Porosity – depth trends for Vienna Basin mudstones: Validation of broad ion beam – scanning electron microscopy as a seal prediction tool

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In order to implement new forms of energy, to transform energy systems accordingly and to create a long-term contribution to the energy transition, alternatives to fossil fuels such as hydrogen are necessary. To enable the safe long-term underground storage of such new energy carriers but also the potential sequestration of CO_2 quickly on a large scale, geological structures such as depleted hydrocarbon reservoirs or deep aquifers may be a feasible solution. However, the use of such "geological containers" for secondary storage demands an evaluation of the regional seal rock quality. In this study, 14 Miocene (Badenian, Sarmatian, Pannonian) seal rock samples of the Vienna Basin from 9 different wells, covering a depth range of 721.5–3,217.5 m, were investigated with respect to porosity depth trends and resulting estimated seal capacity. The main target was to validate broad ion beam – scanning electron microscopy (BIB-SEM) as a tool to derive reliable pore structural data for seal quality prediction. For this, image-segmented porosity and pore size distributions were collected from multiple 2D high-resolution BIB-SEM maps with representative imaging areas of ~40,000 µm² for each individual sample. These pore characteristics were then correlated with porosity data and calculated theoretical maximum hydrocarbon column heights derived from mercury intrusion porosimetry (MICP) and He-pycnometry. Furthermore, the image-based porosity characteristics were compared with bulk mineralogical compositions from X-ray diffraction. The BIB-SEM data reveal porosity values ranging from 1.7–14.7 vol.-% for the investigated samples. Despite considerably lower absolute porosity values (BIB-SEM is limited to pore sizes > 30 nm), the image-based porosity values show a close correlation with the corresponding MICP (R^2 = 0.87) and He (R^2 = 0.87) porosity values, as well as clear decreasing depth trend (R^2 = 0.91). The total BIB-SEM porosity shows a power-law correlation with the calculated maximum hydrocarbon column heights (R2 = 0.82); furthermore, the mean pore diameter derived from BIB-SEM pore distributions shows a weak trend with the corresponding displacement pore throat diameter derived from MICP capillary pressure curves (R^2 = 0.42). The porosity values as well as the pore geometries seem to be unaffected by the quartz and total clay mineral content of the samples, however a compaction influence on pore shapes indicated by a depth trend of increasing pore aspect ratios (as well as a weak decreasing trend of average pore circularity) can be observed. In summary, the imaging results confirm that BIB-SEM can be used as a complementary porosimetry technique for seal quality estimation. Furthermore, the results show that mudstone porosity and resulting estimated seal capacity follow a porosity depth trend matching previous normal compaction trend models. The generated pore structural data set may serve as an additional calibration tool for future seal quality models in the Vienna Basin.