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CORRELATION ANALYSIS OF PETROPHYSICAL PARAMETERS WITHIN THE MAIN DOLOMITE SEDIMENTATION ZONES ON THE GROTÓW PENINSULA

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Abstract: The study area in geological sense is located on the Grotów peninsula within Gorzów Block in north-western part of Poland, on the border of Fore-Sudetic monocline and Szczecińska Through. In that area two generalized sedimentary zones were recognized: carbonate platform (barrier and platform plain) and slope of the carbonate platform (edge of the slope with bay plain). The aim of this study is the analysis of the relationships between petrophysical parameters of the carbonate reservoir rocks. This research was conducted on the base of mercury porosimetry for 318 rock samples. The analysis showed that not all pore space is available for the accumulation of hydrocarbons. Availability of pore space for accumulation strongly depends on the average capillary, and the amount of pores with diameter higher than 1 μm. In general, slope of the carbonate platform has better conditions for accumulation of hydrocarbons.

Keywords: correlation, Main Dolomite, petrophysical parameters

INTRODUCTION

Relationship between petrophysical parameters of the carbonate reservoir rocks is not always clear. Mutual dependences of these parameters are far more complicated than in case of terrigenous reservoir rocks. In general sedimentary rocks lose their porosity with compaction and lithification of the sediments. It is very often that pore

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space of the carbonate rocks is affected by dissolution and recrystallization. Diagenesis influences both porosity and permeability (Semyrka et al., 2014). In order to get better understanding of the reservoir properties of carbonates it is very important to examine the correlation between petrophysical parameters of this kind of rocks.

GEOLOGY

The study area in the geological sense is located on the Grotów peninsula within the Gorzów Block in north-western part of Poland, on the border of Fore-Sudetic monocline and Szczecińska Through (Fig. 1).

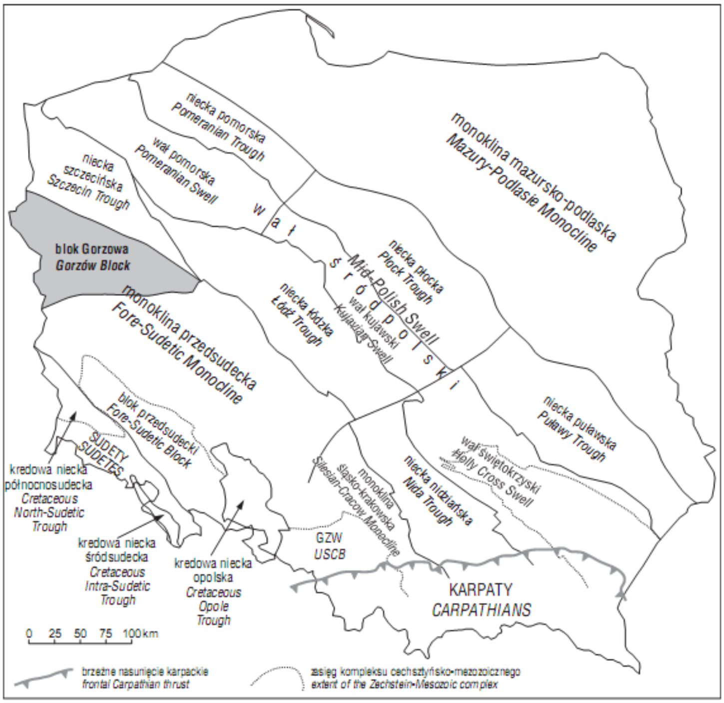

Fig. 1. Localization of Gorzów Block, on the geological map of Poland (Dadlez, 1998 – modified)

Main dolomite (Ca2) is closely related to the early Zechstein development of anhydrite platforms of PZ1 cycle, which is a base for the platform sedimentation of Main Dolomite (Wagner & Kotarba, 2004). Microfacial analysis along with detailed sedimentological analysis allowed for a precise description of sedimentation zones in analyzed part of Main Dolomite basin. The study was conducted on profiles of different paleographical zones and allowed to distinguish generalized depositional zones:

slope of the carbonate platform, barriers and the carbonate platform (Jaworowski & Mikołajewski, 2007).

