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CORE DATA STATISTICAL ANALYSIS FOR NATURAL GAS RESERVOIRS FROM THE SOUTHERN PART OF TRANSYLVANIAN DEPRESSION

1. INTRODUCTION

The analysis performed in this paper has the following targets:

– the statistical analysis of the main parameters of the rock (porosity, permeability) and of the rock-fluid system (gas saturation) determined from the cores of the natural gas reservoirs of the Southern part of Transylvanian Depression;
– fulfilment of some correlations between the parameters: porosity/gas saturation, porosity/permeability, gas saturation/permeability, porosity/depth, gas saturation/depth, permeability/depth, such as to be estimated average values for these parameters for the reservoirs that does not have so many analysis from cores;
– the presentation of the results obtained after the correlations between the parameters;
– a comparison between the resulted parameters from statistical analysis and the present parameters used in the volumetric estimation of the resources from the natural gas reservoirs.

2. GENERAL DATA REGARDING THE PHYSICAL PARAMETERS DETERMINED FROM CORES

In the Southern part of Transylvanian Depression there are 87 natural gas reservoirs and there were analysed 8401 de cores from Meotian, Pliocene, Sarmatian, Buglovian, Badenian, Helvetian, Eocene, Cretacic and Jurassic.

The number of cores analysed on each reservoir varies from 1 and 736. The cores were grouped on geological formations and the most important from the determination of the physical parameters point of view are: Badenian (3386 determinations), Buglovian (1896 determinations), Sarmatian (2460 determinations) and Pliocene (461 determinations).

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There are determinations of physical parameters in the geological formations situated under the Acvitanian salt in the cores taken from the few high depth wells: Eocene (82 determinations), Cretacic (49 determinations) and Jurassic (73 determinations).

The available data from the core analysis of the natural gas reservoirs in the Southern part of Transylvanian Depression are: effective porosity, permeability parallel with stratum, permeability perpendicular on stratum, water saturation, core salt content, water salt content, calcium carbonate content, specific gravity and grain-size analysis.

In this paper there were used for statistical analysis and correlations the physical parameters referring to the reservoir rock geometry, fluid saturation and fluid flow through rock properties: effective porosity, permeability parallel with stratum, permeability perpendicular on stratum, water saturation.

It was observed that there are missing from core analysis data referring to connate water saturation and there is available information on pores water saturation. In order to estimate the gas saturation it was considered that the water saturation determined in the lab is similar with the connate water saturation, ignoring the zero values only. There were eliminated from the initial data the zero values of the porosity and of the permeability.

The other data resulted from core analysis (core salt content, water salt content, calcium carbonate content, specific gravity and grain-size analysis) are not representative for the correlations with the physical parameters for natural gas resources estimation.

3. PROPOSED WORK IN ORDER TO KNOW THE PHYSICAL MODEL

The main part of the gas reservoirs are already in the production period and plenty of them are even at the end of production. For these reservoirs is not required to know the physical model, as it is already contoured, based on production data and production history.

For the new discovered reservoirs, where the initial physical parameters can be determined, in order to know better the physical model at production starting, it is proposed to extract cores and to analyse the parameters as those are the only direct reservoir information. The main uncertainties of the core analysis come from the fact the obtained data are isolated, not continuous. From this reason, for a continuous description of the reservoir properties it is proposed the analysis of the geophysics properties, from complex well logs interpretation, 3 D seismic and well testing.

4. POROSITY-DEPTH CORRELATION

The regression lines and the correlation coefficients for porosity-depth variation were determined for each reservoir, each geological formation and total gas reservoirs and total geological formations.

It was noticed a rather good porosity-depth correlation and generally porosity goes down when depth grows. The correlation coefficient is between –0.31 (Sarmatian) and –0.57 (Jurassic), on total formations. The worst porosity-depth correlation is for Pliocene, where the correlation coefficient is –0.02.

