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METHODICAL APROACH FOR SANDSTONES GAS-POTENTIAL ESTIMATION IN DOBROUDJA COAL BASIN

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РЕЗЮМЕ

В настоящата работа, на базата на характерни сондажни разрези, е разработена методика за оценка на газовия потенциал на горнокарбонските пясъчници от Добруджанския въглищен басейн и на перспективите за извличане на природен газ от тях. Оценката на газовия потенциал се основава на интерпретацията на резултатите от електрометричните, радиоактивните и акустичните изследвания в сондажните разрези. В резултат на това са определени петрофизични показатели на пясъчниците, на базата на които е оценена тяхната порестост, водонаситеност и газонаситеност. За целта са построени палетки за конкретната апаратура и за специфичните особености на пясъчниците в изучавания район. Предложен е количествен показател – "газ-капацитивен обемен фактор", който характеризира газовия потенциал. Филтрационният потенциал на пясъчниците, на този етап на изследванията, се характеризира с показателя проницаемост.

INTRODUCTION

Dobroudja Coal Basin (DCB) contains natural gas in coal beds as well as in the Upper Carboniferous sandstones. The sandstones are from different type - lititic, volcanomictic, grauvacs and volcanic and reach up to 40% from the section. They are cemented by shale, shaly carbonate or anhydrite.

The estimation of the gas potential of sandstones is connected with examination of their reservoir and filtration properties and their gas saturation as well. Such estimation was not run till now because the carried out during the period of survey in DCB geophysical investigations in the well have directed to the coal, physics and mechanical studding. The newly received information contains basic petrophysical parameters obtained by well log interpretations.

The goal of the present paper is on the basis of the typical of well logging sections from DCB to develop a method for evaluation of petrophysical properties of UCS and to offer some principles for complex generalization and estimation of their gas potential and the possibility of natural gas extraction.

METHODS FOR ESTIMATION OF PERTOPHYSICAL PARAMETERS USING WELL LOGGING

Petrophysical parameters of the sandstones from DCB are estimated on the basis of well logging survey. The existing information includes: resistivity methods – Lateral logs with length from 0,2 m to 4 m, Self Potential (SP), Neutron-gamma method (NGR|), Gamma ray (GR), Sonic log (ΔT), Caliper and Resistivitymeter. In the interpretation of the well geophysical data the following sandstone parameters are defined: shale volume (V_{sh}) and relative shale content (η_{sh}); porosity (ϕ); residual water saturation (S_{rw}); water saturation (S_w) and gas saturation (S_g).

The lithologic characteristics of the examined sandstones is too complicated because of the wide variety of shale content, the presence of carbonate cement and in some beds the presence of coal. These conditions led out the necessity to elaborate specific methods for log analysis determination of the shale content by the GR and porosity by the sonic and neutron-gamma methods (Larionov, 1969; Nikolova, 1974;Nikolova, 1978a;Nikolova, 1978b; Nikolova, 1981). For the purposes of the petrophysical characteristics is also used data from the core analysis: porosity, permeability, shale content, silicate and grain-size. The content of U, Th, Ra, K^{40} is studied as well. On the base of the estimating characteristics and well logging data for the conditions of Carboniferous in DCB are updated some charts for log interpretation as follows: $\Delta J_{GR}=f(V_{sh})$, $\phi_{sh}=f(\Phi_{NG(S),}V_{sh})$, $\Delta T_{sh}=f(\phi_{sh})$, $\eta_{sh}=f(S_{rw})$, $I_g=f(S_g)$- all examined below. Using this charts (fig.1,2,3,4,5 and 6) is ensured the improvement of the well log interpretation.

Shale volume (V_{sh}) is determined by the natural gamma-ray and the relationship between gamma-ray index (ΔJ_{GR}) and shale volume $\Delta J_{GR} = f(V_{sh})$ (fig.1):

$$\Delta J_{GR} = \frac{GR - GR_{\min}}{GR_{\max} - GR_{\min}} \quad (1)$$

where GR, GR_{min} and GR_{max} are as follows: the intensity of the natural gamma radiation in the bed, in nonshaly bed and in shales.