Slope of the carbonate platform – Slopes are very narrow, usually several hundred meters but less than 1 km in width, height of the escarpment ranges between 40 and 120 m. Two types of the sedimentary environments were observed: a high energy outer barrier edge (shallow water) with rocks redeposited from the barrier (rudstones, floatstones, and packctones) and a low energy area (deep water) of the basin floor with mudstones and wackestones alterations (Kotarba & Wagner, 2007).

Barriers –they are observed at the edge of the carbonate platforms and microplatforms. They isolate the area of platform plain from the open sea (outer barrier). Barrier strata represent active environment of sedimentation, and they are connected to the highest energy of water. We observe here pery and sublitoral carbonate sands and microbial strata, more rare are carbonate mudstones. Microfacialy we observe: grainstones, boudnstones, packstones, wackstones, floatstones and rudstones (Jaworowski & Mikołajewski, 2007).

Platform plain – Sedimentation of the Main Dolomite on platform plain is related to the shallow – water depositional environment. Changes in the bathymetric level were a base for existence of high and low energy zones. In high–energy zone we observe ooid grainstones with some levels of boundstones. Biostabilistation of strata is common. The low-energy zones are built with mudstones, wackstones, peloid packstones with oncolites and frequent bioclasts. Intraclasts and ooids are redeposited from the high-energy zones. (Jaworowski & Mikołajewski, 2007)

METHODS

The study was conducted with usage of 318 rock samples coming from the 12 boreholes from Lubiatów-Międzychód Grotów reservoir zone. The correlation analysis of the petrophysical parameters was conducted with usage of STATISTICA 10 software. Authors analyzed following petrophysical parameters: Bulk density g/cm3, Matrix density g/cm^3, average capillary μm, effective porosity %, dynamic porosity for gas %, dynamic porosity for oil %, specific surface area m^2/g, diameter threshold μm, pores with size higher that 0,1 μm %, higher that 1 μm % and compactness % in order to perform quantitative and qualitative analysis of the correlation. The correlation parameter is quantified by the correlation coefficient r. For the qualitative description of dependence, authors performed cross-plots.

The analysis was conducted in two sedimentary zones:

- Carbonate platform (barrier and platform plain)
- Slope of the carbonate platform (edge of the slope with bay plain)

CORRELATION ANALYSIS

First step of the analysis is to check strong correlations between petrophysical parameters in the whole analyzed area, and within specified depositional zones (Tab. 4, 5). Strong correlation is defined by value of correlation coefficient (r) higher than 0.7 or lower than –0.7.

Values of r are listed respectively for the whole area, slope of the carbonate platform and carbonate platform.

This is the case for the relation of effective porosity with:

- compatness r = –0.965 , r = –0.946, r = –0.995
- bulk density r = –0.873 , r = –0.880, r = –0.867
- dynamic porosity for Oil r = 0.797 , r = 0.931, r = 0.705
- dynamic porosity for Gas r = 0.991, r = 0.991, r = 0.991

The highest correlation coefficient is observed for the relationship between effective porosity and compactness. Value of the correlation coefficient is very similar in both sedimentary zones (Tab. 4, 5). For the higher values of effective porosity we observe decrease of compactness. The more porous rock is, the compactness decrease is higher (fig. 2 A, B). This happens because carbonate rocks are vulnerable for cracking and natural fracturing. Such similar values of correlation coefficient are resulting from very similar average value of effective porosity and compactness in both sedimentary zones.

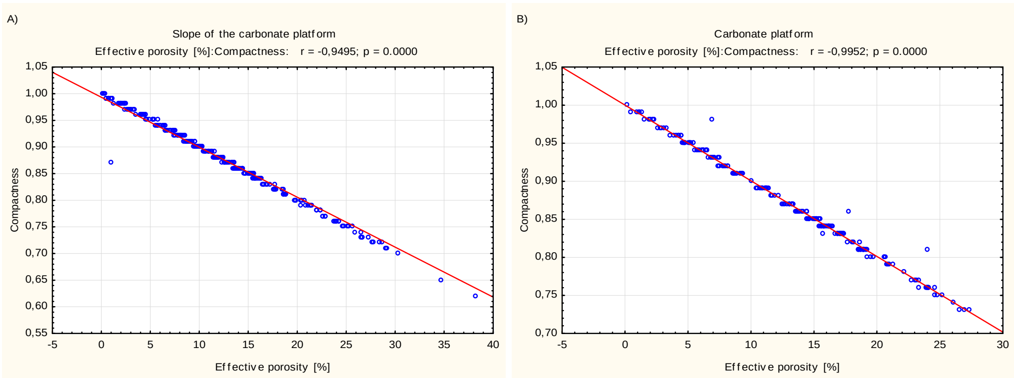

Fig. 2. Cross plot – effective porosity vs compactness on the:
A) slope of the carbonate platform, B) carbonate platform