5. GAS SATURATION-DEPTH CORRELATION

The regression lines and the correlation coefficients for gas saturation-depth variation were determined for each reservoir, each geological formation and total gas reservoirs and total geological formations (Fig. 1).

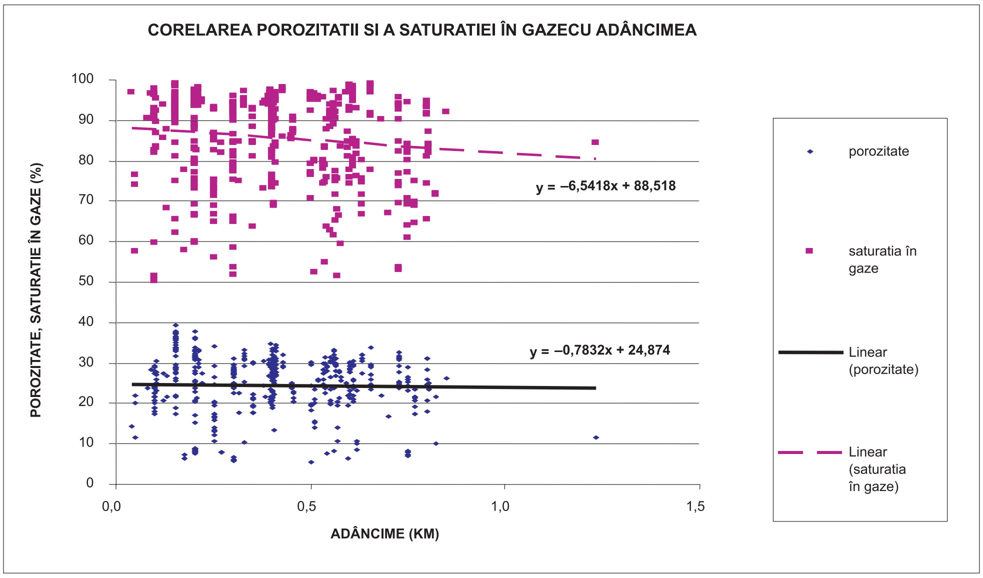

Fig. 1. Porosity and gas saturation – depth correlation for Pliocene

It was noticed a poor gas saturation-depth correlation and the correlation coefficient is between 0 (Sarmatian) and 0.12 (Pliocene), on total formations. The best gas saturation--depth correlation is for Eocene, where the correlation coefficient is –0.45.

6. PERMEABILITY-DEPTH CORRELATION

The regression lines and the correlation coefficients for both permeabilities-depth variations were determined for each reservoir, each geological formation and total gas reservoirs and total geological formations (Fig. 2).

It was noticed a rather good permeability parallel with stratum-depth correlation for Badenian, Eocene and Cretacic and the correlation coefficient is between –0.2 and –0.64 a poor correlation for the other geological formations where the correlation coefficient is between –0.07 and –0.14, on total formations. The best permeability parallel with stratum--depth correlation is for Cretacic, where the correlation coefficient is –0.64.

It was observed that the permeability parallel with stratum-depth variation is different from permeability perpendicular on stratum-depth variation.

