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Analysis of rock pore space saturation distribution with Nuclear Magnetic Resonance (NMR) method. Part II

Introduction

Measurements accomplished with Nuclear Magnetic Resonance (NMR) method, carried out on fluid saturated rock samples, provide useful information to characterize their pore structure. The examinations reflect general sensitivity of NMR measurements on pore size distribution, which is of particular significance in applications used in petroleum geology [4, 5, 8].

Each pore size within the rock pore system has characteristic value of T_2 transverse relaxation time and signal amplitude proportional to the volume of fluid contained in pores of that size. Low value of T_2 transverse relaxation time is expected for small pores, while high value of the time values corresponds to large pores [7].

Routine NMR application used in Well Geophysics Department of INiG which enables evaluation of reservoir properties of rocks includes total and effective porosity and irreducible water saturation coefficient. Total porosity (Kp_{NMR}) is calculated from the whole T_2 spectrum range, while effective porosity (Kp_{NMR_ef}) is calculated from NMR signal of T_2 time decays higher than 3 ms. Total NMR porosity is divided into three main constituents: porosity of free water pore space, capillary bound water and irreducible water. Porosity of free water pore space (Kp_3) corresponds to long transverse relaxation times T_2. Short T_2 times are attributed to irreducible water (Kp_1) bound in clay minerals or micropores [1]. According to Coates [3], irreducible water may be defined as volume of water that cannot relocate and cannot be displaced from pore space. Determination of free water volume (that freely moves), as well as bound water, enables determination of potential reservoir rock ability to deliver hydrocarbons in the process of reservoir production.

The aim of the study was evaluation of pore space saturation distribution for Upper Rotliegend Aeolian sandstones originating from G1, O-3 and R-1, R-2 and R-3 boreholes, for the same samples for which microtomographic analysis was carried out, presented in Zalewska et al. part I [10].

Results of examinations

Examinations with Nuclear Magnetic Resonance method were carried out with Maran-7 spectrometer, while analysis of pore space saturation distribution for rock samples was accomplished according to methodology described in Ciechanowska et al. [2].

The material under examination was rock samples originating from drill cores representing Rotliegend formations from G-1, O-3, R-1, R-2 and R-3 boreholes.

Collective list of change ranges and mean values of NMR determined parameters and permeabilities for individual boreholes was presented in table 1 and figure 1. The samples were characterized with:

- total porosity coefficient $Kp_{NMR} \in (2.59 \div 17.43\%)$ with mean value equal to 9.69%. Approximately 60% of all samples under examination featured porosity under 10%, 31% samples had porosities in range from 10

Table 1. Collective list of change ranges and mean values of NMR determined parameters and permeabilities for analyzed boreholes

Parameter	Range of parameter change		Mean value	Range of parameter change		Mean value	Range of parameter change		Mean value
	from	to		from	to		from	to	
	G-1 well (n = 12)			O-3 well (n = 12)			R region (n = 13)		
Irreduc. water – Kp_1 [%]	2.10	4.43	3.21	2.17	3.61	2.88	2.53	4.76	3.60
Capillary water – Kp_2 [%]	0.41	5.45	3.64	0.33	4.89	3.21	2.58	6.37	4.00
Free water – Kp_3 [%]	0.07	9.50	3.09	0.09	8.79	3.77	0.27	7.62	2.38
Total porosity – Kp_{NMR} [%]	3.67	17.43	9.94	2.59	16.45	9.86	7.27	16.45	9.98
Effective poros. – Kp_{ef} [%]	0.48	14.28	6.73	0.42	13.68	6.98	2.94	12.80	6.38
Irr. wat. satur. – Sw_{nr} [%]	16.64	86.92	39.31	16.84	83.78	36.85	20.59	58.36	38.82
Permeability – $Kprz$ [mD]	0.203	15.137	3.91	0.321	110.013	20.47	0.862	99.747	11.38