Porosity *(ϕ)* is defined by complex interpretation of neutron gamma log (NGL), gamma log (GL) and sonic log (ΔT) by the methods described by J.B. Nikolova (Nikolova, 1974;Nikolova, 1978a; Nikolova, 1981), and shortly exposed down below.

Sonic porosity. In the common occasion the porosity by the sonic method is defined by the average travel time equation:

$$\phi_{S(NG)} = \frac{(\Delta T - \Delta T_{ma}) - V_{sh}(\Delta T_{sh} - \Delta T_{ma})}{\Delta T_w - \Delta T_{ma}} \qquad (2)$$

where: ΔT is the travel time in the bed; ΔT_w - into the water (Dahnov, 1972); ΔT_{ma} - is the matrix travel time and ΔT_{sh} – the shale travel time. The parameter ΔT_{ma} is defined by the chart $\Delta T = f(\phi_{NG,limest.}, \Delta T_{ma})$ (fig. 2) and ΔT_{sh} – by chart $\Delta T_{sh}=f(\phi_{sh})$ (fig. 3).

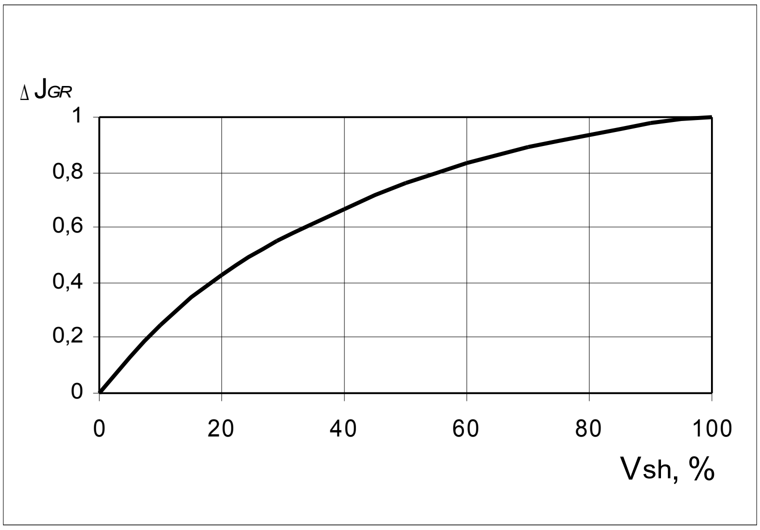

Figure 1. Relationship between natural gamma-ray index (ΔJ_{GR}) in sandstones and shale content (V_{sh}).

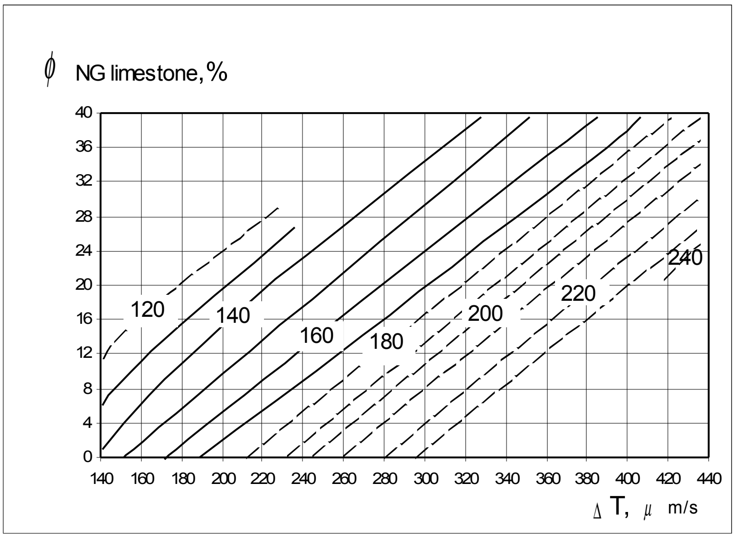

Figure 2. Relationship between travel time (ΔT) and neutron porosity ($\phi_{NG\ limestone}$) (cipher of curves – matrix travel time, ΔT_{ma}).

