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Features of some petrophysical interrelations of reservoir rocks of Western Siberia

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Summary

This article contains several kinds of petrophysical interrelations derived from dataset of core investigations performed at 16 fields of Western Siberia (Neocomian and Jurassic deposits).

Interrelations between a number of parameters and properties of the rocks were investigated by using application-dependent software developed by ***PANGEA Inc****.*

It's shown that the conclusion derived from statistical analysis coordinates well with existing knowledge of the object derived from professional expertise.

There are also presented two ways of estimating permeability from porosity and clay content and proposed usage of complex parameters H_{cl} *(ETA clay) and* H_{cem} *(ETA cement) in petrophysical studies.*

Description of performed investigations

Our try to construct generalized interrelations is caused by the fact that the studied object located in Western Siberia, Russia, is missing any information concerning clay content and irreducible water saturation.

We performed statistical analysis of results of core investigations performed in 16 fields. The following parameters measured at core samples were the subjects of our study:

Z_{abs} – Absolute depth where the sample was taken, m;
V_{carb} – Carbonate content, %;
V_{cl} – Clay content (content of fraction < 0.01 mm), %;
S_{wirr} – Bound water content (derived from centrifuge studies), %;
θ – Porosity (derived by using gas), %;
K – Permeability, mD (derived by using gas).

Its worth mentioning that the above mentioned parameters were derived by various enterprises and using various equipment. This could introduce additional diffusion into statistical analysis.

We used petrophysical software **ModERn**™ developed by **PANGEA Inc.** for carrying out this study. The most extensive representation of data is shown at Fig. 1. This matrix plot illustrates common pattern of the above-mentioned interrelations and their relative stability. At the same time this pattern coordinates well with the petrophysical expertise of current object, concerning nature of these interrelations, their features and intensity.

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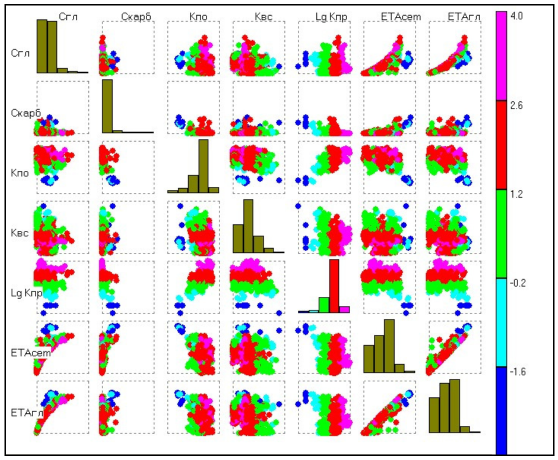

Fig. 1. Matrix plot of interrelations between parameters with differentiation by logarithm of permeability.

From this matrix plot one can mention that variables $\boldsymbol{H_{cl}}$ (ETA clay) and $\boldsymbol{H_{cem}}$ (ETA cement) were used. Both these complex parameters were introduced by B.Yu. Wendelstein [ ] and one of the authors [ ].

These parameters are defined as follows:

$$\mathrm{H}_{cl} = \frac{V_{cl}}{V_{cl} + \theta} \qquad (1)$$

Introduction of these complex parameters allows distinguishing between reservoir and non-reservoir rocks more efficiently (Fig. 2b), if comparing with correlation using single variables (Fig. 2a):

$$\mathrm{H}_{cem} = \frac{V_{cem}}{V_{cem} + V_{cl} + \theta} \qquad (2)$$

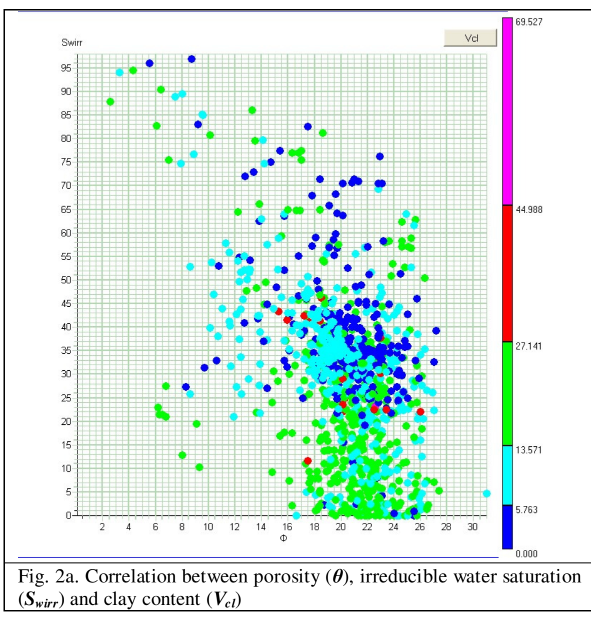

Fig. 2a. Correlation between porosity ($\boldsymbol{\theta}$), irreducible water saturation ($\boldsymbol{S_{wirr}}$) and clay content ($\boldsymbol{V_{cl}}$)

