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DISTRIBUTION OF THE TEMPERATURE FIELD IN A WELLBORE AND SURROUNDING ROCKS AFTER COMPLETION OF LOGGING

(Представлено членом редакційної колегії д-ром геол. наук, доц. О.В. Шабатурою)

Background. The possibilities of using well geophysical logging data to assess the zone of wellbore influence on the temperature field of formations in the near-wellbore space are considered. The study is based on the results of interpretation of geophysical logging data from a well drilled within the Solotvyno Depression of the Transcarpathian Trough.

Methods. The thermophysical properties – thermal conductivity and heat capacity – of rocks of different composition and genesis within the well section were calculated. Maxwell's equation was used to calculate the thermal conductivity. The value of the thermal conductivity of the fluid filler was calculated based on the additive effect of individual components: formation water and gas. Using classical equations, namely the Fourier equation describing radial heat-flow propagation from the wellbore and the heat-capacity equation, the radial heat-flux density and the extent (depth) of the zone of significant wellbore influence on the temperature distribution in the near-wellbore space were determined.

Results. The effect of the shut-in time after cessation of drilling-fluid circulation on temperature changes in the wellbore, the radial heat-flux density, and the extent of the wellbore influence zone was investigated. With increasing time after well shutdown (downtime, or relaxation time), the relative error in estimating the true formation temperature relative to the measured temperature in the well decreases sharply. The new approach in calculations is that the temperature distribution around the well is represented by analogy with the formation of a drilling fluid filtrate invasion zone. The largest gradient in error reduction occurs during the first two days after the circulation of the flushing fluid in the well is stopped. It was established that, in addition to the thermophysical parameters of the formations, the substantial variability of the wellbore diameter should be taken into account when calculating the current formation temperature in the well.

Conclusions. An express method is proposed for calculating the radial heat-flux density and the extent (depth) of the zone of significant wellbore influence on the temperature distribution in the near-wellbore space. The proposed calculations make it possible to assess the parameters of wellbore impact on rock temperature in the radial direction at different times after termination of drilling-fluid circulation.

Keywords: wellbore, geothermal gradient, temperature, Fourier equation, thermal conductivity, rock, heat flux

Background

Study of the geothermal gradient distribution as a function of depth for a specific section of the earth's crust is usually performed in two ways.

The first is calculated, when the values of the layer temperature at certain depths are known. But, still, it is impossible to do without temperature measurements at individual points of the well. Such measurements are performed in wells in which all work has been stopped for a long period. Without such measurements, approximate values of the thermal gradient are calculated based on heat flux density maps using the well-known Fourier equation. Such maps are available in works (Baysarovych, Mitropolsky, & Chupryna, 2000; Gordienko et al., 2002), thanks to which it is possible to approximately estimate the average value of the geothermal gradient for any section of the territory of Ukraine.

The second method requires direct temperature measurement by thermal logging equipment throughout the depth of the well, provided that it is in a "resting" state for a long time, i.e. without work in the wellbore, without circulation and mixing of the flushing fluid. The necessary standards for settling time for such a well will be considered later. Unfortunately, such studies with compliance with time requirements are not performed often, rather "episodically", which leads to the use of the "analogies" method when assessing the temperature distribution of rocks in a specific area where there are no direct measurements of the geothermal gradient.

Assessing the influence of a real well and its individual sections on the distribution of the thermal field in the near-well space at different time intervals after thermal logging is an important task both in practical and theoretical aspects.

In the work (Dang et al., 2024) it was investigated how the design features of the drill string, the configuration of the channels of the movement of the mud and the flow regime affect the value of the convective heat transfer coefficient. Based on the comparison with the well-logging data of two ultra-deep wells of the Shunbei block (China), the deviation of the calculated temperature at the bottom did not exceed 2 %. The work analyzed the main factors and patterns of the formation of the temperature regime in the annulus. It was established that a decrease in the temperature at the bottom is observed with a decrease in the temperature of the drilling mud at the inlet, as well as its thermal conductivity and the thermal conductivity of the drill pipe. In contrast, a decrease in the flow rate, density, viscosity and heat capacity of the drilling mud leads to an increase in the bottomhole temperature. It was shown that the temperature of the mud at the inlet is a determining factor that affects the temperature at the outlet, while the heat capacity of the drill string is of secondary importance for the temperature regime in the annulus. The results obtained form a reliable tool for predicting the temperature field in ultra-deep inclined directional wells of the Shunbei block and can be used in thermally controlled drilling. Other works (Beier, 2020; Beier, 2024; Waples, Pacheco, & Vera, 2004) are devoted to the