Neutron porosity. Neutron porosity in shaly sandstones ($\phi_{NG(S)C}$) corrected for the shale content is defined as follows (Larionov, 1969):

$$\phi_{NG(S)C} = \phi_{NG(S)} - V_{Sh}\phi_{Sh} \qquad (3)$$

where: ϕ_{Sh} – shale porosity. It is defined by the equation $\phi_{Sh}=f(\phi_{NG(S)}, V_{sh})$ (fig. 4); $\phi_{NG(S)}$ is defined by the chart $\Delta J_{NG} = f(\phi_{NG}, \Delta T_{ma})$ (fig. 5) (Nikolova, 1978a;Nikolova, 1978b; Nikolova, 1981; Tenchov, et al., 1988).

$$\Delta J_{NG} = \frac{NG - NG_{\min}}{NG_{\max} - NG_{\min}} \qquad (4)$$

where: NG is the NGR tool response in the bed , NG_{min} is NGR in water and NG_{max} – NGR in the bed with porosity close to zero.

Average porosity ϕ_{ol} is defined as follows:

$$\phi_{ol} = \frac{\phi_{NG(S)C} + \phi_{S(NG)}}{2} \quad (5)$$

Porosity by the resistivity methods. In 100% water saturated beds, porosity (ϕ_R), derived by the resistivity of the flushed zone (R_{xo}) and by the resistivity of the noninvaded zone (R_o) is equal to the neutron and sonic porosity.

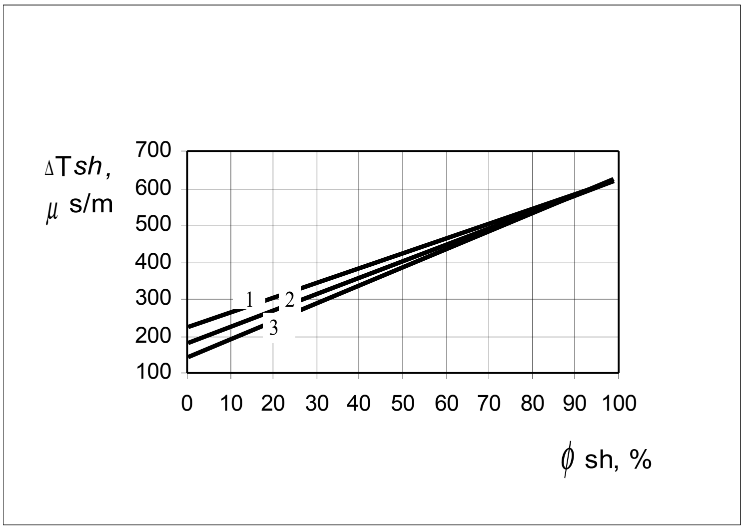

Figure 3. Relationship between shale travel time (ΔT_{sh}) and shale porosity (ϕ_{sh}) cipher of curves 1, 2, 3 – for different type sandstones.