Bulk density is the measure of the mass of the sample in some specific volume. Voids in rocks highly influence bulk density of the rock (Semyrka, 2008), therefore it is not surprising that we observe negative correlation between parameter of effective porosity and bulk density. As in case of correlation between compactness and effective porosity, we also observe almost identical values of r in both sedimentary zones, and again the reason for that is that the average value and standard deviation of bulk density are very similar. This very strong correlation (fig. 3 A, B) allowed us to adopt following trend of variation between these two parameters (Tab. 1).

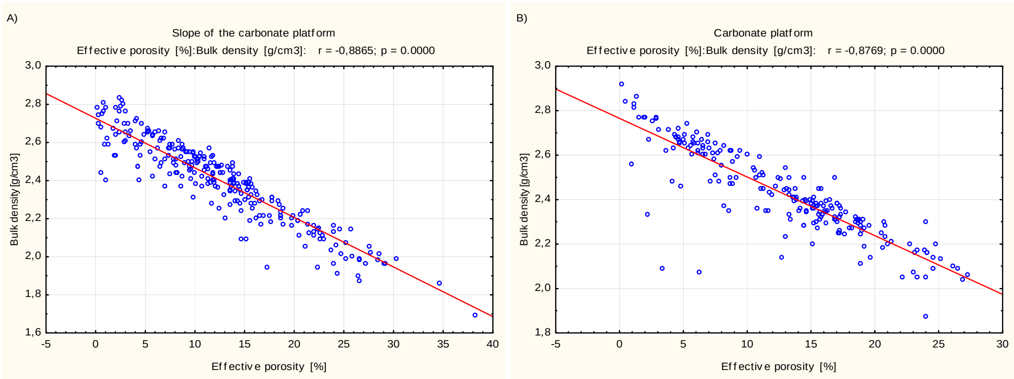

Fig. 3. Cross plot – effective porosity vs bulk density on the:
A) slope of the carbonate platform, B) carbonate platform

Tab. 1. Dependence of bulk density and effective porosity
within two sedimentary zones on the Grotów Peninsula

Carbonate platform		Slope of the carbonate platform	
Effective porosity, %	Bulk density, g/cm^3	Effective porosity, %	Bulk density, g/cm^3
5	2,7	5	2,6
10	2,5	10	2,4
15	2,35	15	2,35
>20	<2,2	>20	2,2

The most interesting is correlation between effective porosity and dynamic porosity for gas and for oil. This correlation, shows in fact how much of the effective pore space is available for the accumulation for gas and for oil.

Tab. 2. Dependence of average capillary and effective porosity
within two sedimentary zones on the Grotów Peninsula

Carbonate platform		Slope of the carbonate platform	
Effective porosity, %	Average capillary, μm	Effective porosity, %	Average capillary, μm
5	0,2	5	0,5
10	0,4	10	1
15	0,8	15	2
>20	>1,5	>20	>4

Tab. 3. Correlation matrix for the petrophysical parameters of the Main Dolomite on the Grotów Peninsula