Fig. 1. Changes of parameters determined with NMR method used for individual wells

a) volume of pore space filled respectively with: irreducible water (Kp_1), capillary water (Kp_2), free water (Kp_3), b) coefficients of total (Kp_{NMR}) and effective (Kp_{NMR_ef}) porosities, c) coefficient of irreducible water saturation (Sw_{nr})

up to 15%, and 10% of samples exhibited Kp_{NMR} coefficient over 15%,

- effective porosity coefficient $Kp_{NMR\_ef} \in (0.42 \div 14.28\%)$, at average equal to 6.45%. Approximately 80% of all examined samples featured porosity below 10%, and 21% samples showed Kp_{NMR_ef} exceeding 10%,
- Sw_{nr} irreducible water saturation coefficient variation in range of 16.64÷86.92%, with mean value – 39.75%,
- capillary water content $Kp_2 \in (0.33 \div 6.37\%)$, with mean value equal to 3.53%,
- free water content $Kp_3 \in (0.07 \div 9.50\%)$, with mean value equal to 2.93%,
- formation factor ranging within 0.20÷110.01 mD, at mean value equal to 11.40 mD. The highest number, that is almost 80% of all examined samples featured *Kprz* permeability below 10 mD and only 6% of them in excess of 90 mD.

Comparison of results obtained for G-1, O-3 wells and R region enable to state that values of NMR method determined parameters in individual wells are characterized by very similar mean values, starting from total porosity, through effective porosity, to end with irreducible water saturation coefficient. The most prominent differentiating parameter is permeability coefficient which varies from 3.91 mD in G-1 well, through 11.38 mD (R region) up to 20.47 mD (O-3 well).

Permeability examinations were carried out in Geology and Geochemistry Department of Oil & Gas Institute by team led by G. Leśniak [6].

Nevertheless, majority of samples originating from G-1 well is characterized by very broad pore size spectrum as well as single- or bimodal shape of T_2 transverse relaxation time distribution (Fig. 2). Samples of total porosity ranging from 3.67÷17.43% and effective porosity 0.48÷14.28% predominate in tested rock material. The following samples showed the highest porosity: 10726 (Kp_{NMR} = 17.43%, Kp_{NMR_ef} = 14.23%; Fig. 2a) and 10729 (Kp_{NMR} = 17.13%, Kp_{NMR_ef} = 14.28%; Fig. 2a), for T_2 time distributions were located within the scale of high T_2 values, which corresponds to high size of pores. These samples belonged to A2 facies formations.

Samples of the lowest porosity, both total and effective, (10733 Kp_{NMR} = 3.74%, Kp_{NMR_ef} = 1.44%; sample 10734 Kp_{NMR} = 3.67%, Kp_{NMR_ef} = 0.48%; Fig. 2b) are samples belonging to P2 facies. Distributions of relaxation time for these drill cores are located within low T_2 values, which corresponds to small pore size. Three samples assigned to A4 facies formations (Fig. 2b) demonstrate intermediate values from indicated porosity range.

Change of parameters determined with NMR method for samples from G-1 well, with consideration given to separated facies, are presented in Table 2.

In G-1 well (Table 2), A2 facies stands out among the three analyzed facies (A2, A4, P2), which has the best parameters:

- the highest mean free water contents Kp_3 (4.49%),
- the highest mean value of effective porosity coefficient Kp_{NMR_ef} (8.67%),
- the lowest mean value of irreducible water saturation coefficient Sw_{nr} (29.81%).

Similarly as before, samples from O-3 well show wide range of pore sizes and T_2 transverse relaxation time distribution (Fig. 3). In this well it can also be observed that Aeolian sandstones of A2 facies have long times of T_2 transverse relaxation. Offset of T_2 times towards lower value takes place in samples of A4 and A5 facies sandstones, which is related to pore size decrease. Further offset of T_2 times towards yet lower values takes place in formations

a) b)

