нические предпосылки для формирования алмазоносных формаций.

Практическая значимость. Выделение эпох активизации и формирования алмазоносных формаций даст возможность по-новому сориентировать прогнозно-металлогенические исследования и применить при поисках и разведке этого типа оруденения ряд важных контролирующих факторов – геолого-формационный, геохронологический, стратиграфический, литологический, палеогеографический. С учетом закономерностей пространственно-временного положения алмазоносных формаций, при анализе геологического строения протоплатформенных структур можно оценить вероятность наличия на их территории алмазов и, соответственно, прогнозировать алмазоносность территории.

Ключевые слова: *активизация, Кировоградский блок, протоплатформа, алмазоносная формация, мантия*

Рекомендовано до публікації докт. геол. наук М.М. Павлунем. Дата надходження рукопису 29.01.15.

УДК 553.81:551.242.5.055(477.4)

A.M. Gazaliyev[1], Dr. Sci. (Chem.), Prof., Academician of NAS of RK,
V.S. Portnov[1], Dr. Sci. (Tech.), Prof.,
R.K. Kamarov[1], Cand. Sci. (Tech.), Prof.,
A.D. Maussymbayeva[1], Cand. Sci. (Tech.),
V.M. Yurov[2], Cand. Sci. (Phys.-Math.), Assoc. Prof.

1 – Karaganda State Technical University, Karaganda, Republic of Kazakhstan, e-mail: vs_portnov@mail.ru; ipk@kstu.kz; aliya_maussym@mail.ru
2 – Academician E.A. Buketov Karaganda State University, Karaganda, Republic of Kazakhstan, e-mail: exciton@list.ru

GEOPHYSICAL RESEARCH OF AREAS WITH INCREASED GAS CONTENT OF COAL SEAMS

А.М. Газалієв[1], д-р хім. наук, проф., акад. НАН РК,
В.С. Портнов[1], д-р техн. наук, проф.,
Р.К. Камаров[1], канд. техн. наук, доц.,
А.Д. Маусимбаєва[1], канд. техн. наук,
В.М. Юров[2], канд. фіз.–мат. наук, доц.

1 – Карагандинський державний технічний університет, м. Караганда, Республіка Казахстан, e-mail: vs_portnov@mail.ru, ipk@kstu.kz, aliya_maussym@mail.ru
2 – Карагандинський державний університет ім. Е. Букетова, м. Караганда, Республіка Казахстан, e-mail: exciton@list.ru

ГЕОФІЗИЧНІ ДОСЛІДЖЕННЯ ЗОН ПІДВИЩЕНОЇ ГАЗОНОСНОСТІ ВУГІЛЬНИХ ПЛАСТІВ

Purpose. To establish links between the main parameters of geophysical methods of mineral prospecting (electrical resistance, scattering intensity of gamma radiation, rate of elastic waves, etc.) and the gas content of coal seams as well as to give practical recommendations on the economic efficiency of industrial methane extraction from the unrelieved coal seams.

Methodology. The research employed the statistical methods of non-equilibrium thermodynamics, which allow us to determine the response function of the areas with increased gas recovery on the impact of geophysical fields.

Originality. The theoretical explanation of a number of effects, such as the dependence of specific electrical resistivity, scattered gamma radiation and velocity of elastic waves on the thermodynamic parameters of the investigated medium have been obtained.

Practical Value. The thermodynamic approach to the solution of geophysical problems allows us to give a theoretical explanation to a number of effects, such as the dependence of specific resistivity, scattered gamma radiation, and elastic wave velocities on the methane content in coal seams. The solution of these problems results into the technological chain of methane production, detection of high gas content areas, gas production and utilization.

Keywords: *methane, electrical resistivity, secondary gamma radiation, speed of elastic waves, gassing, thermodynamic parameters, method of analogy, well*

Formulation of the problem. Methods of methane extraction for industrial purposes have been applied relatively recently due to the growing interest of scientists in renewable and alternative energy sources. The difficulty of solving this problem is connected with the diverse structure of geological and petrophysical characteristics as well as with the mechanical and reservoir properties of coal seams. Today, one of the main directions of methane extraction is the intensification of the process of methane emissions from coal seams which is primarily connected with their low gas permeability.

