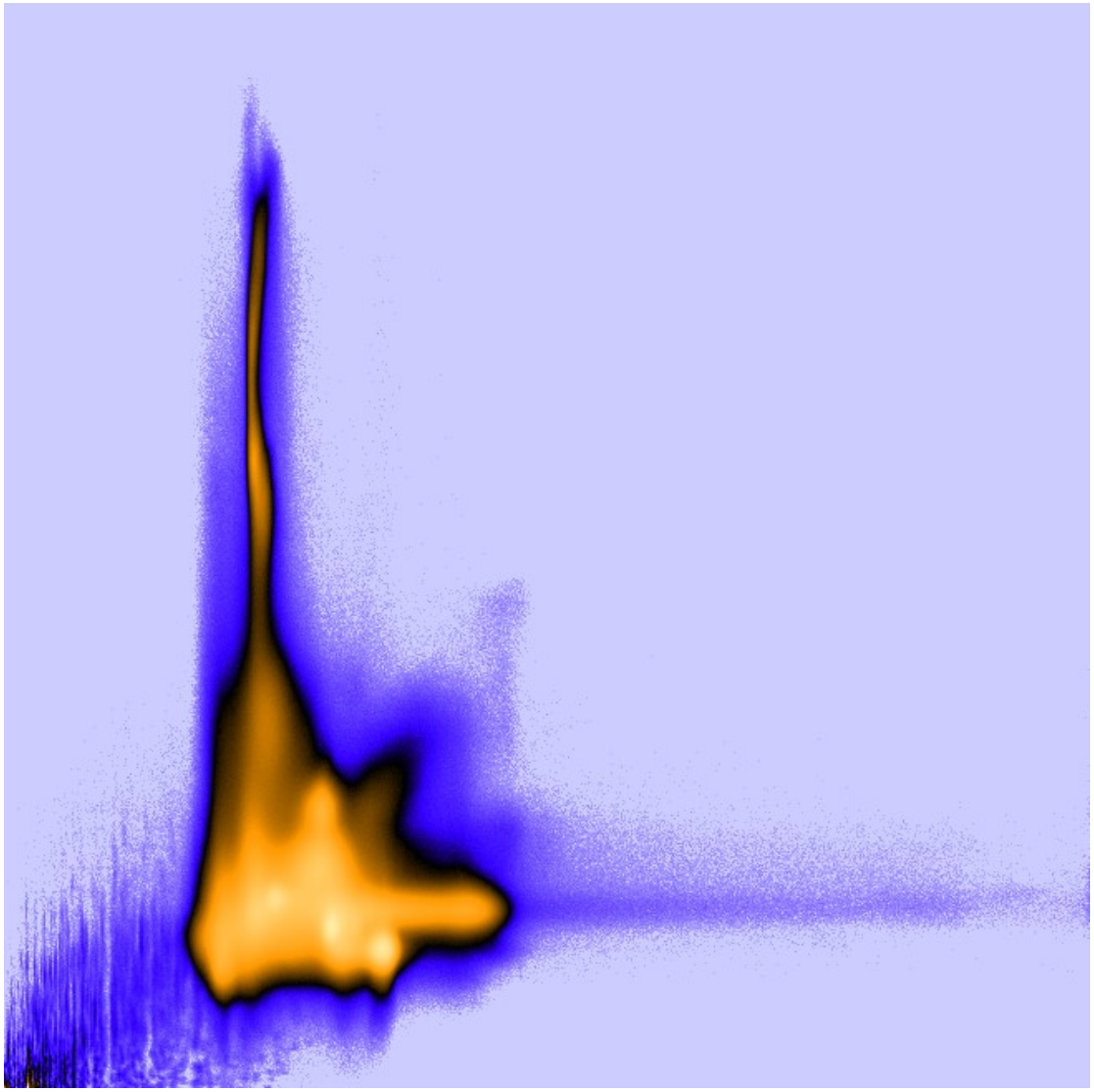
X-ray-Neutron composite image

Reddish hues: neutron attenuation

Yellow: strong neutron attenuation

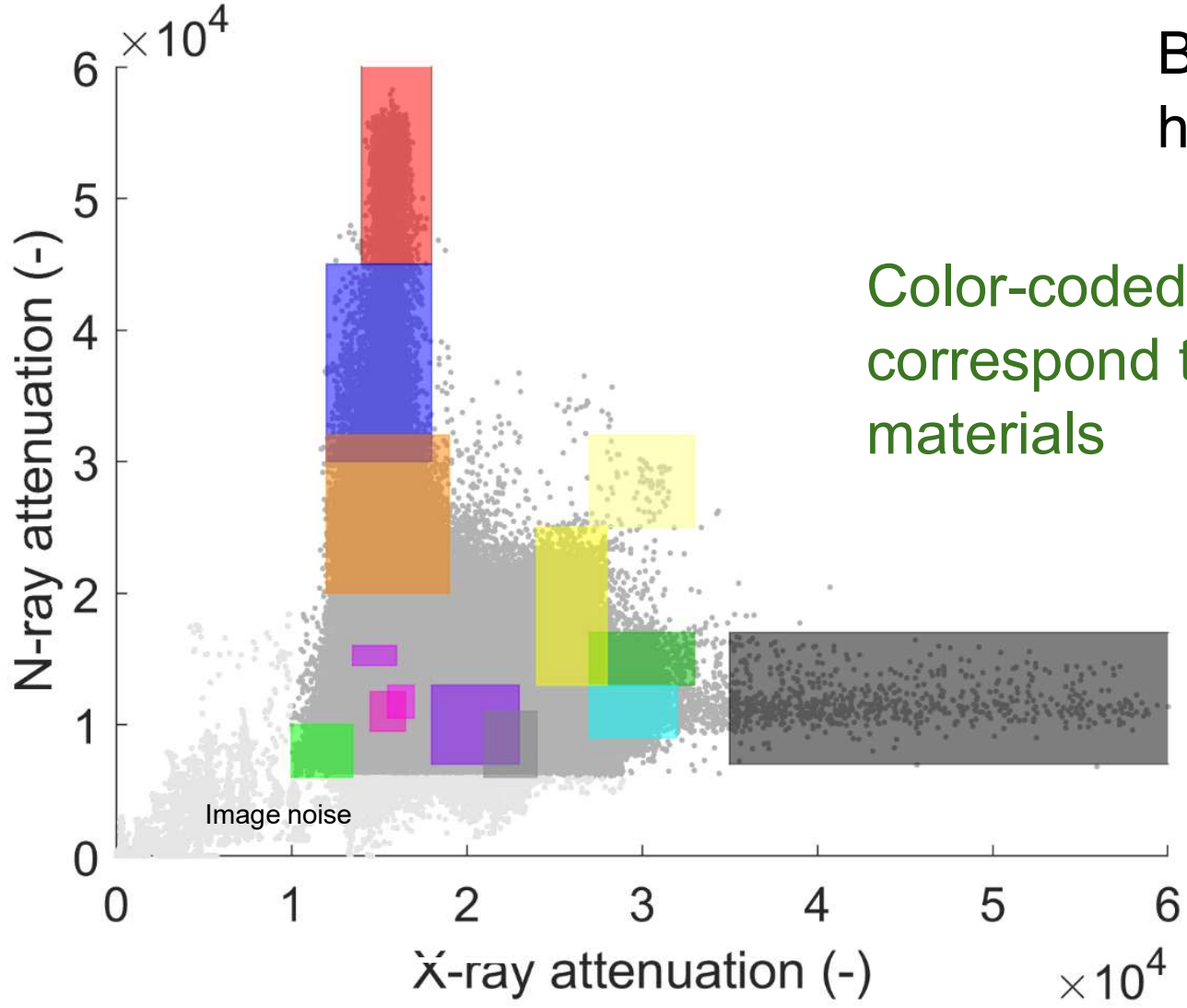
Blue-scale X-ray attenuation: (white == strong, black == weak)

Results Combined 3-D neutron and X-ray imaging



Bi-modal histogram

Results Combined neutron and X-ray imaging



Bi-modal histogram

Color-coded boxes correspond to specific materials