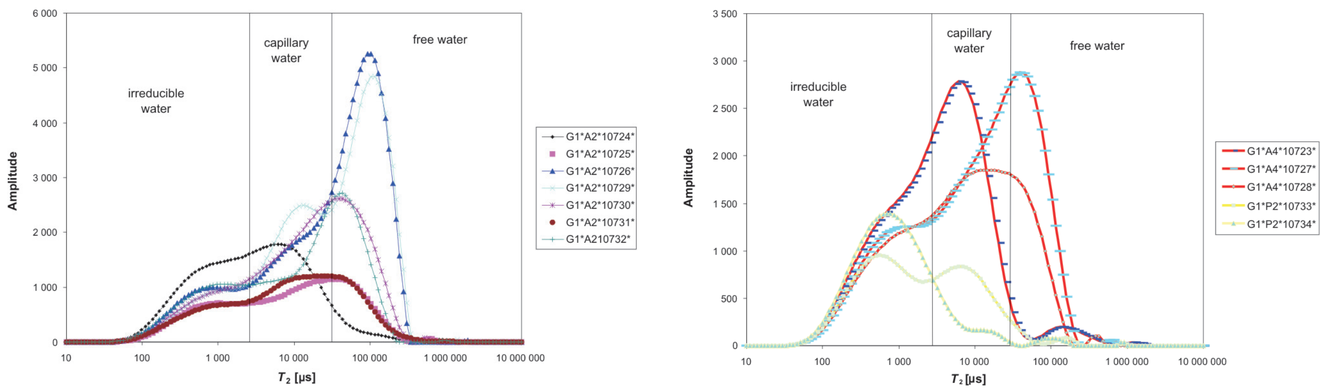


Fig. 2. T_2 transverse relaxation time distributions for samples from G-1 well

a) samples belonging to A2 facies formations, b) samples belonging to A4 facies formation (red) and samples belonging to P2 facies formation (yellow)

Table 2. Summary of change ranges and mean parameters determined with NMR method, and permeabilities for individual facies in G-1 well

Parameter	Range of parameter change		Mean value	Range of parameter change		Mean value	Range of parameter change		Mean value
	from	to		from	to		from	to	
	G-1 well								
	A2 facies			A4 facies			P2 facies		
Irreducible water – Kp_1 [%]	2.10	3.66	3.14	3.28	4.43	3.67	2.30	3.19	2.75
Capillary water – Kp_2 [%]	2.76	5.45	4.18	3.96	4.46	4.26	0.41	1.31	0.86
Free water – Kp_3 [%]	0.41	9.50	4.49	0.38	3.25	1.80	0.07	0.13	0.10
Total porosity – Kp_{NMR} [%]	6.52	17.43	11.81	9.00	11.00	9.72	3.67	3.74	3.71
Effective porosity – Kp_{ef} [%]	3.34	14.28	8.67	4.74	7.71	6.06	0.48	1.44	0.96
Irreducible water saturation – Sw_{nr} [%]	16.64	52.08	29.81	29.91	48.31	38.22	61.50	86.92	74.21
Permeability – *Kprz* [mD]	1.249	15.137	5.81	0.269	4.338	1.82	0.203	0.539	0.37

of P2 sandy playa facies, which gives evidence of small size of the pores. Free water dominates in A2 facies formations, with exclusion of 10738 sample (Fig. 3a). Whereas in sample 10741, representing A4 facies formation, low percentage of free water is observed (Kp_3 = 0.5%) and significant increase of capillary (Kp_2 = 2.42%) and irreducible water (Kp_1 = 3.61%) percentage in relation to A2 facies (Fig. 3b). Even lower (as compared to A4 facies) percentage of free water (Kp_3 = 0.23%) (Fig. 3b) is observed in sample 10742, which is representative of A5 facies formations.

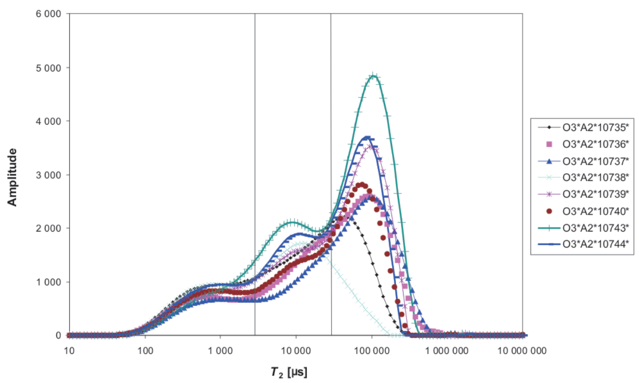
Sample 10746, representing P2 facies, has the worst parameters of all the analyzed samples.