The aforementioned complexities are typical for the Karaganda coal basin too. At the basin's mines, the average methane-bearing capacity constitutes 25 m^3/t, at a number of mines it reaches 60–80 m^3/t, and at some mines with high methane content it exceeds these values 1.5–2 times. A small amount of methane extracted by means of degassing (20–30% of the total volume), is characterized by low permeability of coal seams (0.05–0.07 mDA). Cost-effective production of methane from the surface isn't feasible on the entire area of the coal seams. It is possible only on the local areas with high gas content, which should be identified prior to drilling of exploratory or industrial wells.

Accentuation of the main problem. In this context, making purposeful theoretical and technological research of methane extraction from gas-bearing unrelieved strata is a very important problem, the solution of which will contribute to the replenishment of fuel and energy resources and ensure safe working conditions in the coal mines. Taking into consideration the specificity of methane detection in coal seams, being unconventional gas reservoirs, the task of identifying local areas of increased natural permeability of coals on the basis of reliable geological and geophysical features are acquiring particular significance. These features characterize the filtration properties of coal reservoirs and influence the formation of favorable areas of increased gas recovery. In this respect, grounding the use of geophysical research methods for the detection of areas with increased gas recovery is an important task. Its solution should reflect: the analysis of the state of methane and its resources in the Karaganda coal basin; geological structure, formation of active fluid areas of coal seams, tectonic features; coal-bearing capacity and metamorphism, gas-bearing capacity, gas release and sorption capacity of coal seams; theoretical models of formation of defects (pores, cracks, etc.) in areas with high gas recovery; sudden outbursts of gas and coal; grounding the use of geophysical research methods for the detection of areas with increased gas recovery.

The nature of the origin of gases contained in coal deposits has not been fully established yet. Most researchers believe that methane was formed during the biochemical processes of the plant material decomposition [1]. In accordance with the second model, in the process of degassing the intense flows of gases (hydrogen, methane, and other gases) were sorbed in pairs by vapors and cracks of carbonaceous seams [2]. Detection of abiotic methane [3] in the mantle gases and liquids found on other planets, theoretical and experimental production of methane on different catalysts make the abiotic concept more convincing [4]. The possibility of formation [5] of methane and light hydrocarbons with a composition close to the natural gas and methane content of 90% by hydration of CO_2 in the presence of the catalyst Fe_2O_3 is shown in work [5].

Thus, coal mine methane can be represented by several sources of its generation:

a) methane of metamorphic origin. It is the most predictable one;

b) methane of deep origin which migrates along the network of tectonic disturbances.

It is divided into:

a) methane from the unrelieved coal seams, as well as from oil or gas reservoirs;

b) mantle methane, penetrating into the main body of the formation with coal beds directly from the mantle through faults of the crystalline basement;

c) methane generated by chemical reactions. The mechanism of the inorganic synthesis of "young" methane is associated with natural analogues of the Fischer-Tropsch reaction (FT-synthesis) and with additional reactions of water shift and serpentization.

A local temperature rise in outburst areas of coal seams by 30–50° as compared with the part of the seam not subjected to outbursts can serve as an indirect evidence of fusion reactions between methane and higher hydrocarbons. This can be an indicator for the detection of such areas by thermometry methods.

Changes in the ratio of the isotopic composition (fitting the correlation of 2C/13C) in methane and carbon monoxides found near the tectonic disturbances of the Donetsk coal basin indicate that the areas with abnormal gas saturation are formed from deep seated sources [1].

Differences between the isotope-geochemical characteristics of gases, as well as the preset correlation between the amount of ferrous iron compounds contained in the coal and the amount of methane accumulated in the given coal [1], provide an opportunity to assess the propensity to emissions in the reservoirs located at depths greater than 800 m, where the rate of generation of "young" methane increases with the average temperature rise of the seam due to the formation of non-stationary synthesis processes of Fischer-Tropsch on the catalysts of bivalent iron compounds.

