PETROPHYSICAL ROCK TYPING AND PERMEABILITY PREDICTION IN TIGHT SANDSTONE RESERVOIR

Anita LIS-ŚLEDZIONA[1]

[1]*Oil and Gas Institute - National Research Institute, ul. Lubicz 25 A, 31-503 Krakow, Poland; lis@inig.pl*

Introduction

Reservoir rock typing drives the quality of the distribution of petrophysical parameters in three (3D) Earth models and is crucial to the reservoir characterization: it provides better understanding of fluid flow, rock storage capacity and pore size distribution. Poorly recognized reservoirs properties can have a significant impact in the reservoir performance predictions. Guo (2005) in his article describes how Rock Typing can be an effective tool for water saturation and permeability modeling. Many relationships between core and well log data might be noticed once the reservoir is grouped according to their rock types (porosity-permeability, wettability-irreducible water saturation). Rock types classification can be based on many different criteria. In this paper, the reservoir was subdivided into several units based on the following criteria; in the first model, porosity, permeability and well log data, were used as an input in the Heterogeneous Rock Analysis (HRA) clustering workflow to define rock classes; in the second model, rock types were defined using flow zone index (FZI), (Amaefule et al., 1993). The third flow unit discriminator was proposed by the author, the proposed model is based on relation between pore structure index, irreducible water saturation and pore sizes. Also, Willie-Rose equation for permeability in analyzed tight reservoir was calibrated and coefficients e, d, and Kw were established.

Samples and methods

The study was carried out within the sandstone formation where due to diagenetic processes original porosity and permeability were reduced (Sikorska & Jaworowski, 2007). The reservoir is built of thin layers of sandstones and mudstones with variable porosity, permeability, pore sizes and irreducible water distribution. Those four parameters are crucial during identification of hydraulic properties of reservoirs. The research was performed in two wells where well log data, the laboratory results of Mercury Injection Porosimetry (MIP), permeability measurements and Nuclear Magnetic Resonance (NMR) data were used as input. The reservoir parameters were determined; permeability was calculated using correlation between porosity (PHI) and permeability (K) and based on modified Wyllie-Rose equation; $K = Kw\,(PHI^{d}/SWI^{e})$. The coefficients e, d, and Kw were changed to calibrate with measured permeability data. The level of the irreducible water saturation (SWI) was established based on Hong's (2017) method. The goal of this study is to identify similar hydraulic units of tight sandstone reservoir based on different methods and compare the results. The first method is based on clustering technique Heterogeneous Rock Analysis - HRA clustering workflow, the module first runs Principal Components Analysis (PCA) to transform the input data onto independent axes that front-load the variance. Well log data were used along with core calibrated porosity and permeability as an input. The second rock types classification is based on calculated Flow Zone Index (FZI) Amaefule et al., (1993): FZI = RQI/PMR. Where reservoir quality index: $RQI=0.0314\sqrt{(K/PHI)}$ and Pore to Matrix Ratio $PMR = PHI/(1 - PHI)$, K is permeability in mD and PHI is porosity in fraction. Finally, the reservoir was subdivided using author's proposed indicator which describes the relation between: porosity, permeability, irreducible water saturation and pore sizes (μm) – the most important reservoir parameters having impact on the process of fluids migration within the reservoir rock. Each of the flow units was described in order to assess its filtration and accumulation properties. The correlation between measured porosity and permeability data indicated that reservoir has dual porosity system. Drilling-induced tensile fractures were identified on Extended Range Micro – Imager (XRMI) images. The interpreted fractures provided additional migration paths for reservoir fluids.

Results

As the results the reservoir was subdivided into four classes of different filtration and accumulation capacities, using three methods. The correlation between flow units and laboratory measurement of porosity and permeability was completed for validation and assessment of the most appropriate method in the tight gas reservoirs. Also, the relationship between fracture occurrence and types of flow units was described.

Conclusions

Using flow unit approach, the reservoir was subdivided into several layers in order to better understand properties of sandstones formation. The integration of well log data and core analysis was performed in order to identify units of different properties. It allowed for a better comprehension of the reservoir performance by identifying the layers that have the most important contribution in the fluids flow in the reservoir.

References

Amaefule J.O., Altunbay M., Tiab D., Kersey D.G., Keelan D., 1993. Enhanced Reservoir Description: Using Core and Log Data to Identify Hydraulic (Flow) Units and Predict Permeability in Uncored Intervals/Wells. Paper SPE 26436 presented at the 1993 SPE Annual Technical Conference and Exhibition in Houston.

Guo G., Diaz M.A., Paz F., Smalley J., Waninger E.A., 2005. Rock Typing as an Effective Tool for Permeability and Water-Saturation Modeling: A Case Study in a Clastic Reservoir in the Oriente Basin. SPE Annual Technical Conference and Exhibition held in Dallas, Texas, U.S.A.

Hong L., Fuqiang L., Liang C., Chao L., Jie L., Heping Y., 2017. Research on evaluation method for water saturation of tight sandstone in Suxi region. IOP Conference Series Earth and Environmental Science, 64 (1): 012040.

Sikorska M., Jaworowski K., 2007. Origin of porosity in Cambrian sandstones from the Polish sector of the Baltic Sea. Biuletyn Państwowego Instytutu Geologicznego, 427, 79–110. (In Polish with English abstract).