Effects of mineralogy and grain-size distribution on pore space morphologies in Boom Clay - insights from 2D high resolution BIB-SEM investigations and Mercury Injection Porosimetry

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Abstract

Microstructures in Boom Clay samples from the ON-Mol-1 borehole ('Mol-Dessel research site', Belgium), with different grain-size distributions, were studied, using broad-ion beam (BIB) milling and secondary electron microscopy (SEM-imaging). Additionally Mercury injection Porosimetry (MIP) was used to correlate direct microstructural pore space insights with bulk sample porosity information.

From BIB-SEM observations, overall Boom Clay fabrics can be described as a porous clay-matrix in which several low-porous, non-clay mineral (NCM) phases are embedded. Each different mineral phase shows its characteristic pore morphologies and visible 'intra-phase porosity', regardless of the depth of sample origin, mineralogical composition or grain-size distribution of the sample.

From the detailed analysis of BIB-SEM segmented porosities, we found largest pores (> ~ 1,000,000 nm^2 pore area) to be concentrated around (big) non-clay mineral grains, with their median pore-sizes correlating with the sample grain-size; those so-called 'inter-phase pores' account for between 11-90 % of the total segmented porosities from BIB-SEM, with the amount increasing with the sample grain-size and non-clay mineral content.

Total porosities detected at the scale of the SEM are between 10 to 15 % of the analyzed areas between 10,000 to 25,000 μm^2 size.

Pore-size distributions observed within the clay-matrices of samples are log-normal, showing a peak ~ 1,000 nm^2 pore area, but since the practical pore detection resolution is as well around that pore-size, we assume for pore-size distributions to be cut off at that point, due to the pore detection resolution, and to actually follow a power-law distribution. Fitting pore-size distributions within a range from ~ 1,000 to 1,000,000 nm^2 pore area, using power-laws, results in power-law exponents between 1.55-1.66. Assuming self-similarity of the pore space in Boom Clay, these power-laws were used for extrapolation of measured pore-size distributions below the limit of pore detection resolution.

MIP experiments down to smallest pore throats accessible of 3 nm in diameter, yield interconnected porosities between 26-33 %. Porosity distributions resulting from MIP are log-normal, with major peaks ~ 60 nm pore throat diameter in the fine-grained, clay-rich samples and ~ 7,000 nm in the coarse-grained, clay-poor sample. A sample of intermediate mineralogical composition and grain-size distribution shows a

bimodal porosity distribution, with a first, major peak ~ 60 nm pore throat diameter and a second, minor one ~ 1,600 nm.

This shows that in the fine-grained samples, the interconnected porosity is mainly controlled by pores smaller than the pore detection resolution of the BIB-SEM method, presumably found within the clay-matrix. In the coarse-grained sample, much larger pores account for the major part of the interconnected porosity measured by MIP. From BIB-SEM observations these large pores were found to predominantly occur at the interfaces between clay-matrix and non-clay mineral (NCM) grains, with their median pore-sizes increasing with the sample grain-size, which indicates that a higher NCM-content and larger sample grain-size lead to an increase in sample permeability, due to a higher contribution of much larger pores, occurring at phase boundaries, to the total interconnected sample porosities. In the sample of intermediate grain-size and mineralogical composition, pores smaller than the BIB-SEM resolution, as well as larger pores contribute to the interconnected porosity. We propose that above a critical non-clay mineral content and median sample grain-size, larger pores, localized in strain-shadows of clast-grains, start being directly connected and might increase the permeability of the sample.

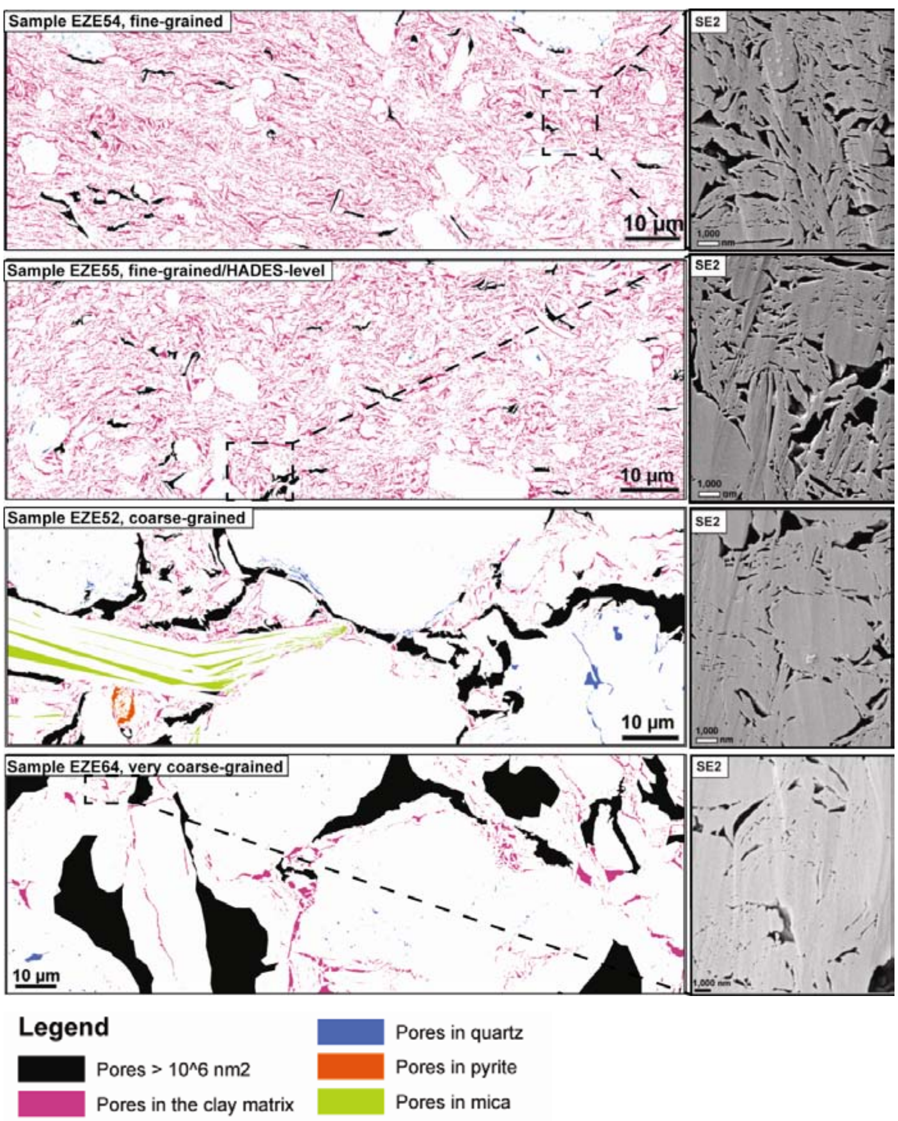

Figure 1: Segmented porosities from BIB-SEM observations, showing different microstructures of investigated Boom Clay samples.