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Petrophysical Analysis of the Tight Modryn Formation in the Lublin Basin Poland

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SUMMARY

Modryn formation in the Lublin Basin in the SE Poland is an example of tight, low porosity and low permeability rock. It was preliminary analysed from the point of being hydrocarbon bearing formation. Standard laboratory measurements together with nuclear magnetic resonance (NMR) and mercury porosimetry (MP) results gave a new insight into the petrophysical parameters of this carbonate lithostratigraphic unit. There were made relationships between standard petrophysical parameters in order to create a detailed petrophysical characteristics. Attention was focused on cementation factor calculation using Borai and Shell formula, which were estimated for low porosity carbonates. Description of flow factors was made to get information about the number of flow units within Modryn formation and to obtain the better relationship between porosity and permeability values. Analysis of the similarity of pore diameter distribution from MP and T2 distribution from NMR provided the relationship between these two different parameters.

Introduction

Nowadays, the subject of the reservoirs potential analysis are tight, low permeability, low porosity formations (Czekanski *et al.*, 2012). In the paper preliminary petrophysical analysis is presented of the Upper Devonian lithostratigraphic unit, Modryn formation (Marcinowski, 2004). In this formation gas shows were detected. When tight reservoirs were not regarded as economically potential hydrocarbons reservoirs, Modryn formation has not been even considered. Now, there is time to take into account formations, which are not conventional but may be potential in hydrocarbons production. The procedures of tight rocks analysis are still developed. The standard laboratory measurements, together with mercury porosimetry and nuclear magnetic resonance results, gave a new insight into the petrophysical parameters of this lithostratigraphic unit.

Material and Method

Modryn formation is dated from Upper Devonian, Frasnian and in general consists of limestones with Anthozoa and Brachiopods and dolomites. Region of Modryn formation is located on the south-east part of Poland, Lublin Basin (Marcinowski, 2004). Within Modryn formation 3 members may appear: Lipowiec, Werbkowice and Zubowice. Standard laboratory measurements were carried out (density, P- and S- wave velocities, Th, U, K content, total and effective porosity, permeability etc.). Mercury porosimetry (*MP*) and nuclear magnetic resonance (*NMR*) results were also considered. Modryn formation characterizes with very low total porosity (about 0.6-1%) and low effective porosity (about 0.5%). Average permeability does not exceed 0.02 mD.

Results

First step in Modryn formation analysis was to find relationships between different petrophysical parameters within the formation. For example, from the thorium/potassium ratio the type of clay was determined. Illites and monmorillonites were recognized as representative clay minerals (Rider, 2002). Having P- and S-wave velocities the dynamic elastic moduli were calculated. Cementation factor (*m*) was calculated using Borai and Shell equations (Borai, 1987). Borai and Shell formula were estimated for carbonate rocks with low porosity. In Shell formula, *m* increases with decrease of porosity in comparison to Borai formula. Figure 1 reflects the *m* behaviour for Modryn formation. Cementation factor calculated from Borai formula reveals stability (*m* close to 2) in comparison to *m* Shell, where division into two groups is visible (below and above 8, Figure 1). Also, permeability (*K_C*) was estimated using Coates & Denoo (1981) model, what gives more precise information about permeability values (higher resolution). The permeability *K_C* average value is equal to about 1.254E-07 mD (ranging from 0.0005E-7 to 5.64E-07 mD). Next stage in analysis was based on flow unit characterization factors for Modryn formation. Reservoir quality index (*RQI*), flow zone indicator (*FZI*) and pore volume to grain volume ratio (*K_p z*) were calculated (Amaefule, 1993). *FZI* analysis revealed two flow units within Modryn formation (threshold about 0.004 μ m). Figure 2 shows relationship between effective porosity and permeability *K_C* using the *FZI* approach. *MP* and *NMR* results were also analysed in the point of their similarity in curves shapes (Figure 3, 4). The most characteristic points on the both distributions were determined (Jarzyna *et al.*, 2007). On the basis of the curves similarity the relationship between the pore diameter (*D*) and *T₂* distribution was discovered (eq. 1):

$$\log T_2 = 0.76 * \log D + 4.21 \quad (1)$$

where: *T₂* [μ s] – *T₂* time distribution from *NMR*, *D* [μ m] – pore diameter from *MP*.

The equation (1) can be used to estimate the *D* or *T₂* parameter, in situation when one of the measurements have not been carried out. Relatively high determination coefficient (*R*²=0.8) confirmed the reliability of the equation.

Conclusions

Modryn formation is an example of tight, low porosity and low permeability reservoir, which shows flow properties. Besides the complexity of petrophysical parameters within the formation it reveals

reservoir potential. Gas shows were the factors leading to the detailed formation analysis. Old samples and limited amount of rock material were the barriers in obtaining satisfactory results. More sophisticated methods of investigations and more precise analysis of tight formation can provide optimistic results. Use of *FZI* approach led the precise relationship between porosity and permeability. Similarity in pore diameter and T_2 distributions provided equation allowing to estimate parameters in full range of diameters and T_2 times.

Figure 1 Cementation factor (m) from lab vs. calculated cementation factor (m Shell, m Borai)

Figure 2 Effective porosity (K_{pnmr} , ef) vs. permeability (K_C)

Figure 3 Pore diameter distribution from MP. Colours: red – Zubowice, blue – Werbkowice, black – Lipowiec member

Figure 4 T_2 time distribution from NMR. Colours as in Figure 3

Figure 5 Relationship between the logarithm of pore diameter and T_2 time distribution

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