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results of temperature measurements in deep wells, in particular hydrothermal ones, in order to estimate the geothermal gradient and take into account/correct the well and near-surface measurement conditions in numerical calculations. It should be noted that these works present certain approaches to making corrections when measuring the temperature in the well in order to obtain reliable values of the geothermal gradient.

In the work (Beier, 2020), the authors considered a model of unsteady heat transfer for a coaxial well, taking into account the geothermal gradient characteristic of deep wells. The analytical solution was obtained using Laplace transform methods with subsequent numerical inversion in real time. The model was verified by comparison with measured vertical temperature profiles in the well, as well as with temperature profiles from previous numerical simulations. This work noted that the lack of information about the real values of the thermal conductivity of rocks leads to significant errors in modeling the geothermal gradient.

Based on the results of research by many specialists, algorithms for numerical modeling of temperature redistribution during flushing with a flushing fluid, performing various technical energy balances, the authors built a numerical model of unsteady heat transfer between the wellbore and the surrounding rock massif. The adequacy of the model was confirmed by operations, as well as after a long downtime of the well. At the same time, the process of formation and the dimensions of the thermal/temperature transition zone in the radial direction from the well wall are not sufficiently described. It also remains an important question how the radial heat flux density changes with time after the well is stopped. These processes can be studied using various numerical modeling approaches. This article considers a fairly simple method that allows evaluating all the listed changes in the distribution of thermal energy around the well. The practical application of such an approach will be described later in this article.

The most interesting and important from the point of view of practical use and scientific research was to investigate how the area or zone of influence of the well on rocks is distributed in terms of changing their natural thermal field, in particular, under the influence of the time factor. This will allow in the future to use the results obtained to predict the magnitude of the geothermal gradient based on the use of well thermometry data during complex geophysical studies, in addition, to clarify the necessary time for settling the well in a non-working state in order to obtain the actual temperature characteristics of rock layers based on the results of thermal logging.

The object of the study is the geological environment and its geothermal characteristics within the Solotvyn Basin of the Transcarpathian Trough. In particular, the Neogene-Paleogene and Mesozoic sediments of the Solotvyn Basin of the Transcarpathian Trough. In tectonic terms, the Solotvyn Basin is located in the southeastern part of the Transcarpathian Trough, separated from the neighboring Chop-Mukachiv Basin by the Vygorlat-Hutyn Volcanic Range. Other adjacent geological structures are the Folded Carpathians from the north and northeast, the Pannonian Basin – from the south and southeast. In the structure of the Solotvynska depression, two structural floors are mainly distinguished: the upper one is Neogene, composed of molasse deposits, and the lower one is Paleogene-Mesozoic, often called the basement. In lithological terms, the sections of the sedimentary cover, which are exposed by wells, are mainly of terrigenous composition. However, in some areas, the rocks are represented by effusive rocks –

tuffs and tuff sandstones, conglomerates (Tereshkulska formation), limestones and marls. As for evaporites, in the section of the Solotvynska depression, halite deposits in the upper Tereblya subsuite are typical. Such a motley ensemble of rocks of different composition and genesis creates a rather difficult task of identifying sediments in well sections according to logging data (Karpenko, Virshylo, & Chupryna, 2024). However, according to the data of geophysical well studies obtained in different years of research of the Solotvyn gas field using the results of core material studies, petrographic, hydrogeological studies, lithological dissection of well sections was performed, and the main lithological and reservoir parameters of rocks were assessed (Fig. 1).

Methods

The objective of this study was to investigate the influence of various factors on the formation of a zone of change in thermal characteristics (primarily temperature) in the near-well space after the work stoppage in a well that is still in the drilling stage. The geological section of the Solotvyn gas field provides an opportunity to assess the inflow of rock layers, composed, as indicated above, of terrigenous, carbonate, volcanogenic and evaporite formations.