The degree of coal metamorphism in the Karaganda basin increases with the stratigraphic depth: from gas coals of tentekskaya series to coke and thin ones in the karagandinskaya and ashlyarikskaya series. The coal metamorphism increases in the southern direction with the growing power of the coal-bearing strata and to the dip. Differences in the coal metamorphism affects the distribution of methane by the forms of its availability. According to the Research Institute of Comprehensive Exploitation of Mineral Resources of Russian academy of sciences, at the depths exceeding 800 m, the vast majority (about 80%) of methane in the Karaganda coal basin is in a state of solid coal-methane solution.

The geological features of deposits: a depth, structural forms of occurrence of coal seams, availability and nature of faults, power and nature of deformation of capping coal beds, petrographic composition of coals, a degree of metamorphism, metallogenic composition of host rocks, and hydrogeological regime have a great impact on the gas content of coal seams. To solve the petrophysical problems connected with the features of coal deposits listed above, to any extent, use the following methods of geophysics: in the ground version – seismology, geoelectrical work, gravitational prospecting; borehole and mining geophysics – seismology, acoustic sounding, geoelectrical work and geophysical methods for well surveing.

The study of structural forms of occurrence of coal seams – the type and nature of faults of tectonic structure – are reliably determined by the methods of seismology, acoustic sounding in the ground and mine variants [6]. Geoelectric methods are applicable in the ground and in the downhole versions. Geophysical methods for wells (GRW) are used to determine the petrophysical composition of coals, coal-bed structure, determination of ash content, lithological composition of host rocks, correlation of coal seams (packs) and evaluation of water inflows (absorption) along the boreholes and hydrogeological regime.

Analysis of the results of recent studies. One of the most effective methods for determining the structure of coal seams – a type of a fold, sizes and position of an axis and wings of the fold in space; breaks and coal seam thickness, delineation sizes and thinning in the interwell and for-the-well space – is the electrical correlation method of coal seams with high resistivity designed by V.A. Shafarenko.

In recent years, traditional seismic exploration methods have been supplemented by various variants of multiwave seismology [6]. Using established regularities between the compressibility factor and elastic parameters of coals on a wave front pattern zones with increased gas recovery can be distinguished.

The connection between areas of methane improved productivity and areas of tectonic coal bed destruction have been established. For mapping of small amplitude and non-amplitude rupture anomalies as well as rock-fracture areas the assessment of 3D seismic coherence have been used.

In work [7], the recommendations are given and the technological results are presented for rapid direct prospecting and exploration of areas with high gas saturation by geoelectric methods – the method of formation of short-pulse electromagnetic field (FSPF) and the method for vertical electric resonance sounding (VERS) in local areas of the Donbass mines.

The geoelectric methods FSPF and VERS allow us to quickly detect and map the areas of free methane in coal-bearing formations. The regularities describing zonal disintegration around underground mine workings were obtained on the basis of the energy research method in work [8]. Development of thermodynamic research methods made it possible to substantiate theoretically the rock bumps, sudden outbursts of gas and water breakthrough [9].

Methods for geological and geophysical testing of ores based on textural and structural factors as well as on the state of a massif have been developed in work [10] on the basis of the thermodynamic approach to problem solving.

A thermodynamic method allows us to calculate the initial stress state of a massif and physical properties of rocks at a given depth, rather than to accept the statistically average values in the confidence spans [8].

Presentation of basic materials. In the Karaganda coal basin, an interest in natural methane in the industrial-scale volumes is based on the predictive data on its reserves in coal seams and on the estimation of these reserves. Coal-bearing deposits of the lower horizons of the Saran Sector in the Karaganda coal basin have been an object for realization of the pilot project on methane extraction.

The intensity of gas release from 1 m borehole drilled in the bulk of coal significantly decreases with an increase of the seam depth. The value of the initial velocity of gas release from 1 m of the seam being redrilled in 15 м^3/d (0,01 м^3/мin) was adopted for the evaluation of the level of gas release from the crosscut coal seams during drilling of exploration wells. Under the overall width of redrilled seams up to 25 m, possible methane release from them will be 0.25 m^3/min.

