Predicting macroscale properties of rocks from nanoscale data

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For a long time, the primary method to characterise the hydrodynamic properties of rocks, such as porosity and liquid permeability, has relied on core plug experiments, i.e. large (>10 cm diameter) cores of a rock formation had to be drilled and from these, smaller, 1" diameter core plugs are extracted. The porosity of the core plugs is then determined by methods for example, that use He expansion or mercury intrusion. Similarly, single phase liquid permeability has been acquired on core plugs by measuring the flow velocity of a gas passing through the porous rock at a fixed pressure gradient.

Efforts have been made to estimate such parameters from 3D images of rocks. These methods are often referred to as *digital rock physics*. It is challenging to get representative data from digital rock physics for a number of reasons: 1) the imaging method might not resolve all pores, 2) the sample volume investigated is generally much smaller than the core plug scale and 3) the simulation of flow properties also relies on how well the physics of the fluid and its interaction with the mineral surfaces is described.

We directly compare the macroscale core plug parameters of chalk with results based on tiny chips (Ø < 100 μm) extracted from 8 1" core plugs of Upper Mastrichtian chalk and imaged by nanotomography at BL47XU, SPring-8, Japan. More than 160 volumes were imaged, reconstructed in 3D, treated for noise and artefacts and segmented by marker based watershed segmentation. From the binary images, we have calculated the porosity, specific surface area, Klinkenberg permeability and formation factor. This study has only been possible because of the development of fast full field nanotomographic instruments at SPring-8, that allowed us to image many samples within a single shift, and because of our implementation of an automatic procedure for data treatment from X-ray projection data to parameter extraction.

We found a very good correlation between the parameters extracted from the nanoscale data and the core plug data. The porosity is apparently slightly underestimated (up to ~2 porosity units), whereas there is very good correspondance between the porosity-permeability relationships found at both scales, separated by more than 4 orders of magnitude.