Structure analysis of rock by X-ray microtomography and PMMA-impregnation

Kiven huokostilavuuden kuvaus tomografiamenetelmillä

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X-ray microtomography (JYFL)

- Sample size from **2 mm** to 68 mm with respective voxel sizes **0.9 μm** to 20 μm
- Characteristics of the internal structure from the complete 3D volume.

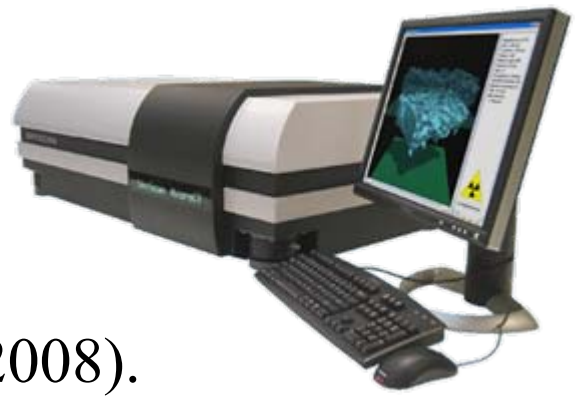
Targets:

1. Detailed structural analysis of (porous) rock samples and combination of results by different methods.

2. Further development of analysis tools.

3. Refereed articles on the results obtained.

4. Preliminary measurements on bentonite (2008).



PMMA, SEM, confocal microscopy (HYRL)

- Sample size up to dm scale
- Areal porosity from ^{14}C-PMMA-impregnated samples.
- Accurate mineralogy from SEM analysis/petrographic analysis
- Confocal microscopy with fluorescent impregnation: 3D down to about 250 µm, resolution of 1µm

Targets:

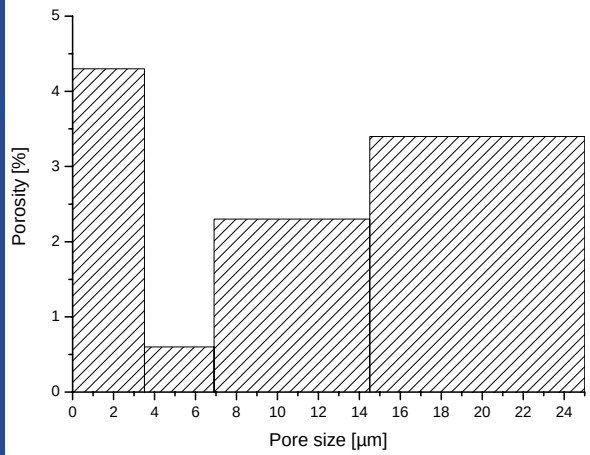
3. Refereed articles on the results obtained.

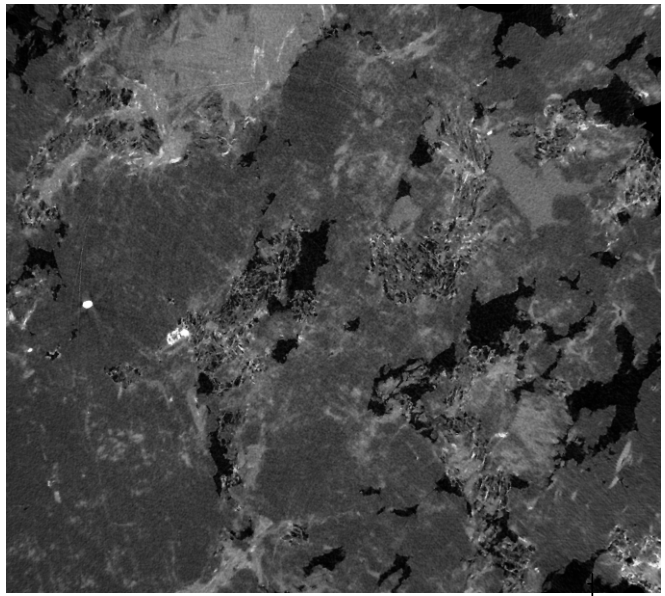
5. PMMA porosity of rock samples to be combined with tomography results.