For further studies, in accordance with the tasks set, the thermophysical characteristics of rocks were calculated based on their lithological and reservoir parameters. The Maxwell equation was used as the most universal and widely used to calculate the thermal conductivity (Fuchs, Balling, & Forster, 2015; Kiradjiev et al., 2019). The value of the thermal conductivity of the fluid filler was calculated based on the additive effect of individual components: formation water and gas. The gas saturation coefficient was determined based on the results of quantitative interpretation of GDS data, test results only for sandstone, siltstone, tuff and tuffite reservoirs.

Petrophysical constants of thermal conductivity for individual rock components – the solid part of the skeleton, the clay part, mineralized formation water and natural gas were used from reference data (Fuchs, Balling, & Forster, 2015; Kobranova, 1986; Physical Properties..., 1984). Table 1 shows the statistical characteristics of the thermal conductivity of rocks from the well sections of the Solotvynska depression based on the results of quantitative calculations (Maxwell's equation).

It should be noted that the differentiation in the value of the thermal conductivity of rocks in the section is quite significant: the largest values, as expected, correspond to evaporite rock – halite – $5,5 \text{ W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$. In second place are sandstones, which have significantly higher values of the parameter in comparison with other terrigenous, carbonate and magmatic rocks (Table 1). The lowest values are in shale, tuffs and tuffites. Thus, in shale – $1,9 \text{ W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$ on average, in tuffs and tuffites – $2,3, 2,2 \text{ W} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$ respectively. Such a distribution of values, as will be shown below, noticeably affects the distribution of the temperature field characteristics in the well and the near-well space.

Similar calculations were performed to determine the heat capacity of rocks. According to the general scheme/algorithm for estimating the heat capacity, the calculation of a multicomponent environment is determined by the additive model (Kobranova, 1986; Physical Properties..., 1984). Here, the contribution of each component is taken into account as the volume or mass content of each component in the rock. As in the calculation of thermal conductivity, petrophysical constants of heat capacity for individual rock components – the solid part of the skeleton, the clayiness, mineralized formation water and

natural gas were used from reference data (Fuchs, Balling, & Forster, 2015; Kobranova, 1986; Physical Properties..., 1984). It is known that anomalous heat capacity is

characteristic of water. Therefore, the water content, and for gas-unsaturated rocks – porosity, is a determining factor in increasing the heat capacity of the rock.

