Multi-resolution CT for the quantification of reservoir properties in complex carbonate rocks

Claes S.[1], De Boever W.[2], Bultreys T.[3], Brabant L.[3], Van Hoorbeke L.[3], Cnudde V.[2], Swennen R.[1]

[1]Geology, Earth and Environmental Sciences, KULeuven, Celestijnenlaan 200E 3001 Heverlee, Belgium

[2]Department of Geology and Soil Science, Ghent University, Krijgslaan 281/S8, B-9000 Ghent, Belgium

[3]Department of Physics and Astronomy, Ghent University, Proeftuinstraat 86, B-9000 Ghent, Belgium

Complex carbonates cause heterogeneity at many scales, which have an influence on reservoir properties (e.g. porosity). Recent developments in CT and image analysis research allow characterization of complex pore networks in three dimensions from sub-micron to centimetre scale.

Travertine rocks are selected in this study because of their large variety in pore types concerning their size and spatial distribution. Excavated blocks (dimensions: 2 by 3 by 2m) of different travertine lithologies are documented using high-resolution photographs of the front, side and top faces. Photographs of smaller areas are used in order to estimate the REA in function of porosity types. Based on these photographs porosity is estimated by point-counting. Out of these blocks large cores are drilled in three perpendicular directions (dimensions: 10cmØ and 15cm height). In these cores, small plugs (dimensions: 2cmØ and 4cm height) are drilled. In a last step micro-plugs (dimensions: 0.7cmØ and 1.5cm height) are drilled out. For each sample size different scanners are used, providing optimal resolutions (sample size/1000). This workflow allows quantifying porosity values of the same sample using datasets with different resolutions. Special attention is paid to the segmentation of porosity in the resulting images. The indicator kriging segmentation algorithm is used, for which automatic parameter selection methods are explored. Using 3D image analysis programs such as Morpho+ allows establishing a new 3D classification of pore shapes based on form ratio's I/L and S/I (Brabant et al, 2011). 5 shape classes are defined: rod, blade, cuboid, plate and cubic shapes. This approach allows separating different types of pore shapes as well as assessing the anisotropy of the porosity in the sample by using the orientation of the longest dimension. However computational limitations do not allow incorporating heterogeneities on small scales in full-field reservoir simulations. Hence a critical decision has to be made at which scale petrophysical measurements should be taken in order for them to be homogeneous and statistically stationary. The concept of the Representative Elementary Volume (REV), i.e. the smallest value that can be taken as a representation for the entire sample area/volume that does not respond to small changes in volume or location, was introduced by Bear in 1972. To define the fluctuation of the porosity parameter the chi-square criterion is used. This parameter measures how much a single tested sample deviates from the mean value of all realizations. The upscaling workflow demonstrates the importance of the resolution of the 3D datasets on the calculated porosity value. Porosity networks in large core samples and plug samples are clearly different. This study also illustrates that the size of the REV is dependent of the lithology of the analyzed rocks. Only by calculating the REV at different scales and resolutions, reservoir properties in complex carbonate rocks can be evaluated correctly.

References :

Bear, J. 1972. Dynamics of fluids in porous media. American Elsevier, New York.
Brabant, L., Vlassenbroeck, J., De Witte, Y., Cnudde, V., Boone, M., Dewanckele, J., Van Hoorebeke, H., 2011. Three-dimensional analysis of high-resolution X-ray computed tomography data with Morpho+*.* Microscopy and Microanalysis,17(2):252-263.