Variable	Matrix density [g/cm³]	Bulk density [g/cm³]	Effective porosity [%]	Average capillary [µm]	Specific surface area [m²/g]	Diameter threshold [µm]	Pores >0.1 µm [%]	Dynamic porosity for gas	Pory >1.0 µm [%]	Dynamic porosity for Oil	Compactness
Matrix density [g/cm3]	1.000	0.375	0.054	–0.098	0.178	–0.111	–0.084	0.033	–0.248	–0.129	–0.053
Bulk density [g/cm3]	0.375	1.000	–0.873	–0.365	0.289	–0.188	–0.540	–0.876	–0.481	–0.762	0.904
Effective porosity [%]	0.054	–0.873	1.000	0.348	–0.225	0.150	0.541	0.991	0.412	0.797	–0.965
Average capillary [µm]	–0.098	–0.365	0.348	1.000	–0.306	0.305	0.243	0.362	0.479	0.526	–0.347
Specific surface area [m²/g]	0.178	0.289	–0.225	–0.306	1.000	–0.208	–0.707	–0.328	–0.533	–0.390	0.228
Diameter threshold [µm]	–0.111	–0.188	0.150	0.305	–0.208	1.000	0.169	0.165	0.302	0.239	–0.154
Pores >0.1 µm [%]	–0.084	–0.540	0.541	0.243	–0.707	0.169	1.000	0.625	0.433	0.446	–0.540
Dynamic porosity for gas	0.033	–0.876	0.991	0.362	–0.328	0.165	0.625	1.000	0.446	0.802	–0.958
Pory >1.0 µm [%]	–0.248	–0.481	0.412	0.479	–0.533	0.302	0.433	0.446	1.000	0.799	–0.408
Dynamic porosity for Oil	–0.129	–0.762	0.797	0.526	–0.390	0.239	0.446	0.802	0.799	1.000	–0.765
Compactness	–0.053	0.904	–0.965	–0.347	0.228	–0.154	–0.540	–0.958	–0.408	–0.765	1.000

Much higher, almost ideal correlation we observe in case of dynamic porosity for gas (Tab. 4, 5). The reason for such high correlation coefficient is found in the bigger portion of pores with diameter higher than 0.1 µm. It is proved by qualification of dynamic porosity for gas, where for the class of low capacity in range 3.5% to 10%, we observe values of effective porosity 4% and 11% respectively. For the class of average capacity where value of 15% of dynamic porosity for gas corresponds to 16% of effective porosity (fig. 4 A, B). It is also worth noticing that the average value of dynamic porosity for gas is very similar within both recognized depositional zones.

In case of correlation between effective porosity and dynamic porosity for oil, we observe much lower r in carbonate platform than in the slope of that platform (Tab. 4, 5). As it was mentioned before, average value of effective porosity is similar in both sedimentary zones, so the reason for such big diversion of the correlation must be found in the distribution of dynamic porosity for oil. In fact, we observe much lower average value of that parameter on carbonate platform than on the slope of the platform. The fact that only such small portion of effective porosity of sediments on the platform is available for oil accumulation can be explained by very small value of average capillary which is significantly higher on the slope of the carbonate platform.

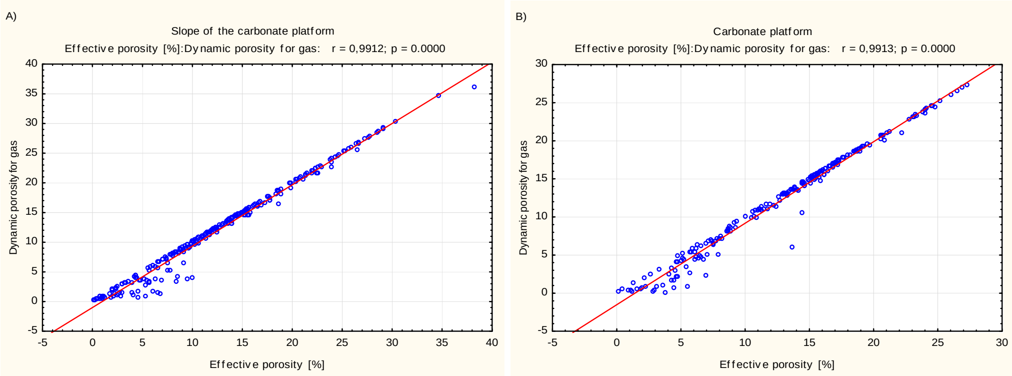

Fig. 4. Cross plot – effective porosity vs dynamic porosity for gas on the:
A) slope of the carbonate platform, B) carbonate platform

Tab. 4. Correlation matrix for the petrophysical parameters of the Main Dolomite on the Grotów Peninsula – slope of the carbonate platform

