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Image-based porosity estimation in Cambrian sandstones from the Vilkyčiai-22 well

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This study focused on the evaluation and comparison of three image-based techniques for pore-space segmentation in Cambrian sandstones from the Baltic Basin: ImageJ thresholding, QuPath thresholding, and a U-Net convolutional neural network. Core samples from a borehole in Western Lithuania were obtained from the Lithuanian Geological Survey storage facility. Conventional epoxy-impregnated thin sections were scanned using a petrographic microscope equipped with a digital camera to acquire high-resolution images.

In QuPath, images were pre-processed and segmented using fixed-threshold pixel classification, followed by visual inspection and manual adjustment to produce validated masks used for U-Net training. ImageJ analysis involved a median filter, conversion to grayscale, automatic thresholding, and binary mask generation. Porosity estimates derived from each method were compared with laboratory-measured core-plug porosity.

The mean absolute error (MAE) relative to laboratory porosity was 3.88% for QuPath, 3.91% for U-Net, and 4.25% for ImageJ. Threshold-based methods performed well in samples with uniform pore–mineral contrast but tended to underestimate pore space where contrast was heterogeneous or pore geometries were complex. The U-Net model more consistently detected smaller and disconnected pores, however, its overall MAE was similar to that of QuPath, reflecting its reliance on threshold-derived training masks.

The results demonstrate that manually validated threshold-based segmentations can serve as effective training data for deep-learning models, enabling reproducible pore-scale characterization of Cambrian sandstones where fully annotated datasets are limited.