6. Mineral composition of rock samples with SEM.

7. Confocal microscopy of fractures and comparison with PMMA and tomographic methods

Target 1: µCT results on Sievi tonalite (for example)



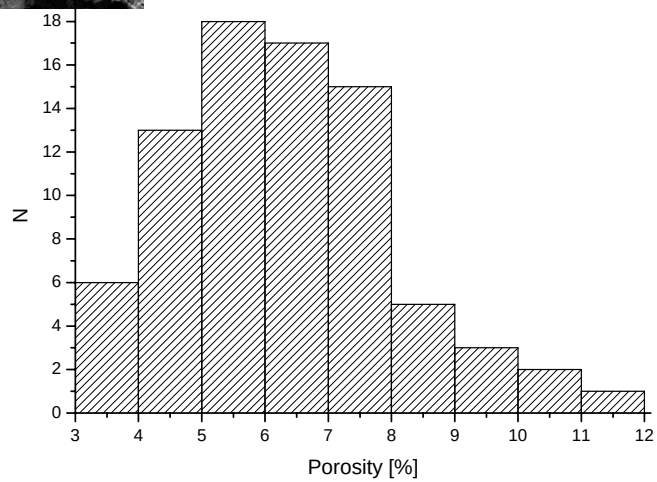


A cross section of a 3D tomographic reconstruction: Pores appear black

Porosity

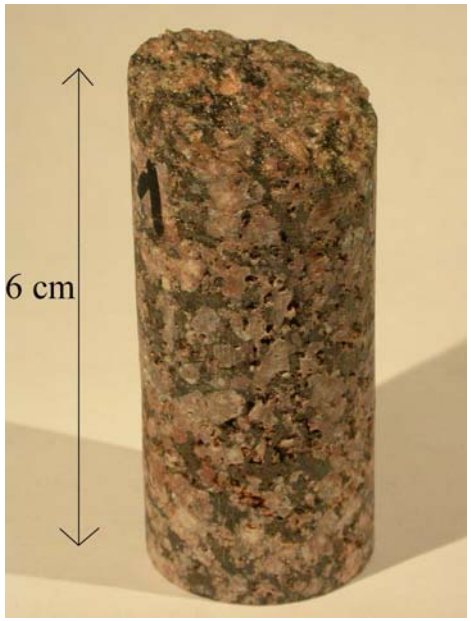
- Measured: 10.6 ± 0.2 % by argon pycnometry
- Pore-size distribution by tomography:

  Resolution dependent pore volume is
  - 3.2 % for 14.5 µm resolution
  - 5.8 % for 6.9 µm resolution
  - 6.3 % for 3,5 µm resolution



