Geology, Geophysics & Environment 2015, vol. 41 (1): 127–128

Identification of tectonic microstructures in flysch sandstones of the Outer Carpathians using X-ray nanotomography and nuclear magnetic resonance – first results

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Deformation bands and microfractures occurring in sandstones affect the petrophysical properties of the rock and determine fluid flow. Deformation bands are quasi-tabular structures, up to 5 mm thick that accommodate offsets on the order of a few centimeters (Fossen 2010). Such bands show different petrophysical properties in relation to the surrounding rocks and may function as either a path or a barrier to the migrating fluids (Antonellini et al. 1994, Fossen 2010). High porosity rocks show commonly low permeability due to the presence of deformation bands. Recognition of such relationships is important in petroleum geology, particularly for proper reservoir characterization (e.g. Fossen et al. 2007, Ballas et al. 2012, 2013).

The aim of the study is to identify and to characterize deformation bands occurring in flysch sandstones of the Outer Carpathians using X-ray nanotomography and nuclear magnetic resonance (NMR). Moreover, the impact of sample size on obtained results was also studied.

For this study, samples of medium-grained arenites showing catalclastic deformation bands have been collected from the lower Krosno Beds of the Silesian Nappe. Permeability of the studied samples measured along deformation bands and in perpendicular direction varies significantly, being 0.13 mD and <0.001 mD, respectively.

Analyses were conducted using X-ray nanotomography Nanotom S General Electric. The recorded data were processed and analyzed using ImageJ and myVGL software. The NMR measurements were carried out on water-saturated samples using the 2MHz Magritek Rock Core Analyzer and 24MHz Tomography System. The pore size distribution (PSD) of the rock sample was determined precisely by T2CMPG experiments. The spatial estimation of the deformation bands achieved from T2 spatially resolved measurements. Complementary data regarding to band geometry was registered using three-dimensional Single Point Imaging (SPI) (comp. Zhang & Blümich 2014). Cylindrical plugs 38 mm high and 25 mm in diameter were analysed. The same plugs were used for permeability measurements.

The X-ray nanotomography measurements were carried out in three resolutions. The first measurement was carried out with a resolution of 4.2 microns, but the resultant images were difficult to interpret. Therefore, successive analyses were performed with a resolution of 20 microns covering the entire volume of the samples. After locating microstructures samples were X-rayed again with a resolution of 2.1 microns.

In sections obtained at a resolution of 4.2 microns, fine structure attributable to deformation band reveals parallel grain orientation and higher

http://dx.doi.org/10.7494/geol.2015.41.1.127 ISSN 2299-8004 | e-ISSN 2353-0790 | Wydawnictwa AGH

density compared with the host sandstone. We observed a slight offset along deformation bands.

Three-dimensional image of the sample obtained at a resolution of 20 microns determined the geometry of tectonic microstructures. In one of samples, two structures were recognized. One of them was oriented parallel to the axis of the core, the other was inclined at an angle of about 60 degrees. The thickness of deformation band visible in the cylindrical plug was much larger (2 mm) than the thickness of the surface obtained by visualization. This was due to the presence of microfractures, which formed along the deformation band.

Measurement with a resolution of 2.1 microns took an upper base of the cylindrical plug. Two thin fractures and one relatively thick fracture (approx. 0.2 mm) were distinguished. This indicates that the deformation band visible on the surface of the core passes into the microfracture within the sample. It was also confirmed by the visualization with a resolution of 20 microns.

Determination of porosity and permeability of the sandstone using the X-ray nanotomograph was impossible due to small pore size that the device is not able to register. However, visualization made with a resolution of 20 microns allowed to clarify the reasons for the different measurements of permeability. Increase of the permeability in the direction parallel to the axis of the core is caused by the presence of open microfractures. The NMR results confirmed possibility to visualize geometry of the bands and their influence for the spatial distribution of porosity.

The results show that too large sample sizes make impossible to perform the analysis with high resolution. According to Rodrigues et al. (2015) sample dimensions of 15 × 10 × 10 mm are sufficient to determine the porosity of deformation bands.

Published results on three-dimensional microtomography of deformation bands concern aeolian sandstones showing high mineralogical and textural maturity (Rodrigues et al. 2015). In contrast, studied flysch sandstones show large diversity of their mineral composition. Therefore, visualization of microtectonic deformation hosted in these sandstones is more difficult to interpret.

The studies were funded by NCBiR project No. PBS2/A2/16/2013.

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