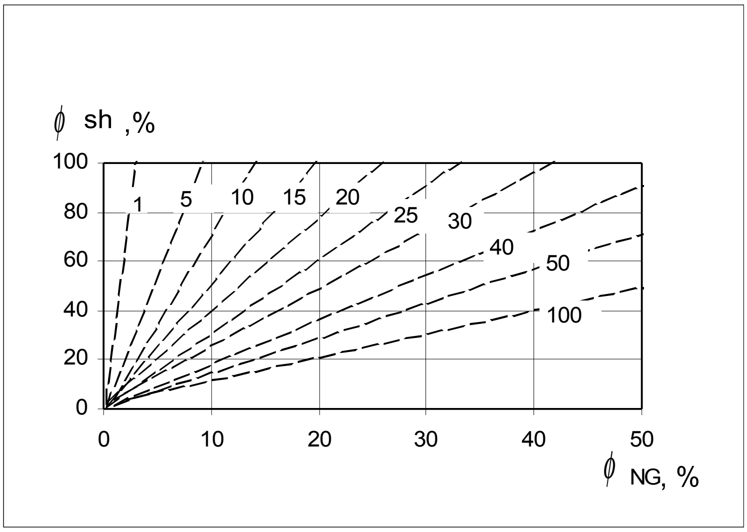

Figure 4. Relationship between shale porosity (ϕ_{sh}) and neutron porosity (ϕ_{NG}) cipher of curves – shale content, V_{sh}.

In shaly sandstones porosity is derived using the following equations:

$$F_{xo} = \frac{R_{xo}}{R_{mf}\,(R_{mix})} = \frac{0.55}{\phi_{Rxo}^{\,2}} \quad (6)$$

$$F_o = \frac{R_o}{R_w} = \frac{0.34}{\phi_{Ro}^{\,2.2}}$$
(7)

where: R_{mf} - the mud filtrate resistivity; R_{mix} - the resistivity of mixture of the mud filtrate and bed water; R_w - the resistivity of the bed water. Equations 6 and Eq.7 are obtained by laboratory data.

Hydrocarbon saturation. Gas saturation in the invaded zone is defined as follows:

$$S_{gxo} = \frac{\phi_{ol} - \phi_{Rxo}}{\phi_{ol}} \quad (8).$$

Gas saturation in noninvaded zone (S_g) is derived as follows:

$$S_g = \frac{\phi_{ol} - \phi_{Ro}}{\phi_{ol}} \quad (9)$$

Gas (Sg) and water saturation (S_w) are derived as follows:

$$I_g = \frac{R_t}{R_o} = \frac{1.4}{S_w^2} = \frac{1,4}{(1-S_g)^2} \quad (10a)$$

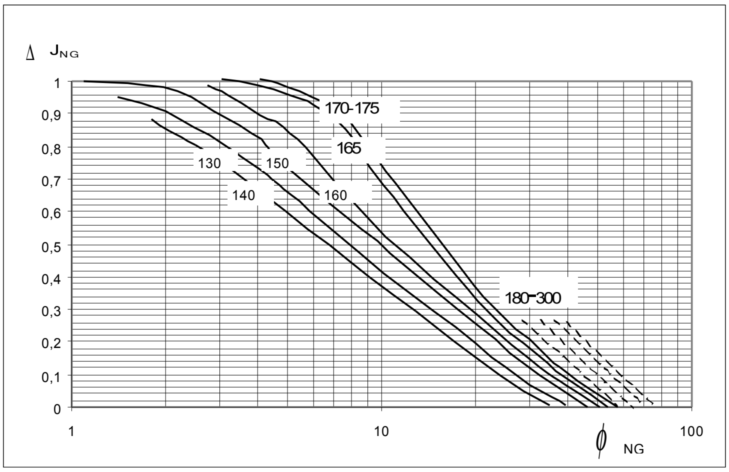

Figure 5. Relationship between neutron gamma-ray index (ΔJ_{NG}) and neutron porosity (ϕ_{NG}) (cipher of curves – matrix interval time, ΔT_{ma}).