Heterogeneity of porosity:
Distribution of porosity of 9x9x0.4 mm3 sub-samples

Targets 1 & 6: Results on Sievi tonalite

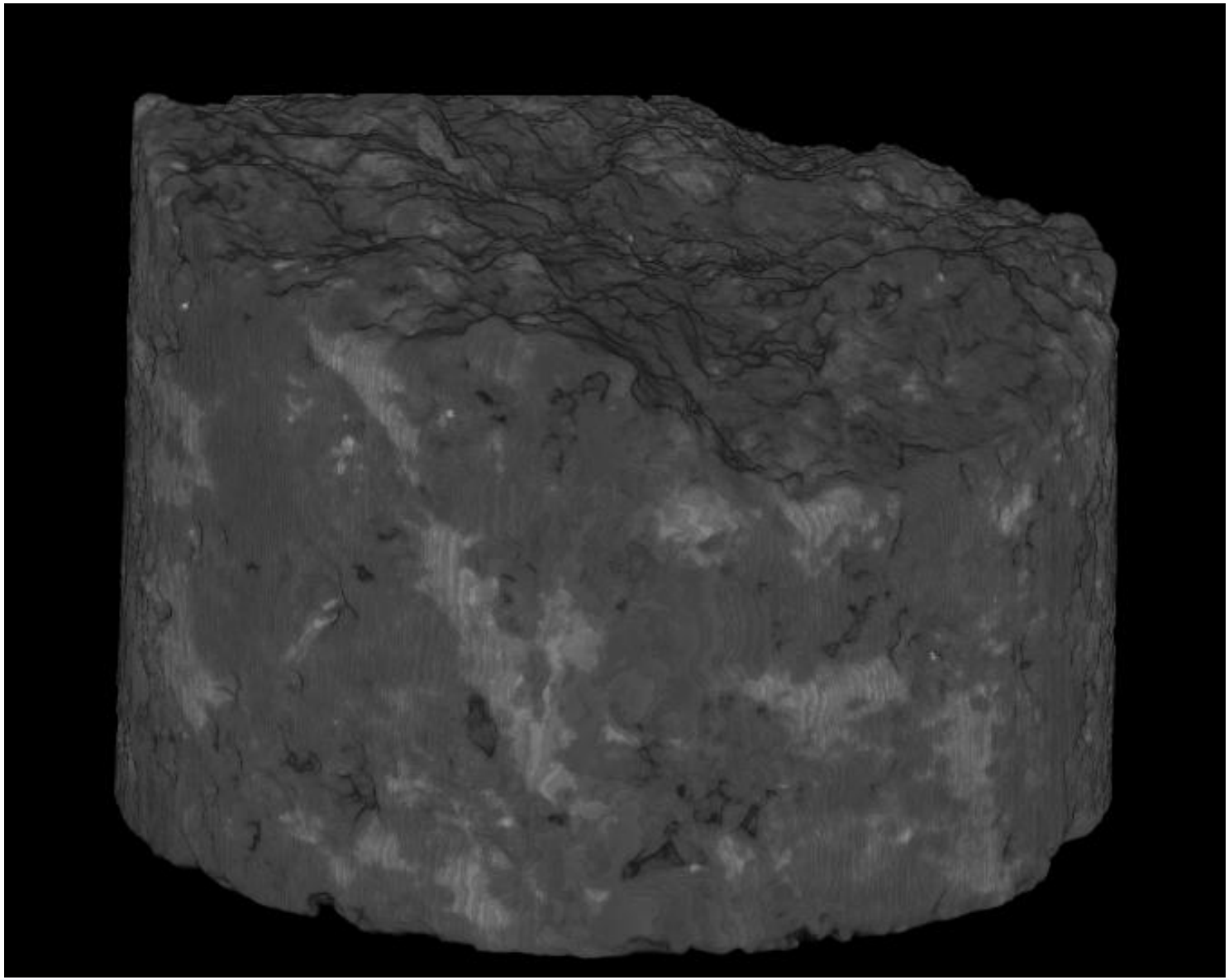


A SEM image of a Sievi sample

Abundancies of main mineral components

1. mineral 75,8 % (µCT): corresponds to feldspars; plagioclase and its weathering products (sericite), LOWEST DENSITY in 3D image
2. mineral 21,5 % (µCT): corresponds to dark minerals; biotite and its alteration products, MEDIUM DENSITY in 3D image
3. mineral 0,5 % (µCT): corresponds to accessory minerals; zircon, apatite, sphene, HIGHEST DENSITY in 3D image

Target 1: µCT results on Sievi tonalite
Segmentation of minerals



Target 2: Development of analysis tools

An extensive comparison of available noise filtering methods

Construction of two new filtering methods:

Local variance based method (extensively used)

Forest fire method (under testing)

An extensive comparison of available segmentation method

Construction of a new segmentation method:

Carpet (widely used)

Construction of two pore-size distribution algorithms:

Largest immersed sphere method

Identification of pores and pore throats based on skeleton of the pore space and the distance map at each point of the skeleton

Target 3: Refereed articles

1. T. Lähdemäki, M. Kelokaski, M. Siitari-Kauppi, M. Voutilainen, M. Myllys, T.Turpeinen, J. Timonen, F. Mateos and M. Montoto, **Characterizing low-permeable grantic rock from micrometer to Centimeter scale: X-ray microcomputed tomography, Confocal laser scanning microscopy and 14C-PMMA method**, MRS Symp. Proc. **985**, 0985-NN11-18 (2007)

2. M. Voutilainen, S. Lamminmäki, J. Timonen, M. Siitari-Kauppi, **Physical Rock Matrix Characterization: Structural and Mineralogical Heterogeneities in Granite,** Accepted for the MRS 2008 meeting (Boston), Article in preparation.