Variable	Matrix density [g/cm^3]	Bulk density [g/cm^3]	Effective porosity [%]	Average capillary [µm]	Specific surface area [m^2/g]	Diameter threshold [µm]	Pores >0.1 µm [%]	Dynamic porosity for gas	Pory >1.0 µm [%]	Dynamic porosity for Oil	Compactness
Matrix density [g/cm^3]	1.000	0.375	0.054	–0.098	0.178	–0.111	–0.084	0.033	–0.248	–0.129	–0.053
Bulk density [g/cm^3]	0.375	1.000	–0.873	–0.365	0.289	–0.188	–0.540	–0.876	–0.481	–0.762	0.904
Effective porosity [%]	0.054	–0.873	1.000	0.348	–0.225	0.150	0.541	0.991	0.412	0.797	–0.965
Average capillary [µm]	–0.098	–0.365	0.348	1.000	–0.306	0.305	0.243	0.362	0.479	0.526	–0.347
Specific surface area [m^2/g]	0.178	0.289	–0.225	–0.306	1.000	–0.208	–0.707	–0.328	–0.533	–0.390	0.228
Diameter threshold [µm]	–0.111	–0.188	0.150	0.305	–0.208	1.000	0.169	0.165	0.302	0.239	–0.154
Pores >0.1 µm [%]	–0.084	–0.540	0.541	0.243	–0.707	0.169	1.000	0.625	0.433	0.446	–0.540
Dynamic porosity for gas	0.033	–0.876	0.991	0.362	–0.328	0.165	0.625	1.000	0.446	0.802	–0.958
Pory >1.0 µm [%]	–0.248	–0.481	0.412	0.479	–0.533	0.302	0.433	0.446	1.000	0.799	–0.408
Dynamic porosity for Oil	–0.129	–0.762	0.797	0.526	–0.390	0.239	0.446	0.802	0.799	1.000	–0.765
Compactness	–0.053	0.904	–0.965	–0.347	0.228	–0.154	–0.540	–0.958	–0.408	–0.765	1.000

Very similar situation as in correlation between effective porosity and dynamic porosity for gas and oil in both sedimentary zones is found in case of dependence of parameters related to bulk density and dynamic porosity (Tab. 4, 5). We observe similar, very high correlation between bulk density and dynamic porosity for gas in both sedimentary zones, but in case of relation of that parameter to dynamic porosity for oil, again correlation differ within both zones (Tab. 4, 5) (fig. 5 A, B). Average density is similar, but the lower value of average dynamic porosity on platform significantly influences correlation between these two parameters.

Tab. 5. Correlation matrix for the petrophysical parameters of the Main Dolomite on the Grotów Peninsula – carbonate platform

Carbonate platform	Matrix density [g/cm^3]	Bulk density [g/cm^3]	Effective porosity [%]	Average capillary [µm]	Specific surface area [m2/g]	Diameter thresh-old [µm]	Pores >0.1 µm [%]	Dynamic porosity for gas	Pory >1.0 µm [%]	Dynamic porosity for Oil	Compactness
Matrix density [g/cm3]	1.000	0.366	0.137	–0.171	0.188	–0.213	–0.069	0.115	–0.169	–0.043	–0.142
Bulk density [g/cm3]	0.366	1.000	–0.867	–0.500	0.301	–0.212	–0.625	–0.872	–0.482	–0.673	0.867
Effective porosity [%]	0.137	–0.867	1.000	0.452	–0.215	0.118	0.620	0.991	0.427	0.705	–0.995
Average capillary [µm]	–0.171	–0.500	0.452	1.000	–0.455	0.010	0.390	0.476	0.681	0.657	–0.450
Specific surface area [m2/g]	0.188	0.301	–0.215	–0.455	1.000	–0.151	–0.689	–0.310	–0.463	–0.358	0.217
Diameter threshold [µm]	–0.213	–0.212	0.118	0.010	–0.151	1.000	0.129	0.126	0.264	0.180	–0.120
Pores >0.1 µm [%]	–0.069	–0.625	0.620	0.390	–0.689	0.129	1.000	0.692	0.299	0.388	–0.625
Dynamic porosity for gas	0.115	–0.872	0.991	0.476	–0.310	0.126	0.692	1.000	0.440	0.703	–0.988
Pory >1.0 µm [%]	–0.169	–0.482	0.427	0.681	–0.463	0.264	0.299	0.440	1.000	0.851	–0.424
Dynamic porosity for Oil	–0.043	–0.673	0.705	0.657	–0.358	0.180	0.388	0.703	0.851	1.000	–0.697
Compactness	–0.142	0.867	–0.995	–0.450	0.217	–0.120	–0.625	–0.988	–0.424	–0.697	1.000