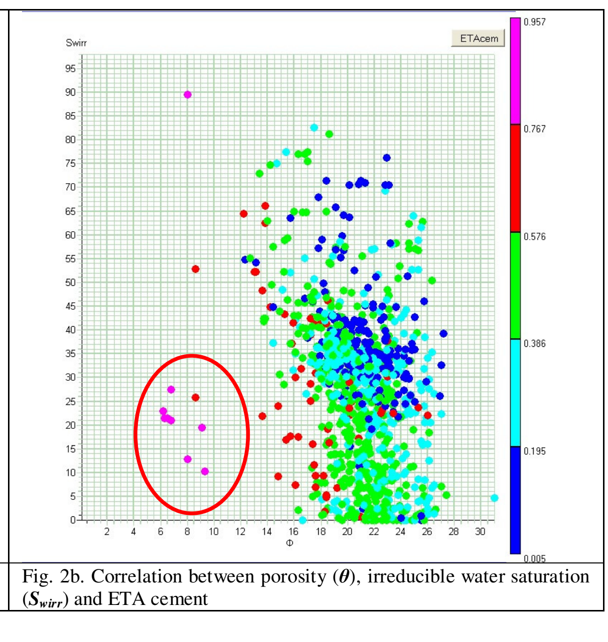

Fig. 2b. Correlation between porosity ($\boldsymbol{\theta}$), irreducible water saturation ($\boldsymbol{S_{wirr}}$) and ETA cement

From Fig. 3 it's clearly seen that carbonate cement content is sufficiently large (>15%), thus we've introduced one more complex parameter, which accounts for both cement and clay content:

C_{cem} – Cement content, % $= V_{carb} + V_{cl}$

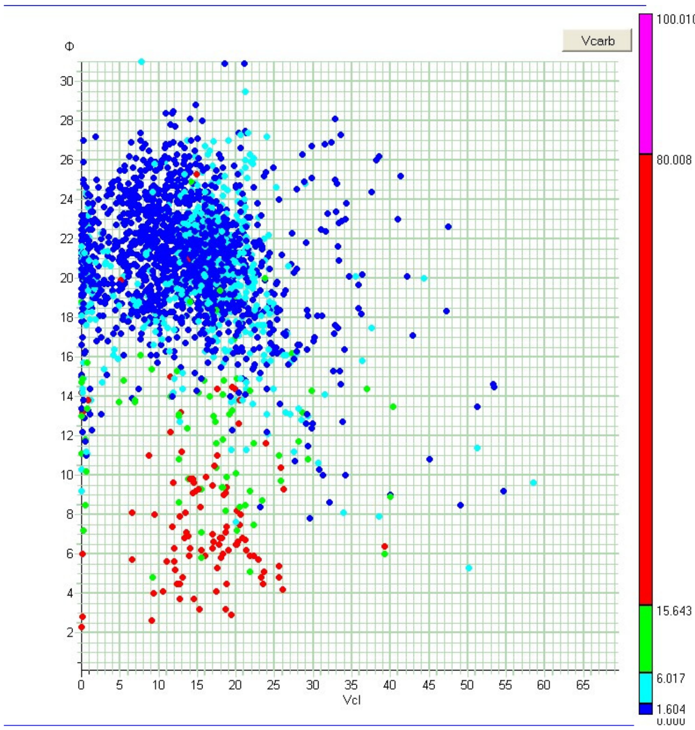

Fig. 3. Correlation between clay content (V_{cl}), porosity (θ) and carbonate content (V_{carb})

Using the above described parameters we constructed the following correlation patterns:

$V_{cem} – \theta – \lg K$ (Fig. 4a), $V_{cem} – \theta – Z_{abs}$ (Fig. 4b);
$\theta – \lg K – H_{cem}$ (Fig. 5a), $\theta – \lg K – Z_{abs}$ (Fig. 5b);
$\theta – S_{wirr} – \lg K$ (Fig. 6a), $\theta – S_{wirr} – Z_{abs}$ (Fig. 6b).