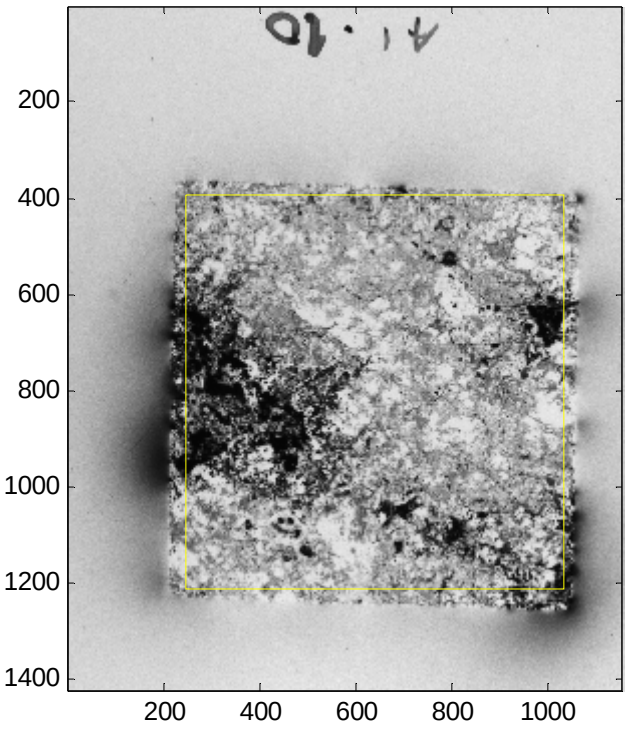
3. M. Voutilainen, J. Timonen, M. Siitari-Kauppi, S. Lamminmäki and M. Markovaara-Koivisto, **Characterization of porosity in crystalline rock**, First draft for an article .

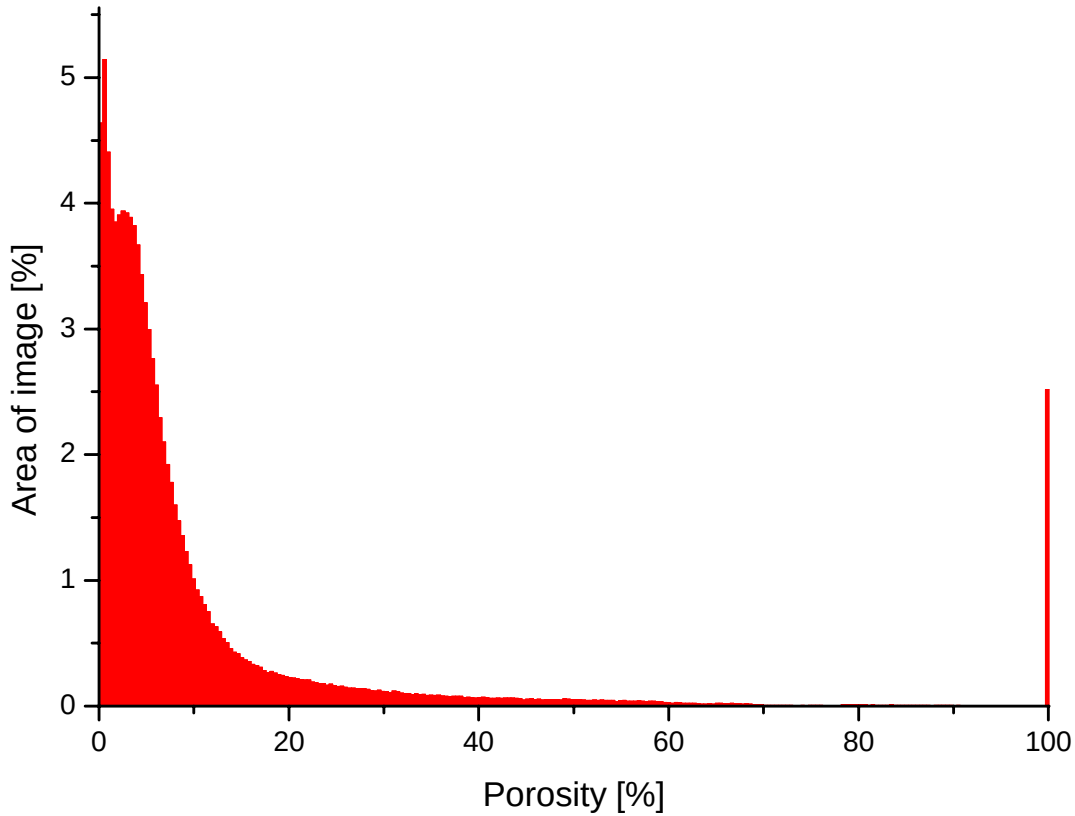
4. Turpeinen, K. Majava and T. Kärkkäinen, **Comparison framework of linear time filtering methods for CT images**, First draft for an article.

Target 4: Preliminary measurements on bentonite have been done.