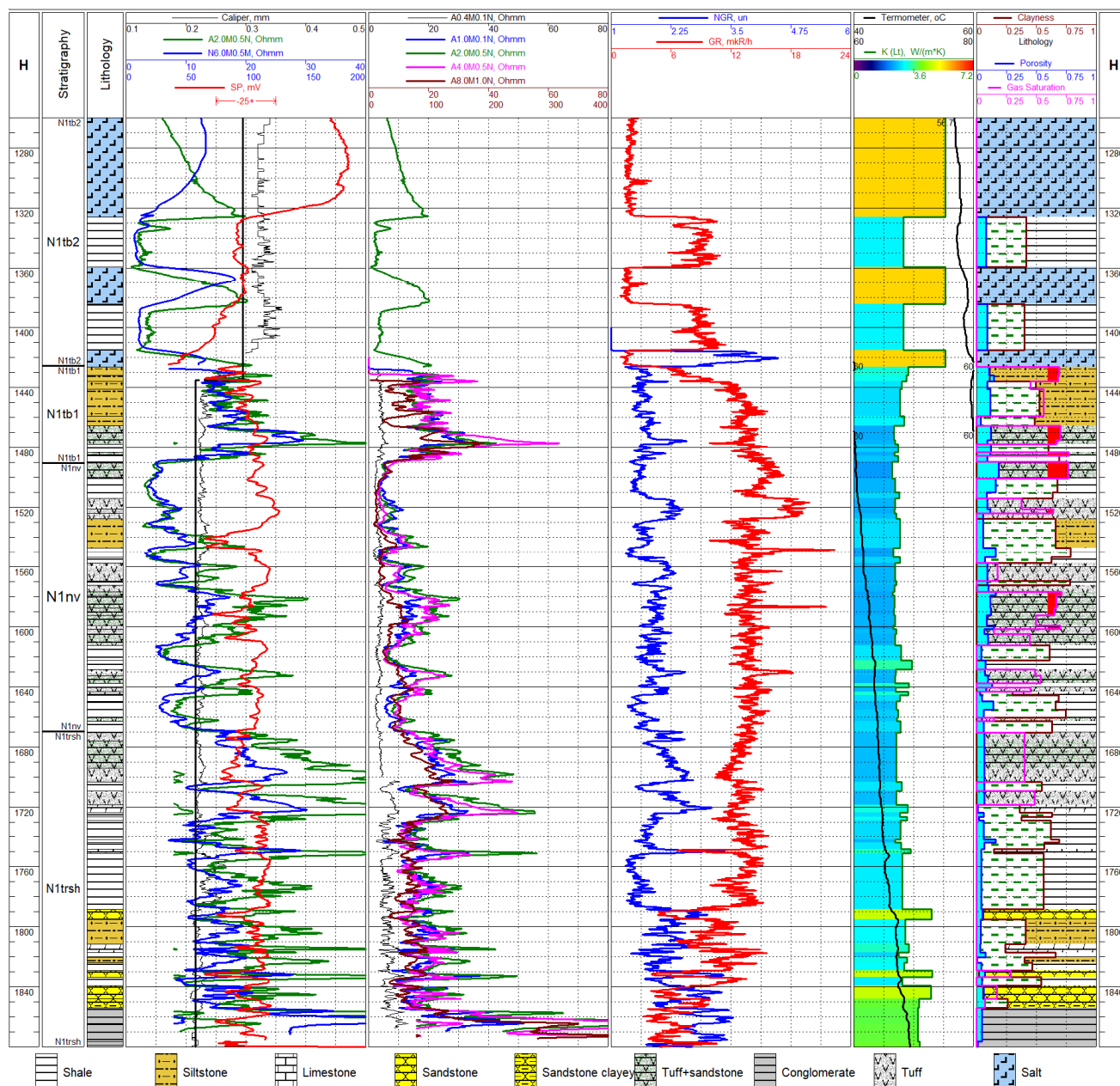


Fig. 1. Fragment of the well section of the Soltvynska area with lithological, geophysical and reservoir characteristics of rocks

Table 1

Statistical characteristics of thermal conductivity of rocks from well sections of the Soltvynska depression

Lithology	Thermal conductivity value, $W \cdot m^{-1} \cdot K^{-1}$					
	Valid N	Mean	Median	Minimum	Maximum	Std.Dev.
Intrusive rock	25	2,9	2,9	2,8	2,9	0,02
Limestone	18	3,1	3,2	2,2	3,6	0,40
Marl	7	2,6	2,5	2,4	3,2	0,28
Conglomerate	31	3,3	3,5	2,4	3,9	0,50
Sandstone	34	3,6	3,6	1,8	4,4	0,48
Sandstone clayey	34	3,0	2,9	2,4	3,7	0,37
Shale	170	1,9	1,9	1,4	2,3	0,15
Siltstone	138	2,6	2,6	1,9	3,1	0,24
Salt	17	5,5	5,5	5,5	5,5	0,00
Tuff	60	2,3	2,3	1,9	2,6	0,20
Tuffities	73	2,2	2,2	1,5	2,8	0,29

In addition to data on the quantitative characteristics of the distribution of rocks along the well section (intervals of occurrence of individual layers), rock thickness, heat capacity and thermal conductivity, thermal logging curves (along the entire well section) were also used during the last geophysical research of the well, as well as data on the typical heat flux density within the Solotvyn basin and point temperature measurements in a well stopped for a long time.

The issue of temperature distribution in a well during drilling operations, oil or gas production has been considered in numerous articles by researchers (Beier, 2020, 2024; Dang et al., 2024; Waples, Pacheco, & Vera, 2004), etc. It should be noted that there are theoretical calculations regarding the downtime from the moment of well stoppage in order to measure the temperature along the wellbore, which corresponds to the temperature of rocks in their natural state, for example, (Rezvanov, 1982). Usually, a period of at least 10 days from the time of well stoppage is recommended so that its temperature does not differ by more than 0,5°C (K) from the natural temperature of the strata (Rezvanov, 1982).