In O-3 well (table 3), similarly as before, A2 facies stands out among the analyzed facies, which also has the best parameters:

- the highest content of free water Kp_3 (5.41%),
- the highest value of effective porosity coefficient Kp_{NMR_ef} (9.38%),
- the lowest mean value of irreducible water saturation coefficient Sw_{nr} (24.38%).

Region R was represented by three boreholes (R-1, R-2 and R-3), and maximum values of T_2 transverse relaxation time distributions for it had decidedly lower amplitude values (2700) (Fig. 4) than T_2 transverse relaxation times determined for samples originating from G-1 (5500) (Fig. 2) and O-3 (5000) (Fig. 3). Mean value of total porosity value for R region, calculated from examination of 13 rock samples, equals to Kp_{NMR} = 9.98%, and effective porosity Kp_{NMR_ef} = 6,38%. The highest value of these parameters was found for samples from R-3 well (sample 10761 Kp_{NMR} = 16.45%, Kp_{NMR_ef} = 12.80%) and from R-1 well (sample 10753 Kp_{NMR} = 13.33%, Kp_{NMR_ef} = 9.51%) (Tab. 1). Both of the samples originated from A2 facies formations.

a)



b)

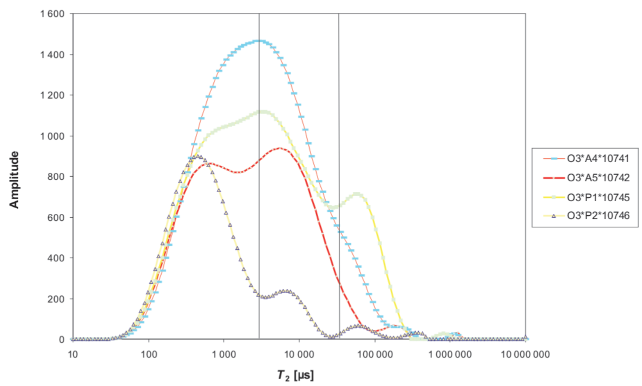


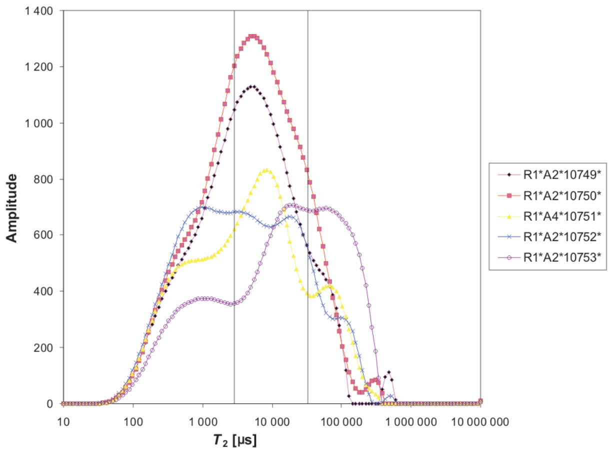
Fig. 3. Distribution of T_2 transverse relaxation time for samples from O-3 well

a) samples belonging to A2 facies formations, b) samples belonging to formations of A4 (10741) and A5 (10742) facies – red, while samples belonging to P1 facies formations (10745) and P2 (10746) are marked with yellow color

Table 3. Summary of change ranges and mean parameters determined with NMR method, and permeabilities for individual facies in O-3 well

Parameter	Range of parameter change		Mean value	Range of parameter change		Range of parameter change	
	from	to		from	to	from	to
	O-3 well						
	A2 facies			A4 + A5 facies		P1 + P2 facies	
Irreducible water – Kp_1 [%]	2.65	3.15	2.81	2.97	3.61	2.17	3.29
Capillary water – Kp_2 [%]	3.46	4.89	3.96	1.94	2.42	0.33	2.15
Free water – Kp_3 [%]	1.07	8.79	5.41	0.23	0.50	0.09	1.10
Total porosity – Kp_{NMR} [%]	7.95	16.45	12.19	5.14	6.53	2.59	6.54
Effective porosity – Kp_{ef} [%]	4.68	13.68	9.38	2.17	2.92	0.42	3.25
Irreducible water saturation – Sw_{nr} [%]	16.84	38.87	24.38	57.78	55.28	83.78	50.31
Permeability – $Kprz$ [mD]	3.464	110.013	29.98	1.080	3.352	0.321	1.015

a)



