PREDICTION OF PETROPHYSICAL PARAMETERS FROM TIGHT CHALK RESERVOIRS BY NANOTOMOGRAPHY

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Summary: We present an extensive statistical comparison of the petrophysical parameters obtained for tight reservoir chalk using X-ray nanotomography

1. INTRODUCTION

The rapid development of 3D X-ray imaging techniques and computational methods, during the past 10 years, allows us to predict petrophysical properties from porous materials at many scales. This field is generally known as Digital Core Analysis [1] and is a very powerful technique for coarser scale natural materials such as sandstones and some types of carbonate rocks. So far however, there are only a few investigations of tighter carbonates, such as chalk. Chalk is dominated by the remains of single celled algae, the coccolithophorids, which produce 0.5-2 micrometre sized calcite crystals that are organized in discs called coccoliths. These typically have a diameter of 3-15 micrometres. The porosity of the North Sea chalk fields is often very high but the small grain and pore size results in low permeability. The range of parameters that can be derived from digital models of the porous materials is very dependent on the resolution of the 3D images [2] and not least, on the ratio between the resolution and the scale of the components in the material [3]. To investigate the feasibility of using imaging, combined with numerical determination and prediction of the petrophysical properties, we have investigated a series of diverse chalk facies, covering the entire Upper Cretaceous epoch from Cenomanian to Maastrichtian and the Lower Paleocene Danian. We collected data from 103 core plugs, which had initially been subjected to classical core plug analysis, using high resolution X-ray imaging. We extracted, on average, 14 chips from each core plug and imaged these at SPring-8, Japan and from the resulting 3D images, we determined the petrophysical parameters for each sample, using an automated procedure [4]. All of the data were compared to parameters derived using classical core plug analyses.

2. EXPERIMENTAL METHODS

The data were all gathered using the X-ray nanotomography installation at beamline BL47XU at SPring-8, Japan [5]. From 103 core plugs, covering more than 10 chalk types from the North Sea Basin, we took chips from the top, middle and bottom of the core plugs, producing 10 to 23 usable samples per plug. They were a millimetre or less in the longest dimension and less than 100 micrometres in diameter. In all, more than 1500 nanotomograms of chalk chips were collected. The samples were imaged at 8 keV, recording 1800 projections over a 180° sample rotation, using exposures of 160-250 msec (depending on the data set). The resulting voxel sizes were between 36.9 and 40.5 nm.

The projection data were reconstructed and processed as described in the abstract by Bruns *et al.* from ICTMS-2017 [4]. This provided the petrophysical parameters: porosity, specific surface area, Klinkenberg permeability, formation factor and elastic mechanical properties.

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3. RESULTS

We determined a series of petrophysical parameters, including porosity, specific surface area, Klinkenberg permeability, formation factor and Young's effective modulus. We were able to process this extensive series of samples in a rather short time, by using an automated analysis procedure that we developed [4]. Although we probed only a fraction of the full core plugs using X-ray nanotomography, the resulting parameters, and not least the correlations between the parameters, compared very well within each set and with the parameters determined using classical core analysis, for all chalk types. From this, we could conclude that, by taking from 10 to 20 samples from each core plug, we could derive representative core plug properties quite well. In addition to the parameters for each core plug, the digital analysis procedure, adds value because we were able to obtain information about the variability of the parameters within the core rather than only the macroscopic value that is obtained by classical core analysis and from the variability within the core, we can assess how the values are distributed and how each correlates with the other petrophysical parameters.

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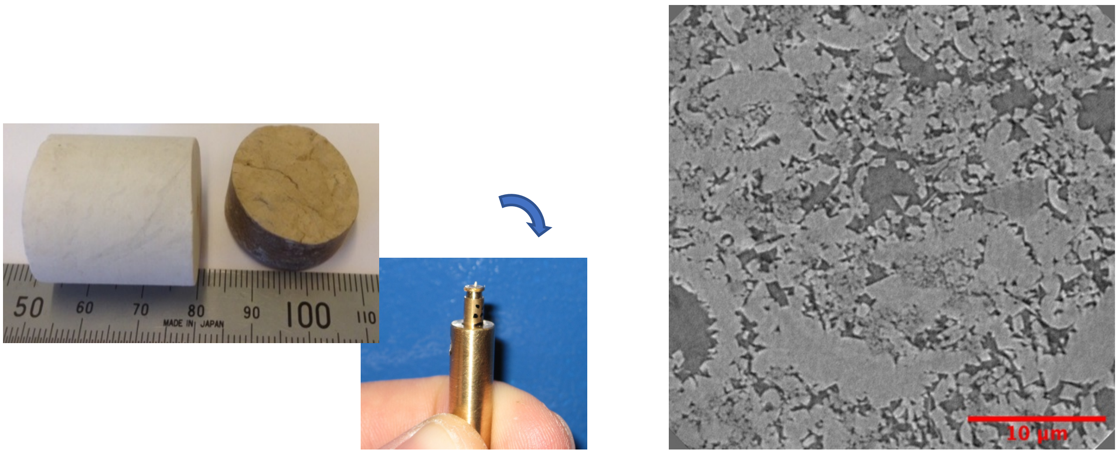

(a) (b)

Figure 1: (a) Using digital analysis, we can move from macroscopic determination of petrophysical parameters, using classical core plug analysis of reservoir rock to only numerical determinations from 3D digital images of tiny rock chips. (b) An example of a tomography reconstruction of a chalk sample (Data Set: 2139_P3_5.1.3C_top_01, slice: 726).