Nano-mechanical properties of chalk from ptychographic imaging

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We imaged chalk samples from the North Sea Basin using ptychographic X-ray tomomography (PXCT)[1, 2] at 21 nm voxel size (optical resolution ~60 nm). After preprocessing the 3D data, i.e. filtering, segmentation and meshing [3, 4], small subvolumes (100^3 voxels) of the full data set were imported into finite element (FE) software [5] and a tensile simulation was made to determine Young's modulus.

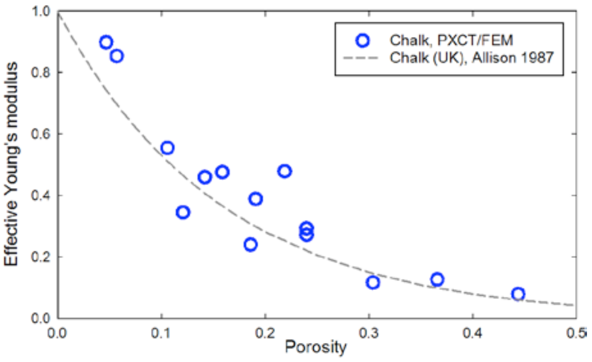

Figure 1: Finite element simulations for effective Young's modulus showing good agreement with literature data.

Figure 1 shows the dependence of the effective Young's modulus on porosity, derived from our FE simulations. For comparison, a fit to published experimental data, [6] determined by classical macroscopic methods, is also shown for a comparable sample. Except for the very low porosity region (porosity < 10%), the simulation data scatter near the literature curve. This is quite remarkable because the volumes in the simulations are a factor of 10^9 smaller than in the experiments (core plug testing). The results demonstrate that this approach on the nanoscale can be used to derive meaningful elasticity-porosity relationships [7] which can be scaled from the nanometre to the centimetre (laboratory) scale and probably beyond.

[1] Dierolf *et al.* (2010) *Nature* **467**, 436-482 [2] Holler *et al.* (2014) *Sci. Rep.* **4**, 3857 [3] Müter *et al.* (2012) *Comp. & Geo.* **49**, 131-139. [4] Müter *et al.* (2014) *Appl. Phys. Lett.* **105**, 043108. [5] Maas *et al.* (2012) *J. Biomech. Eng.* **134**, 011005. [6] Allison (1987) *Geo. Soc. Spec. Pub.* **9**, 63-69. [7] Sørensen *et al.* (2016) *in prep*.