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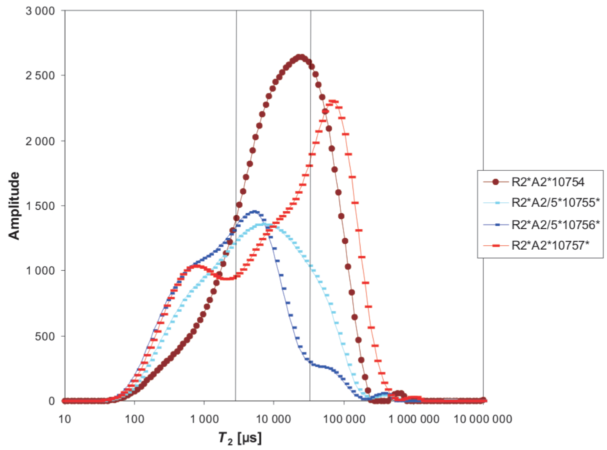

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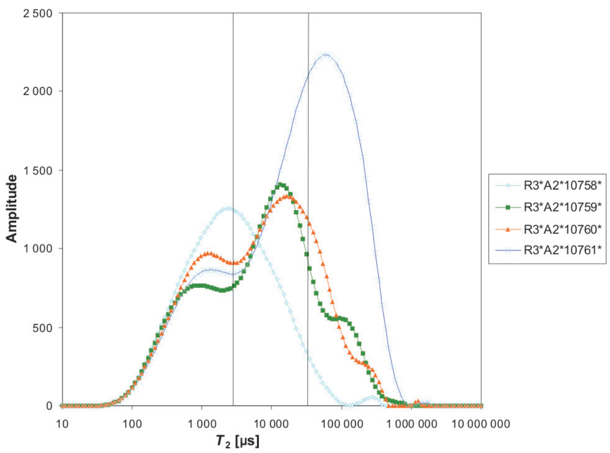

Fig. 4. Distributions of T_2 transverse relaxation time for rock samples from R region

a) R-1 well, b) R-2 well, c) R-3 well

In R region (Tab. 4) represented by 3 wells, A2 facies shows the best parameters in R-2 well, because it has:

- the highest free water content Kp_3 (4.08%),
- the highest mean value of effective porosity coefficient Kp_{NMR_ef} (9.22%),
- the lowest mean value of irreducible water saturation coefficient Sw_{nr} (24.91%).

Formations of A2 facies in the remaining wells (R-1 and R-3) have mean parameter values (Kp_3, Kp_{NMR_ef}) close to each other, but they are lower than in R-2 well, while mean Sw_{nr} value is higher. Neither P1 facies nor P2 facies representatives were present in samples originating from this region.

The next grouping of measurement results obtained with NMR method was carried out with the use of concentration analysis, which enabled separation of three rock groups featuring similar parameters describing pore space. Rock samples showing good reservoir properties were counted among the first group, while rocks samples showing poor reservoir properties were counted among the third group.

Table 4. Summary of change ranges and mean parameters determined with NMR method, and permeabilities for A2 facies within R region

Parameter	Range of parameter change		Mean value	Range of parameter change		Mean value	Range of parameter change		Mean value
	from	to		from	to		from	to	
	A2 facies Aeolian dune sandstones								
	R-1 well			R-2 well			R-3 well		
Irreducible water – Kp_1 [%]	3.51	4.16	3.80	2.53	3.59	3.09	3.21	4.12	3.65
Capillary water – Kp_2 [%]	2.67	4.74	4.00	3.93	6.37	5.15	2.67	5.18	3.96
Free water – Kp_3 [%]	1.09	4.77	2.03	3.39	4.76	4.08	0.27	7.62	2.90
Total porosity – Kp_{NMR} [%]	7.27	13.33	9.84	12.28	12.29	**12.29**	7.06	16.45	10.51
Effective porosity – Kp_{ef} [%]	3.76	9.51	6.04	8.69	9.76	**9.22**	2.94	12.8	6.86
Irreducible water saturation – Sw_{nr} [%]	28.66	48.28	40.21	20.59	29.23	**24.91**	22.19	58.36	38.58
Permeability – *Kprz* [mD]	0.86	2.96	1.80	11.729	99.75	55.74	2.17	4.75	3.02