Let us consider the use of the results of electric coring for the assessment of the coal seam gas content. Specific resistivity of rocks and minerals mainly varies due to the change in the conductivity of solutions which saturate the pores and the porosity parameter itself.

First, consider a homogeneous isotropic medium, which contains conduction electrons, and which is characterized by the Gibbs thermodynamic potential G^o. The emergence of the current with density j in the medium is the response of the system of non-interacting electrons in the external field and it has the form [9]

$$\Phi = \frac{1}{1 + C_1 \exp\left\{ -\frac{E_m - G^0/\overline{N}}{kT} \right\}}, \qquad (1)$$

where $C_1 = 2\Delta Sk\tau_p/\tau = \text{const}$; $E_m = eE$, e – an electron charge; k – Boltzmann constant; T – temperature; G° – Gibbs energy.

After linearization (1) if $\Phi = j$, we get

$$j = \frac{kT}{C_1}\frac{eE}{G^0}\cdot\overline{N}. \qquad (2)$$

If $\overline{N} = \text{const}$, from (2) have Ohm's law in the differential form [10]

$$j = \sigma E,$$

where

$$\sigma = \frac{kT}{C_1}\frac{e\overline{N}}{G^0}. \qquad (3)$$

Conductivity σ is connected with resistivity ρ by the ratio

$$\rho = 1\Big/\sigma\; C\cdot G^0\Big/e\overline{N},\quad C = \frac{C_1}{kT},$$

where ′ σ and ρ – conductivity and resistivity of the medium.

The constant *C* characterizes the electron system transition from the excited state to the ground one and it is just about the same for many substances. Those substances in which specific mechanisms of dissipation are realized can be an exception. Thus, the heterogeneity of the medium will affect its conductivity through the Gibbs energy.

In work [9] a quadratic dependence of the gas release (C) on the methane content of the coal beds (C_0) has been obtained

$$C = \frac{kT}{C_1}\cdot\frac{A}{G_0}C_0^2, \qquad (4)$$

where *A* – work (energy) of the external forces (fields); C_1 – a constant.

Table 1 shows the mean values of C_0 for coal beds of the Karaganda basin.

Methane is mainly available in coal beds in the absorbed and adsorbed states and in relatively small quantities – in a free state. With an increase in depth of mining operations, the volume of methane in a free state increases and it may reach 10–12%.

Comparing the formulas (4) and (3), we find the relation between the methane content and the coal resistivity in the linear approximation

$$c_0 = \text{const}/\rho. \qquad (5)$$

The resulting expression conforms to the model of fluid active zones [9] and the research results.

In the density gamma-gamma method (GGM-D), the main factor in the change of the intensity of the secondary gamma-ray is Compton scattering in rocks and ores of different densities.

In the diffusion approximation, the dependence of the scattering intensity of gamma radiation from the substance is expressed explicitly

$$J/J_0 = \mathrm{const}\cdot\frac{\rho}{R}e^{-\xi},$$

where ρ – density of the substance, coefficient of attenuation of gamma radiation; *R* – spacing of the sonde (a distance between the source and detector of gamma radiation). In the limiting case ($R \to 0$), at $\bar{\mu}_{эф}=:\mu/\rho$ the asymptotic expression has the form

$$J/J_0 \approx \mathrm{const}\cdot\frac{1}{\bar{\mu}_{эф}}.$$

In the selective gamma-gamma method (GGM-S) the photoelectric absorption cross section depends strongly on the energy of the gamma ray and the atomic number of the substance. For the photoabsorption the following correlations are valid

$$\mu = \sigma_{ф}\cdot\frac{\rho\cdot N_A}{A},\quad \sigma_{ф} = \mathrm{const}\cdot\frac{Z^4_{эф}}{E^3_{\gamma}},$$

where *A* – atomic weight of an element; N_A – Avoga dro's number, $Z_{эф} = \sqrt[3]{\sum_i q_i Z_i^3}$ – an effective atomic number of the investigated medium; *qi* – the percentage of the i element in the ore; *Zi* – am atomic number of the element in the periodic table; *Eγ* – an energy of the gamma-ray source.