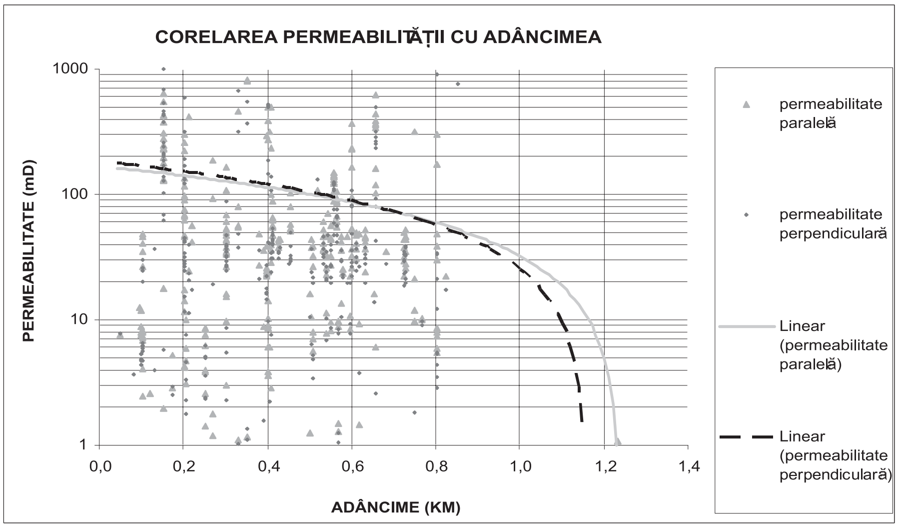

Fig. 2. Permeability-depth correlation for Pliocene

7. POROSITY-PERMEABILITY CORRELATION

There were determined the regression lines and the correlation coefficients for porosity-permeability parallel with stratum variation, for each reservoir, each geological formation and total gas reservoirs and total geological formations, as it is considered that the permeability parallel with stratum shows better the real situation in the gas reservoir.

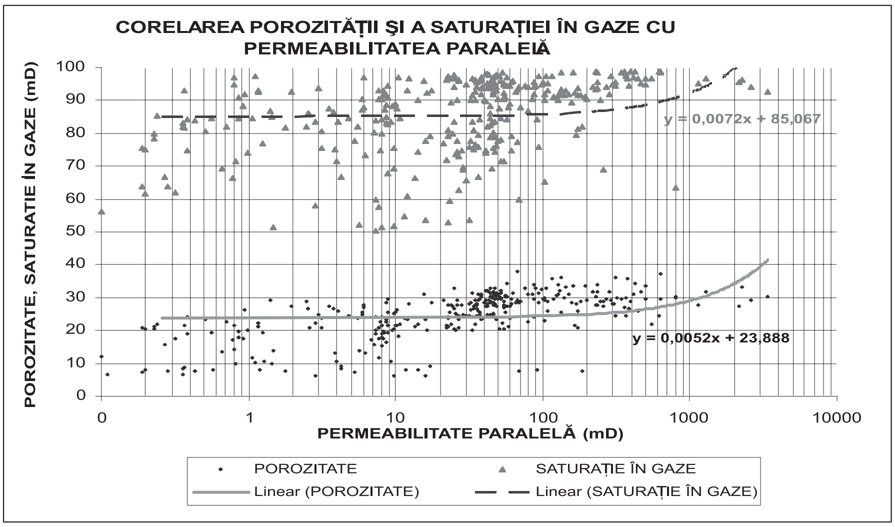

Fig. 3. Porosity and gas saturation – permeability parallel with stratum correlation for Pliocene

It was noticed a rather good porosity-permeability parallel with stratum correlation and generally permeability parallel with stratum grows when porosity grows. The correlation coefficient is between 0.24 (Pliocene, Buglovian) and 0.8 (Eocene, Cretacic), on total formations (Fig. 3).

8. GAS SATURATION-PERMEABILITY CORRELATION

There were determined the regression lines and the correlation coefficients for gas saturation-permeability parallel with stratum variation, for each reservoir, each geological formation and total gas reservoirs and total geological formations, as it is considered that the permeability parallel with stratum shows better the real situation in the gas reservoir.

It was noticed a rather good gas saturation-permeability parallel with stratum correlation and generally permeability parallel with stratum grows when gas saturation grows. The correlation coefficient is between 0.13 (Buglovian) and 0.84 (Jurassic), on total formations.

9. POROSITY-GAS SATURATION CORRELATION

The regression lines and the correlation coefficients for porosity-gas saturation variation were determined for each reservoir, each geological formation and total gas reservoirs and total geological formations (Fig. 4).

It was noticed a rather good porosity-gas saturation correlation and generally gas saturation grows when porosity grows. The correlation coefficient is between 0.23 (Cretacic) and 0.66 (Eocene), on total formations.

