AFFECTING WETTABILITY ON RELATIVE PERMEABILITY PARAMETERS FOR QUARTZ SANDSTONES

Such P. Leśniak G.

Oil &Gas Institute – National Research Institute Kraków, Poland

This paper was prepared for presentation at the International Symposium of the Society of Core Analysts held in Snowmass, Colorado, USA, 21-26 August 2016

ABSTRACT
Full lithological profiles of the Cambrian sandstones were investigated. Alteration of wettability upon contact with oil were observed (predominantly oil wetting). The following parameters were recorded: porosity, permeability, relative permeability, wettability and MICP. Subsequent Correlation between wettability and relative permeability were investigated. The investigation demonstrated that the relative permeability to water increases when oil wetting tendency increases. For single samples a great variability of results was observed. No correlation between Amott Wettability Index and pore space parameters (porosity, permeability, threshold diameter, fractal dimension [8], specific surface) was obtained.

INTRODUCTION
The Cambrian quartz sandstones are the base reservoir rocks in the Baltic Syneclise. Reservoir sandstones belong generally to Pardoxides paradoxissimus bed. There are silificated quartz sandstones, fine and mid grained, classified as quartz arenites. Quartz is a dominating mineral which content comes up to 98%. Quartz also dominates in cements (quartz overgrowths). Reservoir bed is formed as sandstone layers mixed with clay – mud layers. Long series of laboratory investigations were performed over the course of a few years. It was found that the oil wetting is a dominating phenomenon for majority of reservoir samples. Amott Wettability Index investigations were performed using Donaldson at al. [2] method. The scale of this phenomenon in showed in a Figure 1 (frequency diagram of Amott Wettability Index). The authors have investigated influence of wettability on oil – water relative permeability.
Figures 2 and 3 presented results of relative permeability measurements and investigations of Amott Wettability Index. The relative permeabilities [9] were measured using the original reservoir fluids in simulated reservoir conditions. Steady state measurement regime was applied. Permeability covers the range from 0.52 to 465 mD, porosity values from 5 to 21%. Our database could be classified as a typical Cambrian sandstones from the North of Poland [4,10].

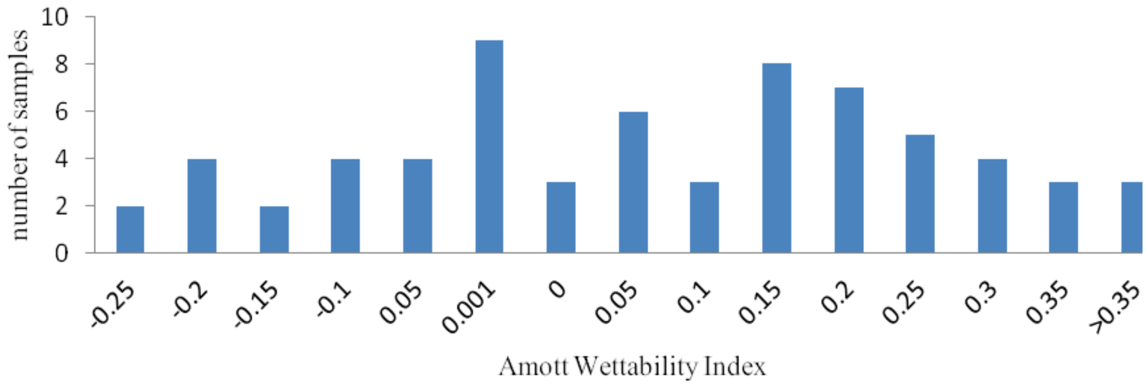

Figure1. Frequency diagram of Amott Wettability Index (AWI) for investigated samples.
.