Target 5: PMMA porosity of rock

Result for Sievi tonalite: Total (areal) porosity is 10.8 %

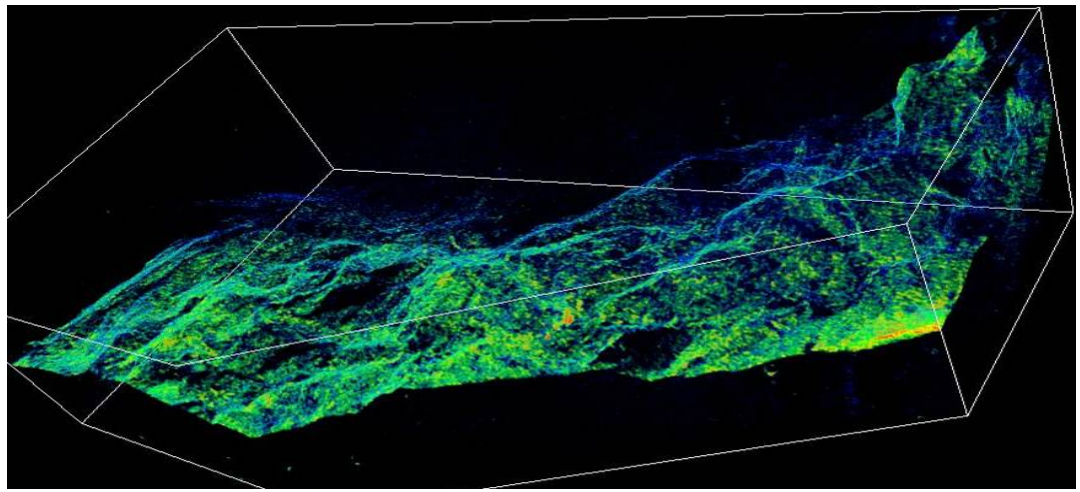




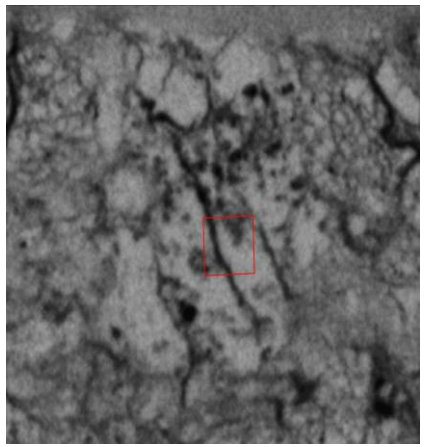
Detailed comparison with tomography results is under way.

-unweathered plagioclase (albite) corresponds to lowest porosity phases ; 0-2%,
-biotite corresponds to porosities from 2-10%
-sericite corresponds to fracture zone showing porosities up to 100%

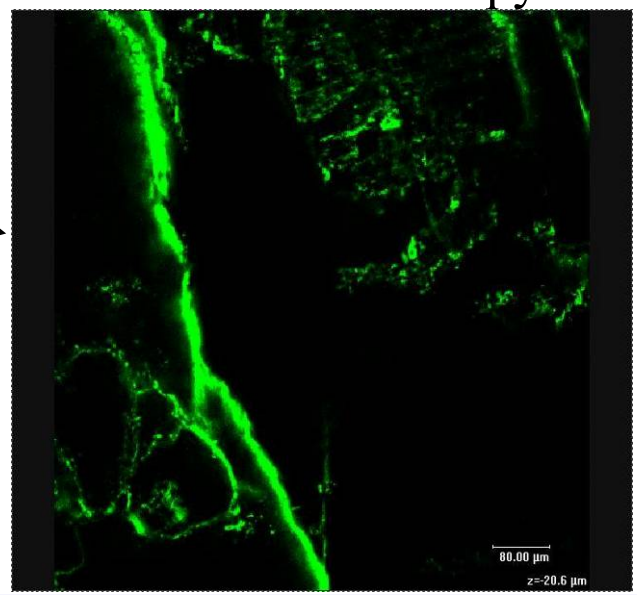
Targets 1 & 7: Results on microfractures



PMMA



Confocal microscopy



Internal fissure in Grimsel granodiorite (750µmx750µmx144µm) Z = - 20 µm (right)

Segmentation of a fracture from a tomographic image: Succeeds only for large apertures (in Muscovite granite above)

CONCLUSIONS

The best combinations of methods for tight granitic rock:

Mineral specific porosity in 3D by combining tomographic results for mineral composition with mineral specific porosity by PMMA and mineralogy

3D mineral composition by microtomography combined with mineralogy based on SEM and other methods

For altered rock with increased porosity:

Pore-size distributions in 3D by tomography combined with 2D distributions by PMMA

Analysis of microfractures:

Noise generally prevents detailed tomographic analysis

Combination of PMMA and confocal microscopy methods is useful