Table 1

The average methane content of coal (m^3/t) in the Karaganda basin

Depth from the *surface*, m	Coal formation			
	Karagandinskay, Ashlyarinskaya		Dolinskaya, Tentekskaya	
	Seams			
	К$_1$ – К$_4$	**К$_5$ – К$_8$**	**D$_1$ – D$_5$**	**D$_6$ – T**
< 150	3,0	2,0	0	0
151-200	6,7	9,0	3,7	0,6
201-250	14,0	13,2	12,2	3,9
251-300	17,0	15,8	15,4	6,0
301-350	18,5	16,4	16,2	9,4
351-400	19,3	16,8	16,5	10,5
401-450	19,8	17,4	16,8	13,7
451-500	20,1	18,0	17,2	15,8
501-600	20,5	18,5	17,9	17,1
601-700	20,7	18,9	18,3	19,0
701-800	20,8	19,5	No information	No information

A thermodynamic analysis of electrical measurement methods can be used for the gamma-gamma method as well. It is connected with the fact that according to this approach the investigated medium is characterized by the macroscopic parameters and only the response of the medium to the external field is taken into consideration. In this case, the microscopic mechanisms of the processes leading to the scattering of the primary radiation by the investigated medium are not taken into consideration. The difference lies in the fact that the energy of the gamma-quants *Eγ* considerably exceeds the energy of magnetic dipoles, so the term (Em /kT) in the expression [9] for the response function can no longer be neglected. Using the relative intensity of the scattered gamma rays with energy *Eγ* as a function of response *F,* we obtain

$$1 - I/I_0 = -B\frac{C_{Fe}}{G^0 E_{\gamma}}, \qquad (6)$$

where $B=(kT)^2/C$, $C = 2\Delta S/k$ – a constant for a given element and a gamma-ray source; *ΔS* – a change of entropy under the quantum transition from the excited state to the ground one, which is $\Delta S = \bar{N}E^2_{\gamma}/2kT^2$, where $\bar{N}$ – an average number of atoms of the element in the rock or ore; $\overset{o}{G}$ – Gibbs energy of the investigated medium.

Using (4) and (6) for the gas bearing bed we get

$$c_0 = \mathrm{const}\cdot(1 - I/I_0). \qquad (7)$$

The equation (7) can be used in the gamma-gamma logging provided that the source energy *Eγ* is constant.

As follows from numerous studies, mineral (elemental) composition of the ore has the greatest impact on the results of the GGM, but presence of the energy *Eγ* in the denominator of the formula (6) allows us to compensate the change of *G0,* so that the condition I/I0 ≈ const. is fulfilled Thus, by analyzing (measuring) the thermodynamic properties of a coal seam it is possible to select the optimal source of gamma radiation.

The specific electrical resistivity of the coal seams *(ρu)* with the ash-content A_u differs from the specific electrical resistivity of the "guide" beds (ρ_0) and (A_0) by the value determined by its methane content (5). The bed of stable thickness and with reliable determinations of ρ_0, C_0 and A_0 is adopted as the guide bed. The ash content of coal is determined by the core samples or correlation between the ash content and the results of measurements by the method of GGM-S. By normalizing ρ_u and A_u relative to ρ_0 and A_0 we obtain an equation that describes the correlation connection between the coal bed methane (S_0^u) and the measured parameters

$$C_0^u = f(1 - \frac{(\rho_u - \rho_0)A_0}{(A_u - A_0)\rho_0}).$$

In the acoustic logging the propagation velocity and attenuation of ultrasonic oscillations in the rocks that form the wall of the well are studied.

The propagation velocity of elastic oscillations depends on the composition, porosity and fracture of rocks while attenuation depends on the composition of the fluid saturating the rock, moreover, the attenuation of oscillations is larger in the gas-bearing beds and in the water-bearing beds it is smaller.

Acoustic measurements enable us to detect coal fields with high porosity (~ 10%) and gas content. The three-dimensional interpretation of obtained data greatly enhances their reliability and resolution capability.

