AUTOMATED ANALYSIS OF PETROPHYSICAL PARAMETERS

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Summary: We present a nanotomography based analysis of petrophysical parameters for 162 samples of North Sea Upper Maastrichtian chalk. Even for a single heterogeneous material such extensive sampling is required to reliably estimate the macroscale petrophysical parameters from nanoscale information. It only became feasible by automating all image processing and analysis tasks between data acquisition and interpretation.

1. INTRODUCTION

Drilling appraisal wells for acquiring core plugs for reservoir property evaluation is often too costly and time consuming for small hydrocarbon accumulations discovered while drilling for other targets. Available material for reservoir property evaluation for small hydrocarbon accumulations are often only drill cuttings but these are too small for a proper evaluation by standard core analysis techniques. Smaller hydrocarbon accumulations can thus often not be properly evaluated today and may be left as stranded reservoirs and the potential hydrocarbon resource in them is left unexploited. Digital core analysis might be able to solve this problem.

The reservoir properties (porosity, permeability, formation factor, etc.) are a consequence of the pore structure and it has been shown that the physical properties of a rock can be derived from milli- or even micrometre sized samples by a combination of X-ray tomography and numerical simulation, i.e., digital core analysis. Given the smallness of the analysed samples and the heterogeneity of natural porous media, it is a challenge to establish representative elementary volumes (REV) for a parameter of interest in a given rock and acquire enough information about the heterogeneity to upscale the microscopic to macroscopic properties.

During the past years, several studies were performed to establish REVs for various porous geomaterials and their hydrodynamic and petrophysical parameters [1,2]. For a rather homogeneous porous material such as North Sea chalk, the REV for simple bulk statistical properties such as porosity and surface area is on a scale that is sufficiently small to be characterized from nanoCT experiments [2]. Individual grains in chalk are generally on the submicrometre scale, i.e., nanometre resolution is also a requirement for segmentation and subsequent “ab initio” simulation of derived petrophysical parameters of chalk, such as permeability or formation factor. Yet, for these parameters the REV is on a scale that cannot be imaged with nanotomography [2]. The precision of permeability estimates from a handful of imaging experiments remains questionable which limits the usefulness of the approach. To characterize the more complex hydrodynamic parameters of a heterogeneous porous medium with imaging techniques and to identify heterogeneities at the core scale, it is therefore necessary to sample repetitively.

A common rule of thumb is that the analysis of a tomographic dataset takes about ten times longer than its acquisition. Thus, it is highly desirable to reduce the amount of person hours spent on image processing and analysis by automating the process as much as possible. Our latest setup operates autonomously and minimizes user interaction for reservoir rock characterization to a point where it is only required to queue the raw projection images. This avoids user bias and allows for a parallelized and fast analysis of hundreds of datasets required for an exhaustive characterization of macroscale rock properties from high resolution nanotomography images. Here we present our results for the analysis of porosity, specific surface area, Klinkenberg permeability and formation factor for 162 samples of Upper Maastrichtian chalk, sampled in the North Sea region.

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2. EXPERIMENTAL METHOD

We performed nanotomography experiments at the BL47XU beamline at SPring-8, Japan. Small chips of 8 core plugs sampled from 5 different cores of North Sea Upper Maastrichtian chalk were taken from three different locations in each core, resulting in 17–23 usable samples per core plug and 162 successfully analysed samples in total. They were imaged at 8 keV with a voxel size of 40.5 nm (1,800 projections, 180° sample rotation, 250 ms exposure). Projection data were then autonomously processed with our image processing and analysis setup. The automated operations performed included: sinogram conversion, completion of truncated sinograms, destriping of sinograms for ring artefact removal, GridRec reconstruction, 3D iterative nonlocal means denoising [3], region of interest selection, watershed segmentation, meshing for finite element simulations and analysis of porosity, specific surface area, Klinkenberg permeability and formation factor.

3. RESULTS

Using this automated approach it was possible to sample and characterize the chalk core plugs quickly and effectively, gathering enough data to provide statistics for a macroscale characterization of the material. . We were able to establish a porosity-permeability relationship that covers a broad range and matched the laboratory based Klinkenberg permeability measurements very well. Porosities were estimated consistently slightly lower, by about 1.5%. Derivation of a full set of formation factors is currently in progress.

References

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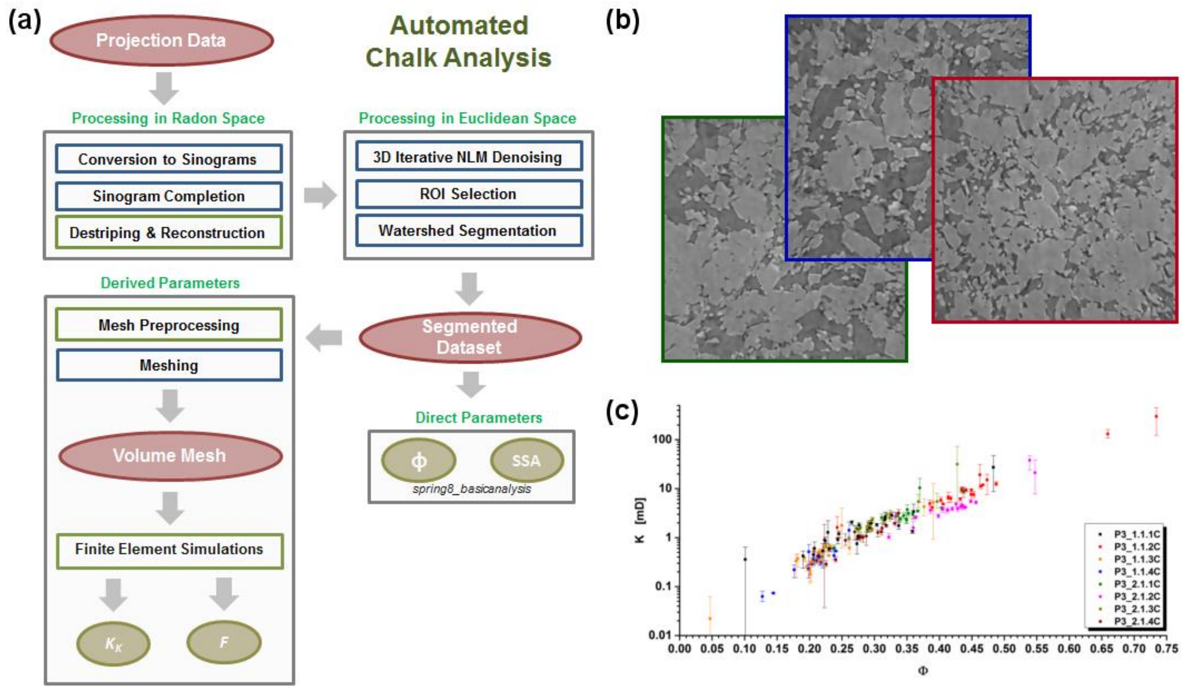

Figure 1: (a) Outline of the operations performed during the automated tomography image processing. (b) Examples of 2D slices after 3D iterative denoising and (c) the final results shown for the porosity-permeability.