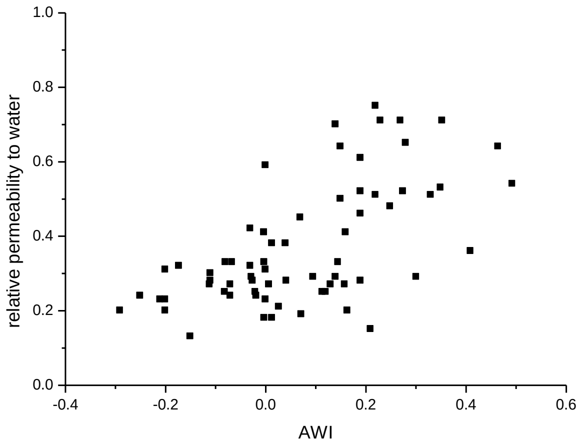

Figure 2. Relative permeability to water as a function of AWI

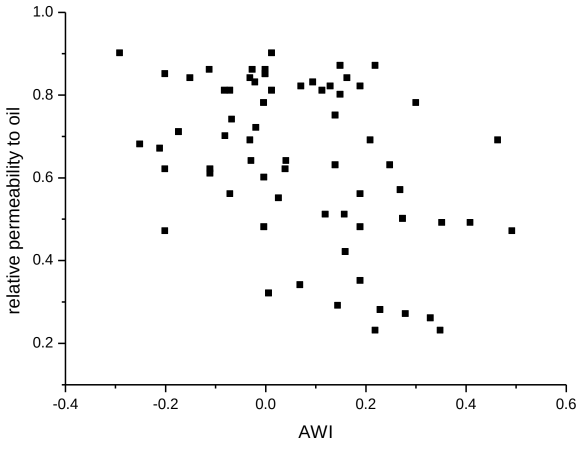

Figure 3. Relative permeability to oil as a function of AWI

Figure 4 presents relative permeability (to water and to oil) as a function of absolute permeability. Authors especially wanted to connect wettability and relative permeability with specific surface and fractal dimension but the results of our attempts were not satisfactory. Such trends were obtained only using values of spontaneously displaced water (during Amott wettability tests) and values of relative permeability to water and oil. Figure 5 and 6 present these results.

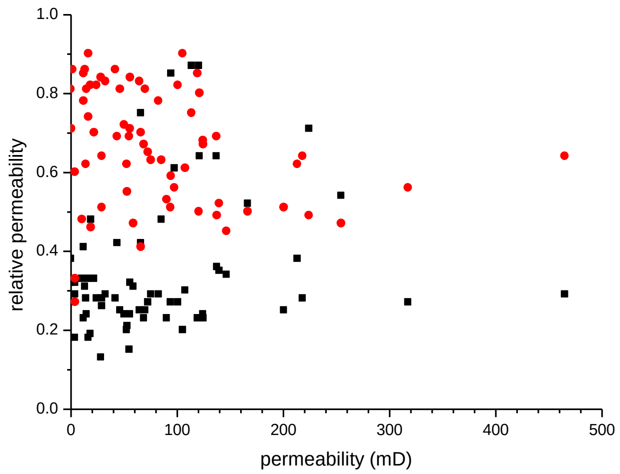

Figure 4. Relative permeability as a function of permeability to gas (red – relative permeability to oil, black – to water)

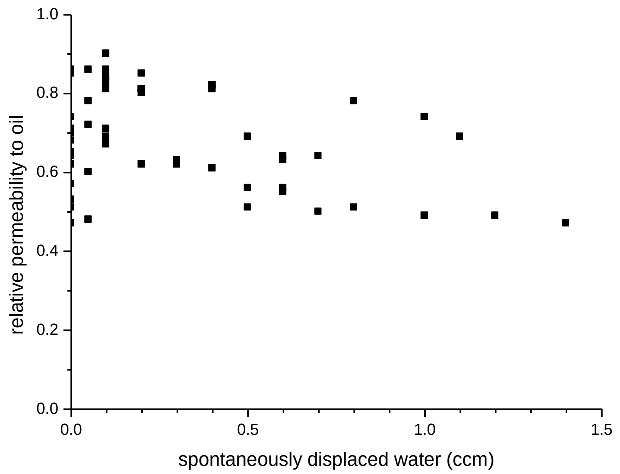

Figure 5. Relative permeability to oil versus spontaneously displaced water during Amott Wettability Tests