The thermal field in a deep well during drilling is formed as a result of the combined action of natural and man-made factors that vary in space and time. The basic background is the geothermal regime of the subsoil, which is determined by the geothermal gradient, thermal conductivity of rocks and regional heat flow. In an undisturbed state, the temperature increases almost linearly with depth, but drilling disrupts this balance, creating a non-stationary thermal field around the wellbore.

An important source of thermal disturbances is the mechanical operation of the drilling tool. The friction of the bit against the rock, the destruction of the rock massif and the operation of the downhole motor or turbodrill are accompanied by the release of a significant amount of heat directly on the face. This leads to a local increase in temperature, especially in the intervals of hard and abrasive rocks, where the specific energy consumption of drilling is maximum.

A significant role in the formation of the temperature regime is played by the drilling fluid, which circulates in the system "pump – drill string – bottom hole – annulus". The temperature and thermophysical properties of the solution, its flow rate and flow regime determine the intensity of heat exchange between the walls of the well, drill pipes and surrounding rocks. During the circulation process, the drilling fluid simultaneously removes heat from the bottom hole and warms up due to contact with hot deep rocks. Basically, the temperature of the drilling fluid at the time of entry into the well is significantly lower than the temperature of deep-lying rocks.

A significant role in the formation of the temperature regime is played by the drilling fluid, which circulates in the system "pump – drill string – bottom hole – annulus". The temperature and thermophysical properties of the solution, its flow rate and flow regime determine the intensity of heat exchange between the walls of the well, drill pipes and surrounding rocks. During the circulation process, the drilling fluid simultaneously removes heat from the bottom hole and warms up due to contact with hot deep rocks. Basically, the temperature of the drilling fluid at the time of entry into the well is significantly lower than the temperature of deep-lying rocks.

No less important is the heat exchange between the well and the mountain massif, which is predominantly non-stationary in nature. After the start of drilling and especially after circulation stops, the temperature in the well tends to restore the natural geothermal profile. The speed of this process depends on the thermal conductivity of the rocks,

the duration of drilling in the interval and the geometry of the well, in particular its diameter and the presence of casing.

Additional thermal effects may be associated with phase and physicochemical processes in the well. These include heat released or absorbed during clay hydration, salt dissolution, fluid degassing, and formation of gas throttling. The combined effect of these factors results in a complex, spatiotemporal nature of the thermal field in a deep well, which must be taken into account when interpreting temperature measurements and modeling thermal processes during drilling.

To conduct research, it was necessary to have two temperature curves along the well section: one during the last logging, the second curve corresponding to the temperature of the formations in their natural state. Typically, temperature curves of the natural thermal field are not often recorded, because keeping the well in a non-working state for at least 10 days is quite often an irrational operation. To obtain such a curve (also called the "temperature gradient" curve), calculations were performed based on the results of the interpretation of geophysical surveys in the well and the known average heat flux of 82 mW·m⁻². Based on the well-known Fourier equation (Fuchs, Balling, & Forster, 2015; Rezvanov, 1982) using data on the thermal conductivities of individual rock layers and the calculated values of the local geothermal gradient for each layer, a curve of natural temperature change T_{rocks} along the well section was constructed (Fig. 2). This figure also shows the temperature change curve along the wellbore T_{well} , which was recorded during the final comprehensive logging. The difference ΔT is the temperature drop in the well due to the impact of drilling operations and the circulation of the flushing fluid during the well flushing process before logging:

$$\Delta T = T_{rocks} - T_{well}. \quad (1)$$

The real temperature equalization time, when ΔT approaches 0 (denoted as ΔT_0), as noted earlier, is estimated by various sources to be at least 10 days (864,000 s).