12 samples were rated among the first group rocks, which represented solely Aeolian dune sandstones of A2 facies (Fig. 5, navy blue). Within this group: three sample originated from G-1 well (10730, 10729 and 10726), five from O-3 well (10744, 10743, 10739, 10737 and 10736) and four from R region (10753 R-1, 10754 R-2, 10757 R-2 and 10761 R-3). Samples from this group show decidedly the best reservoir proper-

Table 5. Statistical analysis of parameters determined with NMR method, separated on the grounds of concentration analysis (in individual groups)

Parameter	Range of parameter changes		Mean parameter value	Standard deviation
	from	to		
Group I				
Capillary water – Kp_2 [%]	3.48	6.37	4.71	0.80
Free water – Kp_3 [%]	3.39	9.50	6.49	1.94
Total porosity – Kp_{NMR} [%]	12.28	17.43	14.26	1.99
Effective porosity – Kp_{ef} [%]	8.69	14.28	11.19	1.99
Irreducible water saturation – Sw_{nr} [%]	16.64	29.23	21.79	4.05
Permeability – *Kprz* [mD]	1.37	110.01	29.36	38.70
Group II				
Capillary water – Kp_2 [%]	2.76	4.46	3.89	0.45
Free water – Kp_3 [%]	0.38	4.95	2.07	1.21
Total porosity – Kp_{NMR} [%]	6.52	11.25	9.33	1.33
Effective porosity – Kp_{ef} [%]	4.42	8.52	5.96	1.26
Irreducible water saturation – Sw_{nr} [%]	24.27	48.31	36.45	6.29
Permeability – *Kprz* [mD]	0.27	15.14	4.97	4.82
Group III				
Capillary water – Kp_2 [%]	0.33	2.93	1.89	1.00
Free water – Kp_3 [%]	0.07	1.10	0.43	0.36
Total porosity – Kp_{NMR} [%]	2.59	7.27	5.58	1.64
Effective porosity – Kp_{ef} [%]	0.42	3.76	2.32	1.26
Irreducible water saturation – Sw_{nr} [%]	46.27	86.92	61.82	14.82
Permeability – *Kprz* [mD]	0.20	3.35	1.41	1.16

ties: $Kp_{NMR} \in (12.28 \div 17.43\%)$, $Kp_{NMR\_}avg = 14.26\%$; $Kp_{NMR\_ef} \in (8.69 \div 14.28\%)$, $Kp_{NMR\_ef\_}avg = 11.19\%$ and filtration ones $Kprz \in (1.37 \div 110.01$ mD), $Kprz\_avg = 29.36$ mD. Free water content prevails in pore space of these samples, and its volume is the highest among all of the distinguished types $Kp_3 \in (3.39, 9.50\%)$, $Kp_{3\_}avg = 6.49\%$. Percentage of capillary water is also the highest as compared to the remaining groups: $Kp_2 \in (3.48 \div 6.37\%)$, $Kp_{2\_}avg = 4.71\%$. The value of irreducible water saturation coefficient falls within $Sw_{nr} \in (16.64 \div 29.23\%)$ range, and its mean value $Sw_{nr\_}avg = 21.79\%$ is the lowest one when compared to the second and third group.