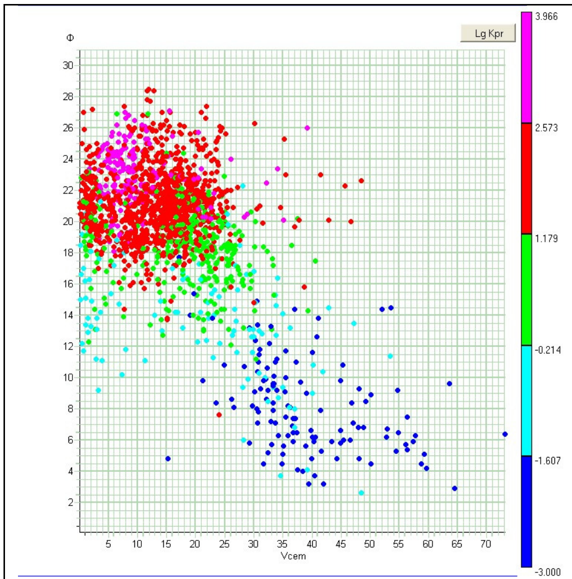

Fig. 3a. Correlation between cement content (V_{cem}), porosity (θ) and logarithm of permeability (lg$K$)

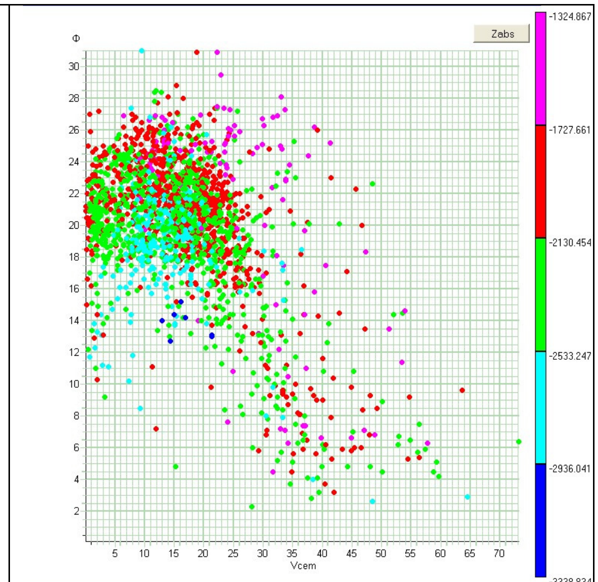

Fig. 3b. Correlation between cement content (V_{cem}), porosity (θ) and absolute depth of sample (Z_{abs})

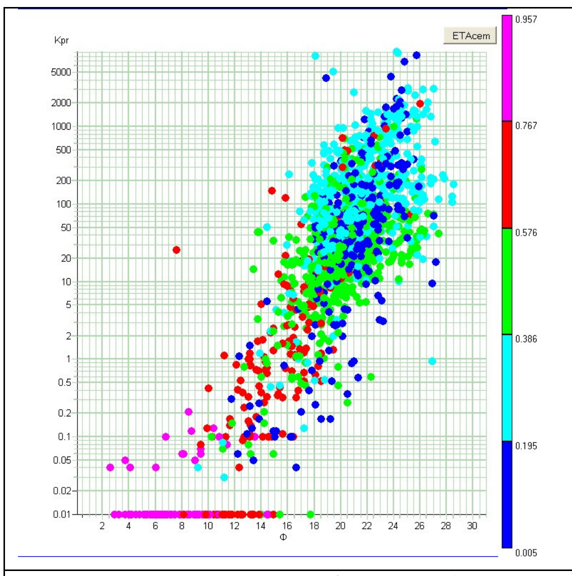

Fig. 4a. Correlation between porosity (θ), logarithm of permeability (lg$K$) and ETA cement

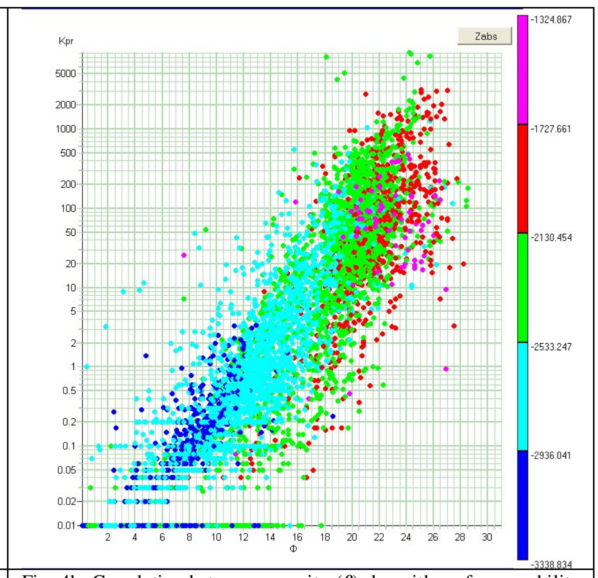

Fig. 4b. Correlation between porosity (θ), logarithm of permeability (lg$K$) and absolute depth of sample (Z_{abs})

From Fig. 4a one may notice that color differentiation by ETA cement remains correlated with porosity-permeability trend. At Fig. 4b color differentiation by ***Zabs*** illustrates a stratification of porosity-permeability interrelations (the deepest samples are on the left of the figure).

