



2D porosity mapping and distribution in an organic rich shale from the Middle East: preliminary results using a broad ion beam - scanning electron microscopy (BIB-SEM) approach

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Conventional methods of determining porosity and permeability in shales have their difficulties to accurately measure these when it comes to very tight rocks. In comparison, the complementary approach of porosity imaging and mapping in shales was enabled and has seen major advances recently in providing smooth, damage free surfaces in reasonable timeframes using ion beam cutting techniques. As mapped areas are very small compared to macrostructural heterogeneities in the investigated rocks, the broad ion beam cutting and polishing technique has been seen as a valuable opportunity to use microstructural characterization techniques in determining bulk rock properties in homogeneous sections and to mitigate the upscaling problem of this approach to a certain extent. We present here first results of a combined semi-automated effort to map and characterize porosity in terms of its distribution related to mineralogy and orientation using a broad ion beam cutting technique in combination with a conventional high resolution SEM. Using a BIB cross-section polisher, the extent of the polished surfaces was enlarged by a factor of thousand compared to focused ion beam techniques and covers an area of approximately 1 mm². Image resolution of the conventional SEM used in this study allows investigation of pores down to the nanometer scale.

From the large BIB polished surface area, porosity was traced in certain representative intervals in using advanced image analysis techniques. Pores detected are segmented from mosaics of secondary electron (SE) images to be statistically interpreted. Identification and mapping of mineral phases were performed using grey values from backscattered electron (BSE) images verified and calibrated by a combination of EDX and bulk XRD analyses.

Two adjacent organic rich core samples from a shale interval in the Middle East were investigated. Based on more than 13000 detected pores, porosity could be classified into two major pore?size classes. Relative large pores ($> 0.5\mu\text{m}^2$) typically found in the organic matter?rich intervals. Their distribution contributes strongly to the overall porosity content of the shale. However the far majority of the pores found have equivalent radius less than 400nm and with areas below $0.5\mu\text{m}^2$. Including these latter pore class, the inferred porosity from both samples gives similar results in the order of $< 1\%$. Most of the pores from the latter pore class are found either as intergranular pores within the matrix, or as intragranular pores in pyrite and Fe(Mg)-rich phases with a mean equivalent radius in the range of 40 to 400nm. Pores in the matrix and Fe(Mg)-rich phases are aligned sub-parallel to the bedding whereas pores in other minor phases are randomly orientated. Most pores in the organic matter have an elongated shape with its longest axes parallel to the bedding.

Detailed information of the morphology of pores and its distribution in shales is a key point in understanding porosity evolution during burial, to later infer permeability through pore modeling scenarios and to investigate sealing capacity, coupled flow, capillary processes and the geomechanical properties of the rock. First results give hints for the method to be a major step in shale characterization down to nanoscale features which become important distinguishing criteria in shale petrography.