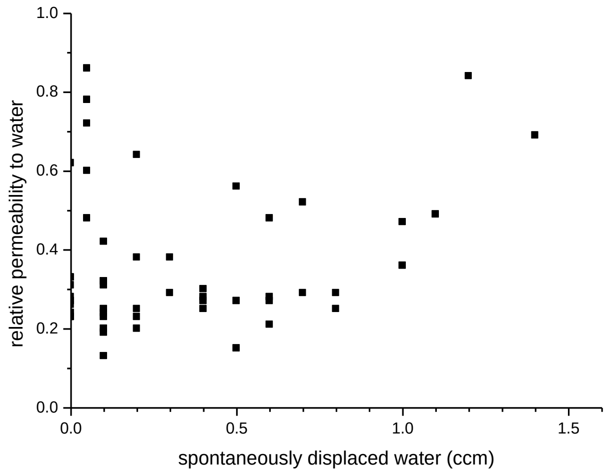

Figure 6. Relative permeability to water versus spontaneously displaced water during Amott Wettability Tests

DISCUSSION

It was demonstrated that wettability of the Cambrian reservoir sandstones was altered when contacted with oil [1, 3]. In this work the full profiles were investigated, so we can compare the original and altered sandstones. Temperatures and pressure fluctuations during geological history of these reservoirs [5] are factors which played the main role in altering wettability. The authors applied correlation procedures to demonstrate processes which are connected with wettability alteration values of relative permeability [6]. Values of AWI for investigated data amounted to 0.49 (strongly oil wet samples). Two obvious trends are observed in fig 2 and 3. i.e. increase of relative permeability to water and decrease of relative permeability to oil associated with shifting AWI towards greater values. Relative permeability to water is more sensitive than permeability to oil for AWI variability. Figure 4 shows relative permeability versus permeability to gas. The greatest values of permeability to water (connected with greater values of AWI) are observed for the range of permeability from 50 to 220 mD. For greater values of permeability the relative permeability to water decreases. All investigated parameters were gathered in figure 7. Only samples with positive value of AWI were taken into account. Such set of data allows us to investigate main trends. Average values of relative permeability to water increased and became comparable with relative permeability to oil in the range 100 – 200 mD. For this range of permeability the AWI reaches the greatest average value. For greater permeabilities a decrease of all investigated parameters is observed. Finally it can be concluded that the investigated parameters show regularity in the range from 10 to 200 mD. For greater permeabilities the phenomenon connected with velocity of flowing fluids became important. For permeability smaller than 10 mD the considerable reduction of relative permeability to oil is observed (connected with resistance of pore space). Figure 8 presents frequency diagram of residual water saturation for the whole database. Process of altering wettability didn't change this parameter. It is connected with the fact that micropores were filled with water all the time.

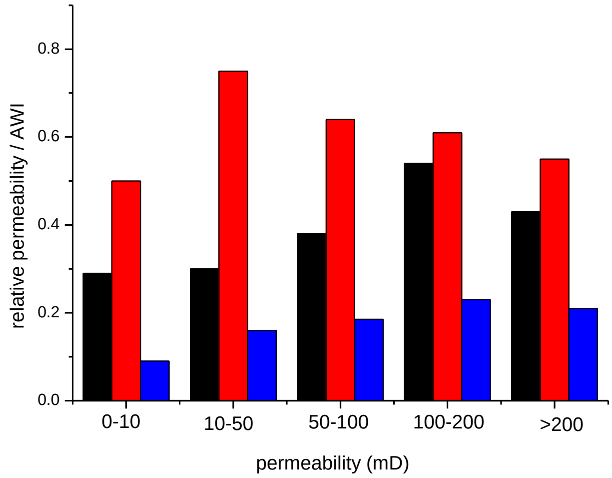

Figure 7. Average values of relative permeability and AWI in given partition of permeability (black – relative permeability to water, red relative permeability to oil, blue – AWI).