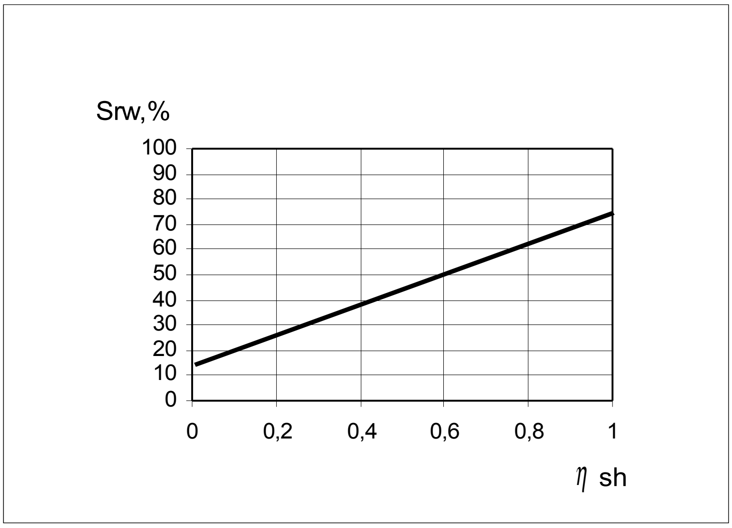

Figure 6. Relationship between relative shale content (η_{sh}) and residual water saturation (S_{rw}).

where: R_t is resistivity of the gas saturated bed;

$$S_g = \frac{1,4}{\phi_{ol}} \sqrt{\frac{R_w}{R_t}} \quad (10b)$$

Both equations are derived using laboratory data.

Residual water saturation (S_{rw}) depends on the relative shale content (η_{sh}) and is defined by the chart $\eta_{sh}=f(S_{rw})$ (fig.6). Relative shale content is defined as follows:

$$\eta_{sh} = \frac{V_{sh}}{V_{sh} + \phi_{ol}} = f(S_{rw}) \quad (11)$$

Permeability. Sandstone permeability (K) was obtained on the basis of 70 core samples laboratory data of K, porosity (ϕ) and residual water saturation (S_{rw}). The following relationship with coefficient of correlation R=0,76, is obtained:

$$K = 0,07\ \exp(0,4119\,\phi\ (1 - S_{rw})) \quad (12)$$

Bed permeability is obtained by Eq.12 where porosity and the residual water saturation are obtained by the log analyses.

PRINCIPLES OF THE COMPLEX GENERALIZATIONS

On the base of the obtained petrophysical parameters are proposed 2 groups qualitative criteria for the estimation of prospective intervals: a) by the filtration possibility and b) by the gas capacity.

Permeability parameter (K) is used as a criterion for filtration possibility. Now is not possible to use of another more appropriate criterion for estimation of the potential productivity of the beds.

The complex parameter ϕ.Sg/100 (gas capacity factor) is used as criterion for gas capacity estimation of the intervals. It characterizes the relative gas content of the pores per unit of rock volume.

Table 1.Classification scale for prospective Upper Carboniferous gas saturated sandstones of Dobroudja Coal Basin

	Qualitative estimation	Estimated parameters and classes					
		by permeability		by gas capacity			
		Permeability (K),md	Class	Porosity (ϕ), %	Gas saturation (Sg),%	ϕ.Sg/100	Class
1	non-conditional	< 0,1	N	< 5	< 20	< 1	n
2	very low	0,1-1,0	A	5-10	20-30	1-3	a
3	low	1-10	B	10-15	30-40	3-6	b
4	middle	10-100	C	15-20	40-60	6-12	c
5	high	100-1000	D	20-25	60-80	12-20	d
6	very high	> 1000	E	> 25	> 80	> 20	e

For comparative estimation of the prospective examined intervals is worked out classification scale (table 1). It is accepted a gradation of the estimating quantitative parameters and criteria. With letter marks were indicated classes by the accepted estimating criteria: by the permeability and by the capacity.

CONCLUSION

The available petrophysical information for the Upper Carboniferous sandstones from the DCB, that contain coal beds, is not sufficient to characterize their reservoir characteristics. There is no information about their gas saturation. It is not possible to estimate the last one on the base of laboratory analyses This specific situation laid out the necessity to develop the specific methods adapted to the DCB conditions.

Using an integrated analyses of petrophysical parameters derived by laboratory analyses and by the well logging are obtained and used charts and relationships that are unique for the sands in the DCB.

It is proposed quantitative criteria for estimation the gas potential of the sandstones and the possibility to extract the natural gas from them. It is offered a classification scale for comparative estimation of prospectivity of the investigated sections and their lithostratigraphical units.

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