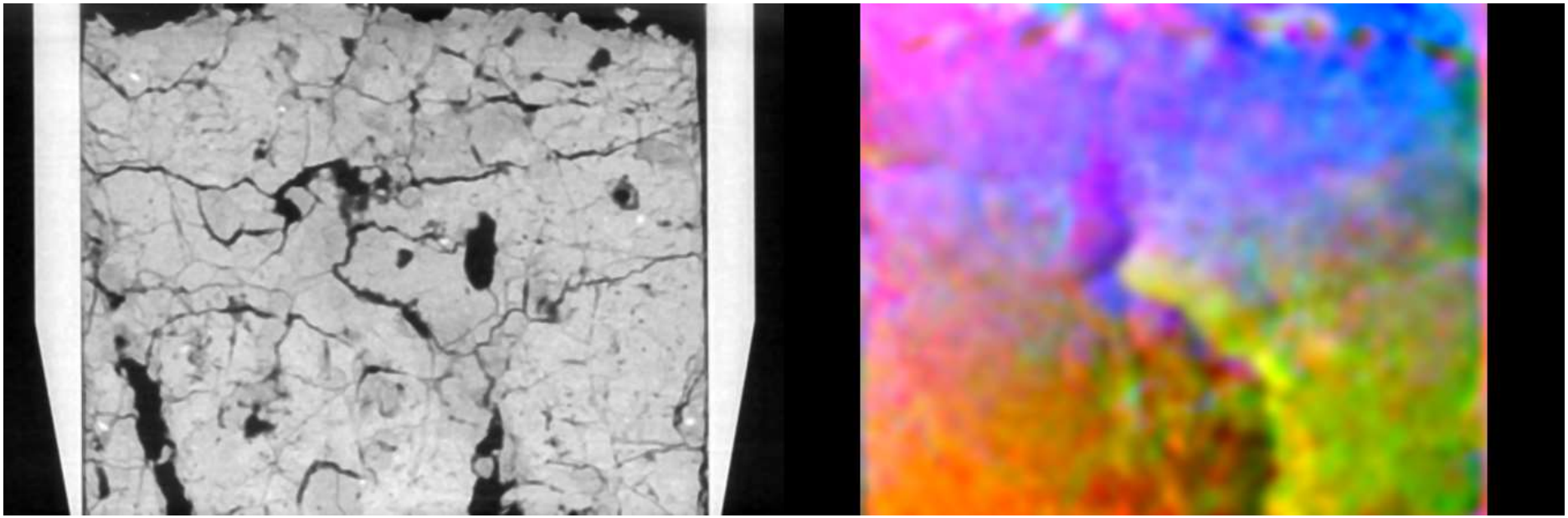
Conclusion

- White beam attenuation method works in principal

- Spatially homogeneous distribution of soil minerals is strong assumption that is probably seldom met

- TOF neutron imaging and X-ray edge imaging may offer a way out by providing means to map soil mineral compositions

Thank you for joining this session!



Do you have questions?