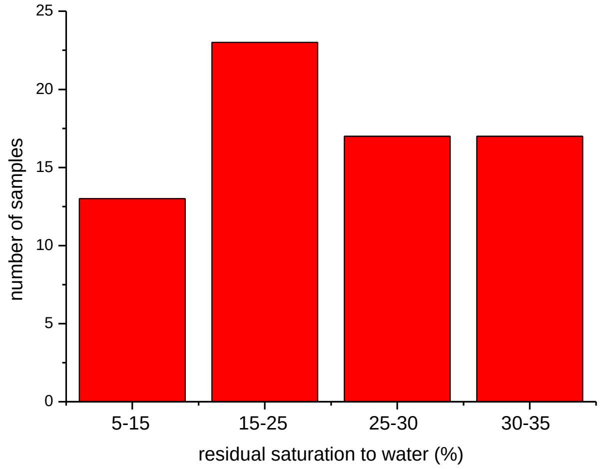

Figure 8. Residual saturation to water (full database)

Table 1. Variability of relative permeability for the same value of AWI

AWI	Relative permeability to water	Relative permeability to oil	Permeability to gas (mD)
0.19	0.46	0.48	19.21
0.19	0.32	0.52	140.0
0.19	0.56	0.64	131.0
0.19	0.28	0.82	24.2

Statistically some regularities are observed but for the single samples the variability of parameters could be huge. In table 1 all samples characterized by AWI equal to 0.19 are shown. Relative permeability to water changes from 0.28 to 0.56, relative permeability to oil changes from 0.48 to 0.82. One can conclude from the above that the process of altering wettability affects only a part of pore space and that this process is rather of statistical nature and does not depend only on pore space parameters.

CONCLUSION

1. Contact with oil is altering wettability of the Cambrian sandstones.
2. Two main trends are observed: relative permeability to water increases and relative permeability to oil decreases while AWI grows. Relative permeability to water is the more sensitive parameter. Statistic trend is coupled with great variability of investigated parameter for single samples.
3. No correlations were found for parameters of pore space.
4. For AWI equal to 0.34 or greater the values of both relative permeabilities are comparable.
5. The greatest values of AWI are observed for the range of permeability 100 - 200 mD.

REFERENCES

1. Buckley J.S., Liu Y., Minsterleet S.,“ Mechanism of Wetting Alteration by Crude Oil” SPE Journal, (1998) 3, 1, p. 54-61

2. Donaldson E.C., Tiabb D.: Petrophysics, Gulf Publishing Comp. Houston, Texas, 1996

3. Flovik V., Sinha S., Hanses A.: “Dynamic Wettability Alteration in Immiscible Two-phase Flow in Porous Media: Effect on Transport Properties and Critical Slowing Down”, Frontiers in Physics. November (2015), vol.3.article 86

4. Karczewska A., Leśniak G., Such P., Żurawski E.: “A pore space development of the Cambrian sandstones and their transport system of reservoir fluids”, The International Conference “Baltic Petrol’ 2010”

5. Roosta A., Escrochi M., Varsandech F., Khatibi J., Sh., Schafiee M.: “Investigating the Mechanism of Thermally Induced Wettability Alteration” (2010) SPE Paper 120354

6. Skauge A., Ottesen B.” A Summary of Experimentally Derived Relative Permeability and Residual Saturation on North Sea Reservoir Cores” SCA Papers (2002)

7. Such P.: The pore space investigations for geological and field engineering purposes. Prace IGNiG, Kraków, Nr 104 (2000),95

8. Such P. Investigations of a pore space of reservoir rock with the use of the fractal approach. Prace IGNiG Nr 115, Kraków (2002), 28

9. Such P., Lesniak G.: “Factors Affecting Relative Permeability Measurements for the Miocene and the Rotliegend Poorly Consolidated Sandstones” SCA Paper, (2003)

10. Such P., Leśniak G., Budak P.: Complex methodic of investigations of petrophysical properties of rocks. Prace INiG, Nr.142, Kraków (2007), 69