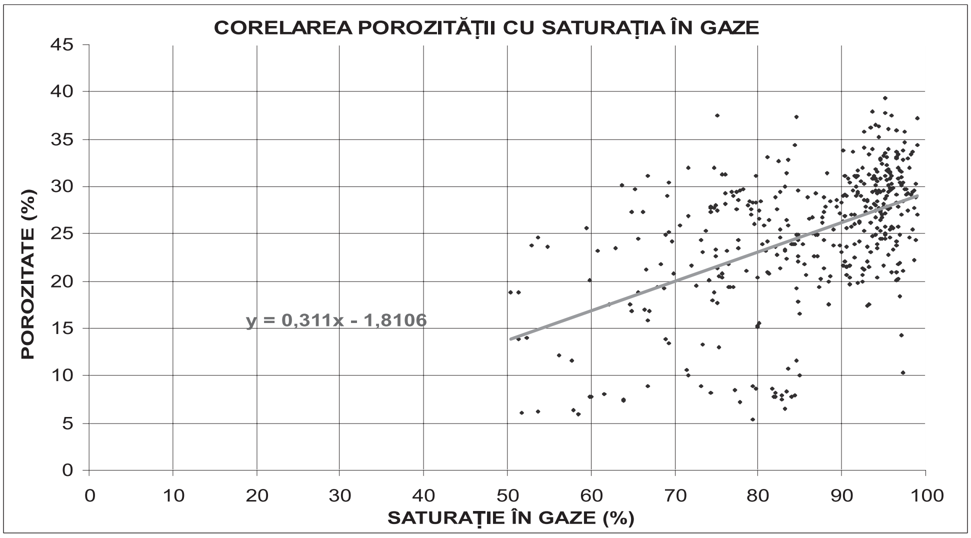

Fig. 4. Porosity – gas saturation correlation for Pliocene

10. ANALYSIS RESULTS AND THE CONFIDENCE OF THE ESTIMATIONS

The fact that the shape of the histograms for the main geological formations (Pliocene, Sarmatian, Buglovian, Badenian, Eocene, Cretacic and Jurassic) from porosity and gas saturation data distribution is not always normal for all the geological formations, or log-normal for permeability, respectively, although the data volume available for statistical analysis is rather high, shows that indeed the physical properties which characterize the reservoir rocks of the gas reservoirs from the Southern part of Transylvanian Depression are very heterogeneous (Figs 5–10).

It was noticed that the average values of the physical parameters obtained through statistical methods (median) are close to arithmetic average (which characterizes porosity and gas saturation) and geometrical average (which characterizes permeability), in Table 1.

