AAPG Datapages/Search and Discovery Article #90310 ©2017 AAPG/SEG International Conference and Exhibition, London, England, October 15-18, 2017

Pore Type Characterization and Extraction of Effective Porosity With Digital Image Analysis: A Case Study From Miocene Lacustrine Carbonates (Southern Germany)

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ABSTRACT

Digital Image Analysis (DIA) provides a tool for quantitative pore system analysis which gained increasing attention over the past decade. In addition to routine porosity (Φ) and permeability (K) measurements, the application of DIA results in quantitative data of pore geometry, which is the main factor controlling petrophysical properties in a sedimentary rock. In this study, we provide a step by step workflow of a new approach based on DIA, performed on 76 samples of marginal lacustrine carbonates from the northern lake margin of the Miocene Nördlinger Ries crater lake in South Germany. The DIA-derived data are utilized to characterize each occurring pore type and to detect the most effective pore types which form an interconnected pore network and therefore determine permeability. The method comprises four main steps, each providing multi-scale information to characterize each individual pore, each pore type and the entire pore system. Step I: Quantification of pore system with DIA which transfers blue-dyed thin-section images into quantitative pore geometry data plus classification of pore types. Therefore, several pore geometry parameters are calculated and their weight on total porosity (Φtotal) and permeability (Ktotal) is quantified by using artificial neural networks (ANN). Step II: Visualizing pore system in a pore width versus pore shape factor g (sensu Anselmetti et al., 1998) plot, representing directly size, shape, abundance and efficiency of each occurring pore type, and indirectly porosity and permeability. Step III: Estimate effective porosity and thus permeability, and detect the most effective pore type(s) by calculating the potential contribution (Kcontr.) of each pore type to Ktotal. Step IV: Establishing a petrophysical facies for each pore type and reconstruct the pore system evolution. As a result, the extraction of the interconnected (or effective) pore network, which is required to perform further fluid flow modeling and permeability simulations, leads to an improved correlation between porosity and permeability which eases the often difficult prediction of both petrophysical parameters in carbonates. Consequently, the workflow helps to increase the resolution of a petrophysical reservoir characterization study and the resulting quantitative data are suitable for integration into further reservoir modeling processes.