THE CARBONATE MINERALS IN SARMATIAN-BADENIAN SANDSTONES FROM CENTRAL PART OF THE CARPATIAN FOREDEEP (POLAND)

Katarzyna CHRUSZCZ-LIPSKA[1], Marek L. SOLECKI[1], Bartosz TRZEWIK[2], Michał MARUTA[1], Joanna WARTAK[1], Danuta ZAGRAJCZUK[1]

[1] *AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, al. Mickiewicza 30, 30-059 Kraków, Poland; lipska@agh.edu.pl*
[2] *Jagiellonian University, Faculty of Chemistry, ul. Gronostajowa 2, 30-387 Krakow, Poland*

Introduction

According to Szuflicki *et al.* (Szuflicki, 2017) in the area of the Carpathian Foredeep 103 natural gas reservoirs exist, of which 76 are exploited. Lot of them have been drilled in Miocene sandstones. Although there are new reservoirs with a low depletion rate, in most cases these reservoirs are largely depleted. For many of these reservoirs, the use of intensification methods is necessary to prolong the operation at an economically viable level.

Acid treatment is one of the oldest methods of the production intensification used for over 100 years (Walker *et al.*, 1991). Nowadays, there are still some restrictions and requirements associated with this method, particular in case of sandstones with carbonate cements. The McLeod's guidelines for sandstone acidizing was published in 1984. It was the first work showing an influence of acid treatment consequences on the rock reservoir mineralogy (McLeod, 1984). From that time, many of research reports describe results of acidizing in mineral compositions of sandstone reservoirs. The more significant factors are: the mineral composition as a percentage of quartz, feldspar, clay, chlorite and silt in the rock (Chiu *et al.*, 1993; McLeod and Norman, 2000). The important issue is content of carbonates in the rock. Generally, for sandstones with high carbonate mineral content (15-20% or more) acidizing treatment of near wellbore zone may be done by using of hydrochloric acid only (McLeod, 1984; Kalfayan, 2008).

Samples and methods

26 samples of Miocene (Sarmatian-Badenian) sandstones, as reservoir rocks from central part of the Carpathian Foredeep in Poland were taken from the collection of drilling cores belonging to the Department of Petroleum Engineering, Faculty of Drilling, Oil and Gas, AGH University of Science and Technology in Kraków. The sandstone samples represent drilling cores from 2 wells, taking in range 1600-2000 m of depth. The carbonates mineral content in the tested samples were determined by the volumetric method (Scheibler's method), petrographic study and wire log data analysis.

Results

The distribution of the carbonates content in the Sarmatian-Badenian sandstones from central part of the Carpatian Foredeep was determined by four different methods and obtained results were presented in Table 1.

Table 1. *Carbonates content in tested sandstone samples. Basic statistical data.*

Method	Number of samples	Average [%]	Median [%]	Minimum value [%]	Maximum value [%]	Standard deviation
Volumetric	26	15.68	15.96	9.48	19.95	3.13
Well log	26	15.62	15.20	14.26	17.72	1.01
Spectroscopic	16	14.34	12.73	8.93	23.00	3.98
Petrographic	9	20.68	20.60	14.24	28.94	5.57

A new method of ATR FT-IR spectroscopy for determination of carbonates content in sandstone samples was elaborated by us. In our work, a mixture of powdered calcite and quartz was prepared for

quantitative analysis of carbonates in the right proportion (calcite content: 5, 7, 10, 12, 15, 17, 20, 22, 25%). The infrared spectra of those mixtures were used to construct the calibration curve. The band at 870 cm^{-1} coming from out-of-plane bending vibration of CO_3^{2-} group (v_2) was successfully used for determination of carbonates in sandstone samples. The choice of that peak for quantitative analysis is good because both the quartz and the feldspar minerals (albite and orthoclase) do not show infrared absorption in this spectral range. The results of the determination carbonate minerals in sandstone samples according to the methodology based on ATR FTIR spectroscopy proposed in our work are in good agreement with data obtained by Sheibler's method ($R=0.87$, $R^2=0.77$, standard deviation 2.22).

Conclusions

The averaged content of carbonates in tested Sarmatian-Badenian sandstone samples is high. Depending on the method used it equals 15.68, 15.62, 14.34 and 20.68 % for volumetric, well log, spectroscopic and petrographic methods, respectively.

Petrographic analysis of Miocene sandstones shows that the framework of sandstone is made up of small to medium (0.05-0.50 mm) grained quartz mono- and polycrystalline particles. Commonly they are loosely packed, well sorted formations with some thin low-porosity zones. Some of quartz particles appear darker. Cementation can be described as inconsistently contact-clod type. The sandstones are cemented by a combination of quartz overgrowth in a form of grain shell and precipitated cements of carbonate minerals and clays.

A new simple and fast method of ATR FT-IR spectroscopy for determination of carbonates content in sandstone samples was presented. It is based on integration of band coming from out-of-plane bending vibration of CO_3^{2-} group (v_2) at 870 cm^{-1} in the range of 890 to 850 cm^{-1}.

Obtained data for tested sandstone samples show high content of carbonates. In such condition stimulation with acid can be similar as in case of carbonate reservoirs using hydrochloric acid only. Application of HF is controversial due to precipitation of calcium and magnesium fluoride, which may reduce rock porosity.

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