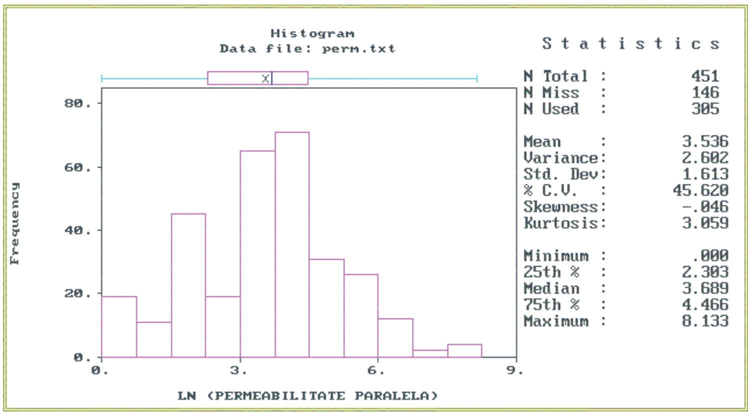

Fig. 5. Permeability parallel with stratum histogram at Pliocene

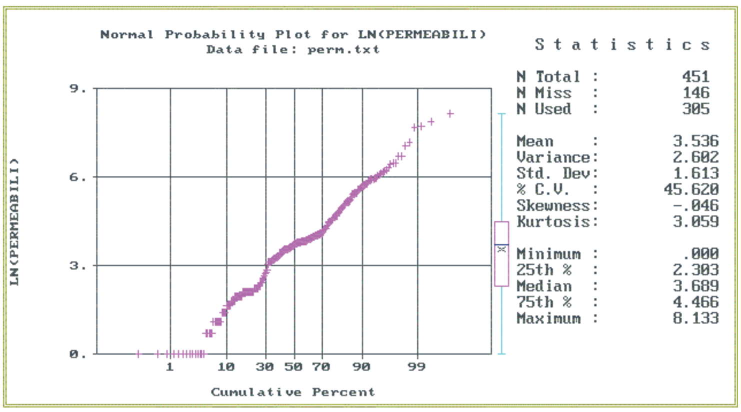

Fig. 6. Cumulative for permeability parallel with stratum at Pliocene

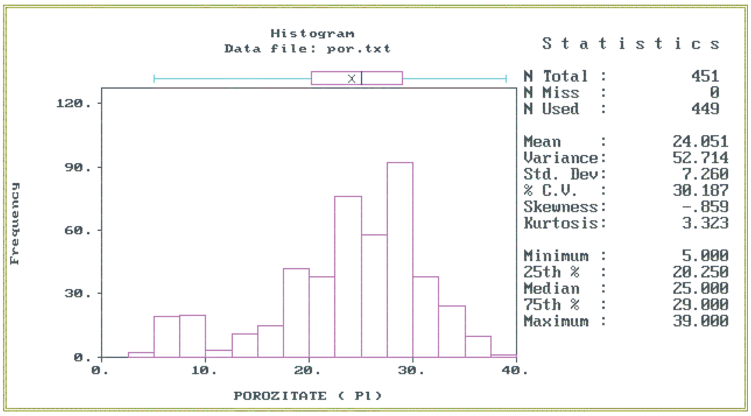

Fig. 7. Porosity histogram at Pliocene

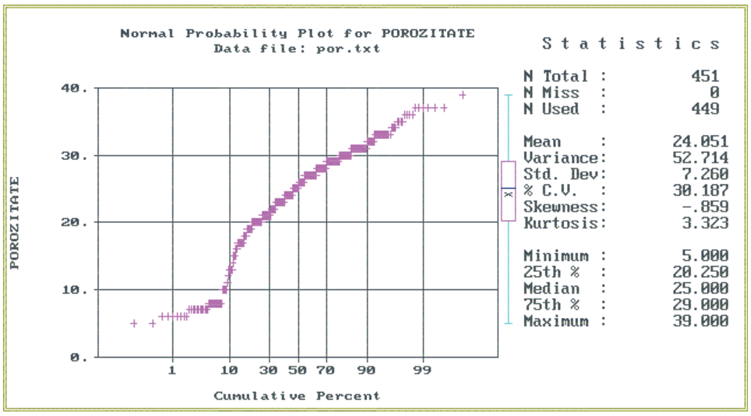

Fig. 8. Cumulative for porosity at Pliocene

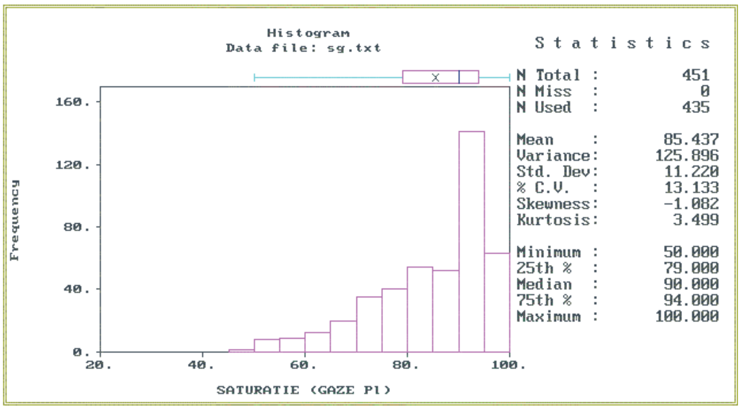

Fig. 9. Gas saturation histogram at Pliocene

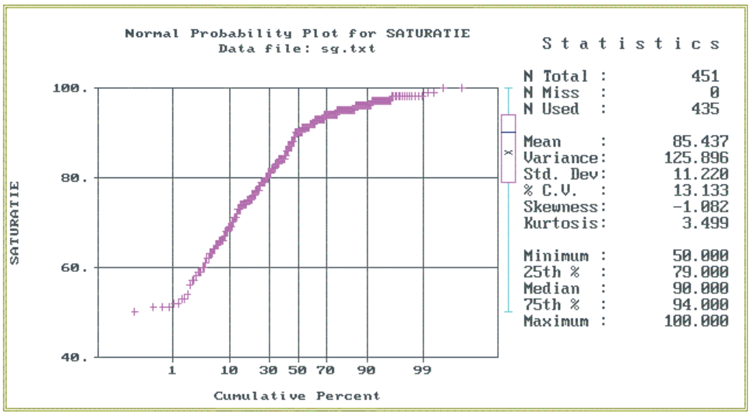

Fig. 10. Cumulative for gas saturation at Pliocene

Table 1

The average values of the physical parameters: median, arithmetic mean, geometrical mean

Formation	Porosity [%]		Gas saturation [%]		Permeability [md]	
	Median	Arithmetic mean	Median	Arithmetic mean	Median	Geometric mean
Pliocene	25.9	24.6	90.4	85.9	35.02	20.24
Sarmatian	16.1	16.2	83.8	80.4	2.21	3.26
Buglovian	9.6	11.8	84.3	82.2	1.05	1.72
Badenian	9.3	11.5	82.9	81.01	0.84	1.18
Cretacic	7.6	8.2	84.11	82.25	0.28	0.35
Jurassic	6.4	7.2	75.03	74.55	0.09	0.08

From the correlations between the main parameters performed for total gas reservoirs on geological formations it was observed:

– a very good correlation between:
  - porosity and gas saturation for Pliocene and Eocene; the correlation coefficient is 0.5 for Pliocene and 0.66 for Eocene;
  - porosity and permeability parallel with stratum for Badenian, Eocene and Cretacic; the correlation coefficient is 0.47 for Badenian, 0.80 for Eocene and 0.79 for Cretacic;
  - gas saturation and permeability parallel with stratum for Jurassic; the correlation coefficient is 0.84;

– good correlations for porosity and gas saturation and for porosity and permeability, for all formations;

