RELATION BETWEEN 3D SPATIAL DISTRIBUTIONS OF PYRITE AND PORE SPACE IN POLISH SHALE GAS DEPOSITS

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Summary: micro-CT technique was used in order to investigate 3D spatial distributions of pores and pyrite crystals in Silurian shale deposits located in Poland. An interesting spatial directionality relation is found in samples taken from Lublin Synclinorium: pyrite tend to gather close to pores and, in addition, both of them, pyrite crystals and pores, are distributed in 3D space along strictly defined planes. This effect is not observed in samples from Peribaltic Syneclise.

1. INTRODUCTION

A thorough understanding of physical and chemical properties of shale gas deposits is closely related with the effective exploration hydrocarbons accumulated in the Silurian and Ordovician formations [1, 2] thus, from the viewpoint of industrial applications, a proper analysis and estimation of parameters characterising shale deposits is especially important, as it may explain, why hydraulic fracturing is not proceeded in a controlled manner. There are two significant factors to be considered in this context: pyrite spatial distribution and heterogeneity of pore space. Pyrite, as a heavy mineral, may greatly affect mechanical properties of the rock, causing uncontrolled hydraulic fracturing for instance. Spatial distribution of pores as well as shape of pore channels are reflected in reservoir potential, and also both affect the mechanical properties. Hence, 3D measurements are required to shed more light on internal structure of shale deposits with a particular attention paid to volumetric representation of pyrite crystals and pore space.

Nowadays, this kind of study brings much attention in Poland where unconventional oil and gas deposits spread along the belt from the north-west to the south-east side of this country [3]. Therefore, the main aim of this work is to analyse, visualise and compare 3D distributions of pyrite and pores extracted from Silurian shale gas deposits located in Poland. Following samples are investigated in order to achieve this goal: samples 5, 6 and 22 were cored from the well (2499.9 m depth) located on the Lublin Synclinorium (south-east Poland), while sample 872 represents the shale from the well (3546 m depth) situated in the Peribaltic Syneclise (north-west Poland).

2. EXPERIMENTAL METHOD

Well known X-ray computed tomography (micro-CT) [4-6] is the main technique employed in this study in order to characterize Silurian shale gas deposits. Micro-CT measurements were performed in Laboratory of Micro and Nano Tomography at Faculty of Physics and Applied Computer Science, AGH University of Science and Technology in Poland. The equipment used consists of GE Nanotom S 180n device, in which cone beam is generated by X-ray tube (57 W power and 180 kV working voltage) and recorded by the Hamamatsu 2300×2300 pixel 2D detector (Ham C 7942CA-02). The reconstruction of the measured 2D data was done using the Feldkamp algorithm. The resulted datasets consists of 2300x2300x2100 voxels – each corresponding to 800x800x800 nm^3. All the data were subjected to a filtering process. Pyrite was segmented after application of 3D median filter and simple threshold for brightest voxels. Pores, in turn, were extracted using Fourier based filtering and triangle thresholding method (see abstract entitled *A new method of pore space segmentation in highly noised micro-CT 3D data applied for Polish shale gas deposits* for more details). In addition, the analysed samples were investigated by x-ray diffraction analysis (XRD) to assess mineral composition, especially pyrite volume fraction.

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3. RESULTS

Pyrite content derived from CT and XRD calculations are consistent, for instance the obtained value in sample 22 is 2.1% (CT) and 2.0% (XRD), whereas in sample 872 the obtained values are 0.3% and less than 1%. Regarding the latter, pore space volume fraction is also negligibly small in sample 872. Therefore, further CT analysis deals only with samples taken from Lublin Synclinorium. All considered cases: 5, 6, 22 share similar observations thus sample 6 is chosen to present interesting correlation between 3D spatial distribution of pyrite and pore space. Clearly, pores form in 3D consolidated volume consisting of planes or elongated pore channels, instead of being homogenously distributed in terms of spatial location. Pyrite, in turn, is located close to the pores. Hence, it is also gathered along particular planes and directions (Fig. 1). As a result, two parallel planes can be seen on Fig. 1(b) and Fig. 1(c) – a navy blue and yellow-green one, whereas Fig. 1(a) presents almost vertical line of pyrite and pore particles. As stated above, this effect is also observed in sample 5 and 22, however spatial distribution contains more parallel planes in these cases. It can be concluded that the analysis performed provides important information about different geological processes of shale formation taking place in Lublin Synclinorium and Peribaltic Syneclise. The revealed relation between spatial location of pyrite crystals and pores can be crucial for hydraulic fracturing industrial processes. It is also related with better reservoir and geomechanical properties.

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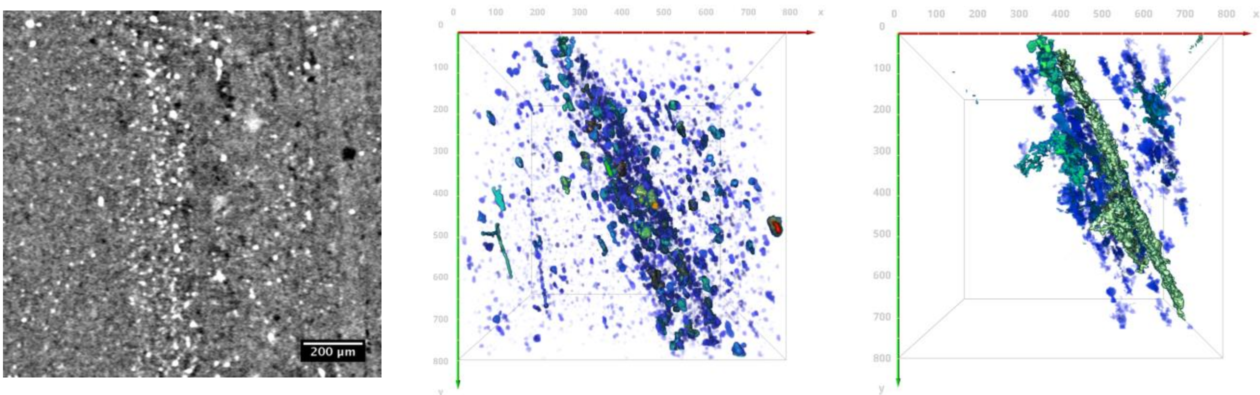

(a) (b) (c)

Figure 1: Micro-CT results obtained for the shale sample 6; (a) 2D slice of 3D data: bright particles – pyrite, dark – pores; (b) 3D vizualization of pyrite with color scale corresponding to volume values: transparent darkblue – more than 8 μm^3, red – more than 100000 μm^3; (c) 3D visualization of pore space volume: transparent darkblue – more than 8 μm^3, yellow – more than 800000 μm^3.