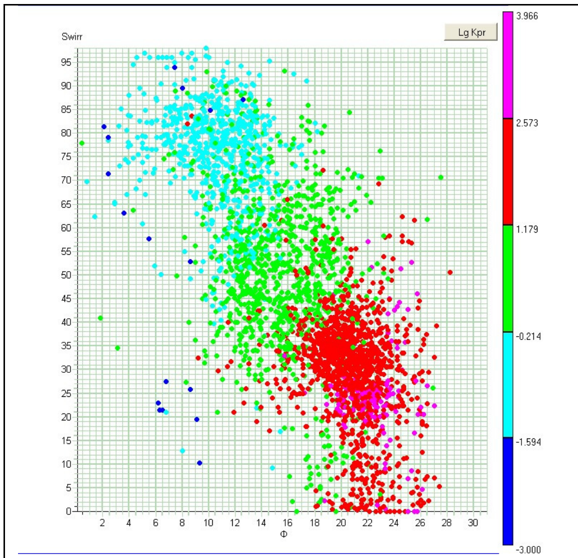

Fig. 5a. Correlation between porosity (***θ***), irreducible water saturation (***Swirr***) and logarithm of permeability (lg***K***)

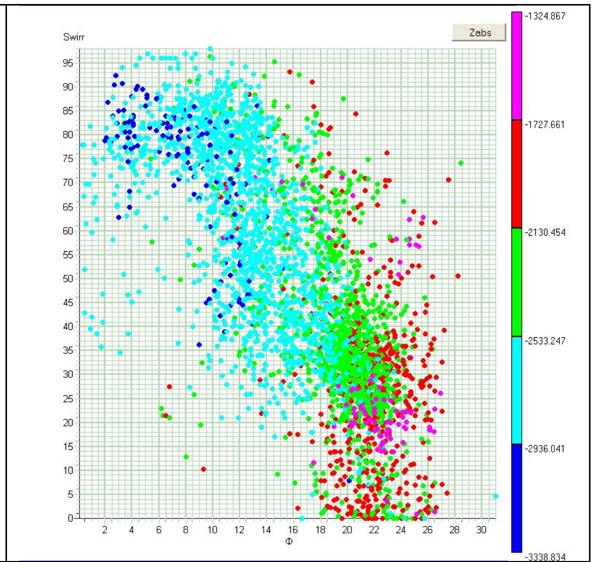

Fig. 5b. Correlation between porosity (***θ***), irreducible water saturation (***Swirr***) and absolute depth of sample (***Zabs***)

Application of least-square method to the correlations described above provides the following expressions (3, 4) that may be used either in reserves' estimation or in production forecast:

$$\lg K = -4.736 + 0.235 * \theta - 0.00065 * Z_{abs} \quad (3)$$

$$\lg K = -4.19 + 0.223 * \theta - 0.00059 * Z_{abs} - 0.509 * \mathrm{H}_{cl} \quad (4)$$

It's up to a petrophysicist to decide which of these expressions to choose for a current investigation. We'll mention that the determination coefficient increases not much (from 0.67 to 0.74) if weights of summands complementary to the influence of porosity increase.

Conclusion

Analysis of obtained results allows stating a number of conclusions:

1. Huge region of Western Siberia (distance between the studied fields makes up to 12 000 km) can be described using integrated petrophysical interrelations that may be used in formation evaluation, production prospecting and basin modeling tasks within this region;
2. It's shown that introduction of multidimensional petrophysical interrelations instead of pair correlations increases accuracy of their determination and hence quality of the result.

References

Wendelstein, B.Yu., Enikeev, B.N., 2004, "Forming, illustrating and using of knowledge based on petrophysical data. Features and future". Geofizika, EAGO, Moscow, pp. 65-73. http://petrogloss.narod.ru/geoph10p.htm *(RUSSIAN)*

Enikeev, B.N., 2008, "Some features of petrophysical basis in interpretation of reservoirs with complex structure using ModERn software". Oil-gas and ore potential of Khanty-Mansiysk (Yugra) region – means of realization. IzdatNaukaServis, Vol. 1, p.1, pp. 225-237,

http://petrogloss.narod.ru/Enikeev_HMAO-2007.pdf *(RUSSIAN)*.