– rather good correlations for porosity and depth, for all formations;

– poor correlations for gas saturation and depth, for permeability and depth, for all formations.

Comparison between the resulted parameters from statistical analysis and the present parameters used in the volumetric estimation of the resources

From the statistical analysis of the cores resulted values of the physical parameters which can be used for the estimation of the natural gas resources.

It was made a comparison between the resulted parameters from statistical analysis and the present parameters used in the volumetric estimation of the resources for some gas reservoirs (see Tab. 2).

Table 2

Comparison between the resulted parameters from statistical analysis and the present parameters used in the volumetric estimation of the resources

Structure	Minimum-maximum values of the core parameters [%]		Parameters obtained from statistical analysis (arithmetic mean-median) [%]		Present parameters used in the estimation of the resources [%]	
	Porosity	Gas saturation	Porosity	Gas saturation	Porosity	Gas saturation
A	6–25	51–72	11–13	57–58	10–25	55–75
B	6–27	50–96	17–19	80–88	12–23	55–72
C	6–35	57–98	22	86–89	16–22	55–70
D	5–29	50–99	11	79–82	13–19	55–65
E	5–50	51–98	8–13	81–79	10–18	55–65
F	5–29	63–98	10–14	86–88	12–23	55–72
G	5–28	50–98	8–12	79–94	17–20	65–70
H	5–25	51–97	9–11	77–79	14–22	55–72

It was observed that in most cases the porosity was overestimated and the gas saturation was much underestimated, excepting structure A, where the gas saturation was overestimated.

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