The second group was most numerous and represented by 15 samples (Fig. 5, red color). Six samples originated from G-1 well (three from each A2 and A4 facies), three samples represented O-3 well (all from A2 facies), and six from R region (four from A2 facies and one from each of A4 and A2/A5 facies). This group has weaker reservoir and filtration properties than group I discussed earlier: $Kp_{NMR} \in (6.52 \div 11.25\%)$, $Kp_{NMR\_}avg = 9.33\%$, $Kp_{NMR\_ef} \in (4.42 \div 8.52\%)$, $Kp_{NMR\_ef\_}avg = 5.96\%$, $Kprz \in (0.27 \div 15.14$ mD), $Kprz\_avg = 4.97$ mD. Free water saturation coefficient Kp_3 adopts values from 0.38 up to 4.95% with mean value of 2.07%. The content of capillary water is also slightly lower than in group I: $Kp_2 \in (2.76 \div 4.46\%)$, $Kp_{2\_}avg = 3.89\%$. Mean value of irreducible water saturation coefficient increases as compared to group I, and falls within range $Sw_{nr} \in (24.27 \div 48.31\%)$, at mean value $Sw_{nr\_}avg = 36.45\%$.

12 samples were counted within the third group. The group showed the highest diversity. Three samples originated from G-1 well and each sample represented P2, P1 and A2 facies (10734, 10733 and 10724, respectively). Four samples originated from O-3 well and represented P2, P1, A5, and A4 facies (10746, 10745, 10742 and 10741, respectively). Within R region one sample from each well was counted within this group, namely: 10752 R-1 from A2, 10756 R-2 from A2/A5 and 10758 R-3 from A2 facies.

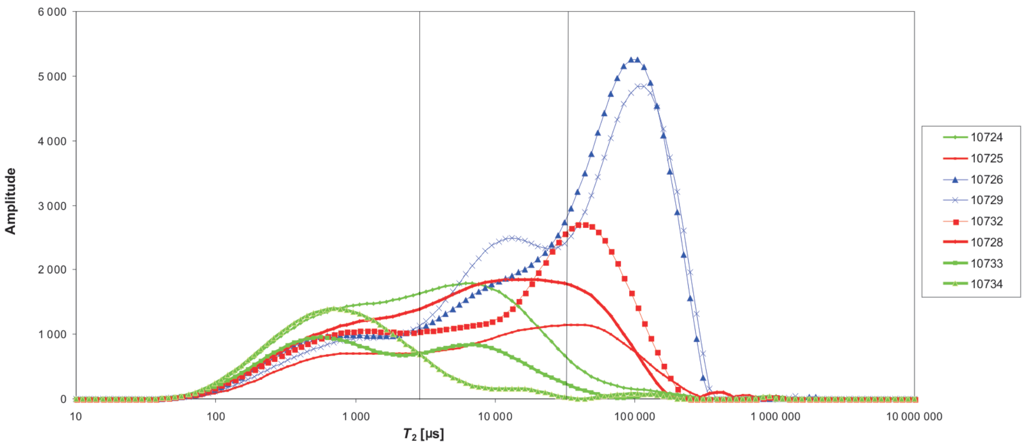

Fig. 5. Model distribution T_2 transverse relaxation time curves, belonging to individual groups

Group I (having good reservoir properties) – navy blue, group II (having weak reservoir properties) – red, group III (having poor reservoir properties) – green

Table 6. Comparison of change ranges and mean values of parameters determined with NMR method and permeabilities for A2 facies formations

Parameter	Range of parameter changes		Mean value	Range of parameter changes		Mean value	Range of parameter changes		Mean value
	from	to		from	to		from	to	
	Aeolian dune sandstones of A2 facies								
	G-1 well (n = 7)			O-3 well (n = 8)			R region (n = 10)		
Irreducible water – Kp_1 [%]	2.10	3.66	3.14	2.65	3.15	2.81	2.53	4.16	3.59
Capillary water – Kp_2 [%]	2.76	5.45	4.18	3.46	4.89	3.96	2.67	6.37	4.22
Free water – Kp_3 [%]	0.41	9.50	4.49	1.07	8.79	5.41	0.27	7.62	2.79
Total porosity – Kp_{NMR} [%]	6.52	17.43	11.81	7.95	16.45	12.19	7.06	16.45	10.60
Effective porosity – Kp_{ef} [%]	3.34	14.28	8.67	4.68	13.68	9.38	2.94	12.80	7.00
Irreducible water saturation – Sw_{nr} [%]	16.64	52.08	29.81	16.84	38.87	24.38	20.59	58.36	36.50
Permeability – $Kprz$ [mD]	1.249	15.137	5.81	3.464	110.013	29.98	0.862	99.747	13.14