On the basis of information on the propagation velocity of longitudinal and transverse waves they build depth profiles of longitudinal waves and body waves for the correlation of coal seams, calculation of elastic-deformation modules, forecast of favorable zones of increased gas recovery in the borehole environment. A comprehensive analysis of research data and GIS of coal seams makes it possible to detect and track the reflections from them in the borehole environment in order to obtain qualitatively new data on the longitudinal and transverse waves.

Borehole seismic observations in the multiwavelength modification show a fundamental methodological quantitative assessment of elastic-deformation parameters of the CBM cut which complement laboratory studies of physical and mechanical properties.

Let us use the method of analogy for obtaining the relationship between the coal seam gas recovery and the speed of propagation of acoustic waves.

Table 2 presents the analogy between electric and acoustic variables and parameters.

By using Table 2 and Ohm's law, we can easily understand that the propagation velocity of acoustic waves is connected with the gas content of coal seams by the equation

$$c_0 = \text{const} / \upsilon.$$

Table 2

The analogy between electric and acoustic variables and parameters

Electrical System		Acoustic system	
Voltage	U	Pressure	P
Electric current	I	Particle velocity	υ
Charge	e	Shift	u
Inductance	L	Density of the medium	ρ
Capacitance	C	Acoustic capacity	$C_A = 1/\tau$
Resistance	R	Acoustic resistance	R_A

The obtained above links between the gas content of a coal seam and the measured value in a particular method of geophysical studies contain a constant, which is determined empirically, using a correlation analysis.

Conclusions and prospects. For the first time, a quantitative substantiation of practical use of electric and acoustic logging and gamma-gamma method has been provided for detecting the areas with increased gas recovery of coal seams.

The obtained results will help in the development of the principles of interpretation of geophysical research methods for the detection of areas with increased gas recovery and methane extraction from the unrelieved coal seams. They can be useful for understanding the mechanism of a sudden coal and gas discharge.

References / Список литературы

1. Alekseev, A., Ulyanova, E. and Razumov, O. (2010), “The nature of coal mine methane”, *Energyonline*, no.1(2), pp. 1–17.

2. Puchkov, A.A. and Slastunov, S.V. (2005), “Solving problems of coalbed methane: methane safety, industrial gas production, environment”, *Ugol*, no.2. pp. 5–7.

Пучков А.А. Решение проблем угольного метана: метанобезопасность, промышленная добыча газа, экология / А.А. Пучков, С.В. Сластунов // Уголь. – 2005. – № 2. – С. 5–7.

3. Glasby, G.P. (2006), “Abiogenic origin of hydrocarbons: An historical overview”, *Resourse Geology,* Vol. 56, pp. 85–98.

4. Proskurowski, G., Lilley, M.D. and Seewald, J.S. (2008), “Abiogenic hydrocarbon production at Lost City hydrothermal field”, *Science*, Vol. 319, no.5863, pp. 604–607.

5. Medina, J.C., Butala, S.J., Bartholomew, C.H. and Lee, M.L. (2000), “Iron-catalyzed CO_2 hydrogenation as a mechanism for coalbed gas formation”, *Fuel*, Vol. 79, pp. 89–93.

6 Pogosjan, A.G. (2012), “Selecting zones with enhanced gas coal seams based on multiwave seismic data and GIS”, Abstract of Cand. Sci. (Tech.) dissertation, Krasnodar, Russian Federation.

7. Levashov, S.P., Yakimchuk, N.A., Korchagin, I.N., Bozhezha, D.N. and Yakimchuk Yu.N. (2010), “Practical experience in the search and charting geo-by electric methods of methane accumulations in the mines of the Donbass”, *Teoretychni ta Prykladni Aspekty Heoinformatyky*, pp. 216–231.

8. Homenko, O.S. (2007), Synergetic approach to the assessment of the strength properties of rocks, *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, Dnipro-petrovsk, no.7, pp. 29–31.