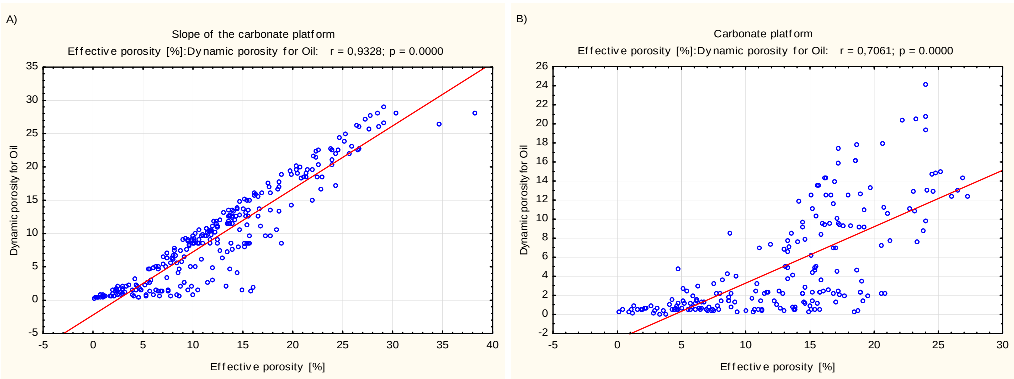

Fig. 5. Cross plot – effective porosity vs dynamic porosity for oil on the: A) slope of the carbonate platform, B) carbonate platform

Cross plot (fig. 6 A, B) between the effective porosity and the average capillary diameter, shows that for the same value of effective porosity the pore space of the carbonate platform is built with the pores with smaller capillary diameter. The correlation coefficient (r) for these two parameters for the carbonate platform equals 0.4188 and for the slope of the carbonate platform equals 0.4145 (Tab. 4, 5). However quantitatively correlation is rather low, closer look on the cross plot (Fig. 6 A,B) allows to distinguish trend of variability (Tab. 5).

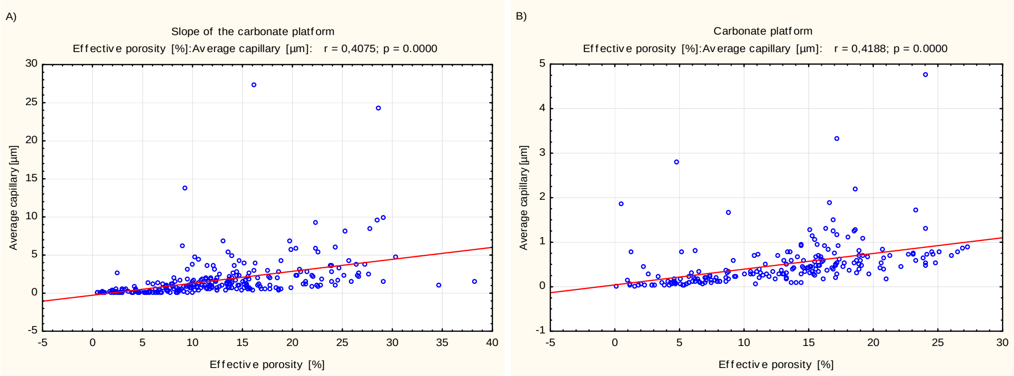

Fig. 6. Cross plot – effective porosity vs average capillary on the:
A) slope of the carbonate platform, B) carbonate platform

CONCLUSIONS

Based on the analysis, it is concluded:

- relation between most of the petrophysical parameters differ within both sedimentary zones. In both zones best correlation to effective porosity is found with following petrophysical parameters: compactness, bulk density and dynamic porosity for oil and gas. Correlation coefficient is usually higher on the slope of the carbonate platform,
- correlation analysis between effective porosity and dynamic porosity for oil and gas, proves that not all pore space is available for the accumulation of hydrocarbons. Availability of pore space for accumulation is strongly dependent on the average capillary, and the amount of pores with diameter higher than 1 µm,
- in both sedimentary zones, most of the pore space is available for the accumulation of gas. Gas particles are small so, even low average capillary allows the accumulation of gas,
- much smaller average capillary and smaller amount of pores with diameter higher than 1 µm on the carbonate platform causes that effective pore space is only partially available for the accumulation for Oil,
- in general, slope of the carbonate platform has better conditions for accumulation of hydrocarbons. The results shown in this paper are consistent with previously published papers (Semyrka et al., 2014, Wandycz & Święch, 2014, Semyrka et al., 2008),

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