This group features poor reservoir properties (Fig. 5, green color). Values of total and effective porosity coefficient and permeability are the lowest among all the separated groups: $Kp_{NMR} \in (2.59 \div 7.27\%)$, $Kp_{NMR}\_avg = 5.58$, $Kp_{NMR\_ef} \in (0.42 \div 3.76\%)$; $Kp_{NMR\_ef}\_avg = 2.32\%$; $Kprz \in (0.20 \div 3.35$ mD), $Kprz\_avg = 1.41$ mD. Irreducible water saturation coefficient definitely prevails: $Sw_{nr} \in (46.27 \div 86.92\%)$, $Sw_{nr}\_avg = 61.82\%$, and also free water percentage is scarce: $Kp_3 \in (0.07 \div 1.10)$, $Kp_3\_avg = 0.43\%$. High value of Sw_{nr} parameter in these samples is related to small (almost null) possibility of saturating them with hydrocarbons.

Table 6 contains comparison of change ranges and mean values of parameters determined with NMR method and permeabilities for examined samples originating from core dune A2 facies formations.

Summary

It has been found on the basis of examination results carried out with NMR method and parameters determined in analyzed boreholes that Aeolian dune sandstones of A2 facies drilled in O-3 borehole, featured the best reservoir properties.

Samples from G-1 well feature slightly worse parameters of A2 facies, determined with NMR method, where mean value of effective porosity coefficient decreased, and mean value of irreducible water saturation coefficient increased.

Samples from R region featured the poorest parameters of A2 facies as compared to O-3 and G-1 wells, for which the mean value of total and effective porosity were the lowest, while the mean value of irreducible water saturation coefficient was the highest.

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References

[1] Allen D.F., Flaum C., Bedford J., Castelijns K., Fairhurst D., Gubelin G., Heaton N., Minh C.C., Norville M.A., Seim M.R., Pritchard T., Ramamoorthy R.: *Trends in NMR logging*. Oil field Review no. 3, vol. 12, p. 2–19, 2000.
[2] Ciechanowska M., Zalewska J.: *Analysis of reservoir rock properties with the use of nuclear magnetic resonance*. Nafta-Gaz no. 1, 2002.
[3] Coates G.R., Xiao R., Prammer M.G.: *NMR Logging Principles and Applications*. Halliburton Energy Services, Houston 1999.
[4] Dullien F.A.L.: *Porous media: Fluid transport and pore structure*. Academic Press, New York 1992.
[5] Kenyon W.E., Day P., Straley C., Willemsen J.: *Compact and consistent representation of rock NMR data from permeability estimation*. SPE, Proc. 61st Annual Technical Conference and Exhibition, 1986.
[6] Leśniak G. et al.: *Determination of processes leading to creation of anomalously low porosity and permeability in Aeolian sandstones in Poznań-Kalisz-Konin region, as well as perspectives of "tight-gas" reservoir discoveries in this zone*. Documentation of 395/ST order, INiG Archive, 2009.
[7] Moss A.K., Zacharapoulos A., De Freitas M.H.: *Shale Volume Estimates from NMR Core Data*. SCA2003-66, 2003.
[8] Sen P.N., Straley C., Kenyon W.E., Whittingham M.S.: *Surface-to-volume ratio, charge density, nuclear magnetic relaxation and permeability in clay-bearing sandstones*. Geophysics, 55, no. 1, 61–69, 1990.
[9] Zalewska et al.: *Evaluation of Upper Rotliegend sandstones pore space in G-R region with the use of nuclear magnetic resonance and X-ray computed microtomography*. Documentation of 454/SW order. INiG Archive, 2010.
[10] Zalewska J., Kaczmarczyk J.: *Analysis of internal pore structure of rock samples based on X-ray computed microtomography data (Part I)*. Nafta-Gaz no. 8, 2011.

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