9. Portnov, V.S., Jurov, V.M., Hamitov, E.S. and Muldagaliev, F.A. (2014), *Geofizicheskie zadachi v issledovanii zon s povyshennoy gazootdachey ugolnykh plastov* [Geophysical Problems in Researches of Zones with Enhanced Gas Recovery in Coal Seams], KarGTU, Karaganda, Kazkhstan.

10. Portnov, V.S. (2003), *Termodinamicheskiy podhod k zadacham geofizicheskogo oprobovaniya zhelezorudnyh mestorozhdeniy* [The Thermodynamic Approach to the Problems of Geophysical Testing of Iron-Ores Deposits], KarGTU, Karaganda, Kazakhstan.

Мета. Встановити зв'язок між основними параметрами геофізичних методів розвідки (електричний опір, інтенсивність розсіювання гамма випромінювання, швидкість пружних хвиль і т.д.) з газоносністю вугільних пластів і на цій основі дати практичні рекомендації щодо економічної ефективності промислового видобутку метану з нерозвантажених вугільних пластів.

Методика. Базується на використанні методів статистичної нерівноважної термодинаміки, що дозволяють у загальному вигляді встановити функцію відгуку зон з підвищеною газовіддачею на вплив геофізичних полів.

Результати. Розроблена аналітична модель, що встановлює зв’язок термодинамічних параметрів з фізичними характеристиками середовища, які вимірюються геофізичними методами, з використанням функції відгуку. Показані основні зв’язки для електричних, ядерно-фізичних (розсіяння гамма-вимірювання) та пружних властивостей вугільного пласта, що містить метан.

Наукова новизна. Отримане теоретичне пояснення ряду ефектів, таких як залежність питомого електричного опору, розсіяного гамма-випромінювання, швидкості пружних хвиль від термодинамічних параметрів досліджуваного середовища.

Практична значимість. Термодинамічний підхід до вирішення геофізичних задач дозволяє теоретично пояснити цілий ряд ефектів, таких як залежність питомого опору, розсіяного гамма-випромінювання, швидкості пружних хвиль від метаноносності вугільних пластів. Вирішення цих завдань веде за собою техноло-гічний ланцюжок видобутку метану – знаходження зон підвищеної газоносності, видобуток і утилізація газу.

Ключові слова: *метан, питомий електричний опір, вторичне гамма-випромінювання, швидкість пружних хвиль, газовиділення, термодинамічні параметри, метод аналогій, свердловина*

Цель. Установить связь между основными параметрами геофизических методов разведки (электрическое сопротивление, интенсивность рассеивания гамма-излучения, скорость упругих волн и т.д.) с газоносностью угольных пластов и на этой основе дать практические рекомендации относительно экономической эффективности промышленной добычи метана из неразгруженных угольных пластов.

Методика. Базируется на использовании методов статистической неравновесной термодинамики, что позволяют в общем виде установить функцию отклика зон с повышенной газоотдачей на влияние геофизических полей.

Результаты. Разработана аналитическая модель, устанавливающая связь термодинамических параметров с физическими характеристиками среды, измеряемыми геофизическими методами, с использованием функции отклика. Показаны основные связи для электрических, ядерно-физических (рассеяние гамма-измерения) и упругих свойств угольного пласта, содержащего метан.

Научная новизна. Получено теоретическое объяснение ряда эффектов, таких как, зависимость удельного электрического сопротивления, рассеянного гамма-излучения, скорости упругих волн от термодинамических параметров исследуемой среды.

Практическая значимость. Термодинамический подход к решению геофизических задач позволяет теоретически объяснить целый ряд эффектов, таких как зависимость удельного сопротивления, рассеянного гамма-излучения, скорости упругих волн от метаноносности угольных пластов. Решение этих задач ведет за собой технологическую цепочку добычи метана – нахождение зон повышенной газоносности, добыча и утилизация газа.

Ключевые слова: *метан, удельное электрическое сопротивление, вторичное гамма-излучение, скорость упругих волн, газовыделение, термодинамические параметры, метод аналогий, скважина*

Рекомендовано до публікації докт. техн. наук Р.О. Дичковським. Дата надходження рукопису 29.10.14.