The theoretical basis for calculating the $\Delta T/T_{rocks}$ ratio, taking into account the thermophysical characteristics of the medium, the well, the well diameter and the "relaxation" time (restoration of the natural temperature) is described in a number of publications, for example (Rezvanov, 1982). In the work (Rezvanov, 1982) the results of such calculations for practical use are presented in the form of a graph-nomogram $\alpha = \Delta T/T_{rocks} = f(t, Db)$ – the error in determining the temperature of rocks depending on the well downtime t and the well diameter Db . The ensemble of curves of the graph was approximated (Rezvanov, 1982, Fig. 98) by an equation that takes into account the change in time and well diameter in a wide range of values. The results of the temperature curve calculations were performed according to the equation:

$$T(t) = T_{well} + \Delta T_0 \cdot (1 - \alpha). \quad (2)$$

The approximation of well temperatures is observed in the direction of true natural temperatures with increasing relaxation time, shown in Fig. 2. It is clearly seen that the maximum rate of "relaxation", or temperature equalization, is observed during the first few days.

The following Fig. 3 shows the calculated dependences $\alpha = f(t)$ and $\alpha = f(Db)$ for typical well characteristics.

It is clearly seen (Fig. 3) that with increasing time that has passed since the well was stopped (downtime, or relaxation time), the relative error in estimating the true temperature of the formations relative to the measured temperature in the well decreases sharply. The largest gradient in the decrease

in the error occurs during the first two days after the circulation of the flushing fluid in the well is stopped. The influence of the well diameter is also a significant factor affecting the relaxation rate. It is quite natural that an increase in the well diameter leads to a slowdown in the temperature recovery in the well. This is due to the anomalous thermophysical properties of water in the flushing fluid - the heat capacity of water is

significantly, 5-6 times greater than that of the rocks that make up the well section. Thus, under normal conditions, water has a heat capacity $C_m = 4,18 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$, quartz has a heat capacity of $0,7-0,8 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$, and rocks have a heat capacity of $0,7-1,1 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$ (Kobranova, 1986; Physical Properties..., 1984).

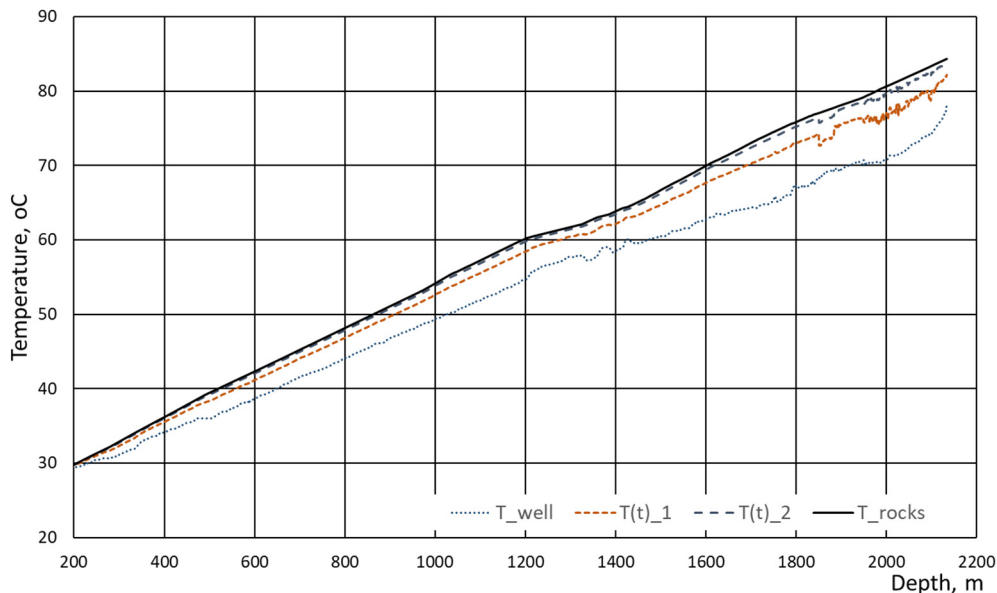


Fig. 2. Temperature distribution curves as a function of depth at different time intervals after the end of the circulation of the flushing fluid in the well: T_{well} – 0 days; $T(t)_1$ – 0.5 days; $T(t)_2$ – 2.0 days; T_{rocks} – >10 days. Explanation in the text

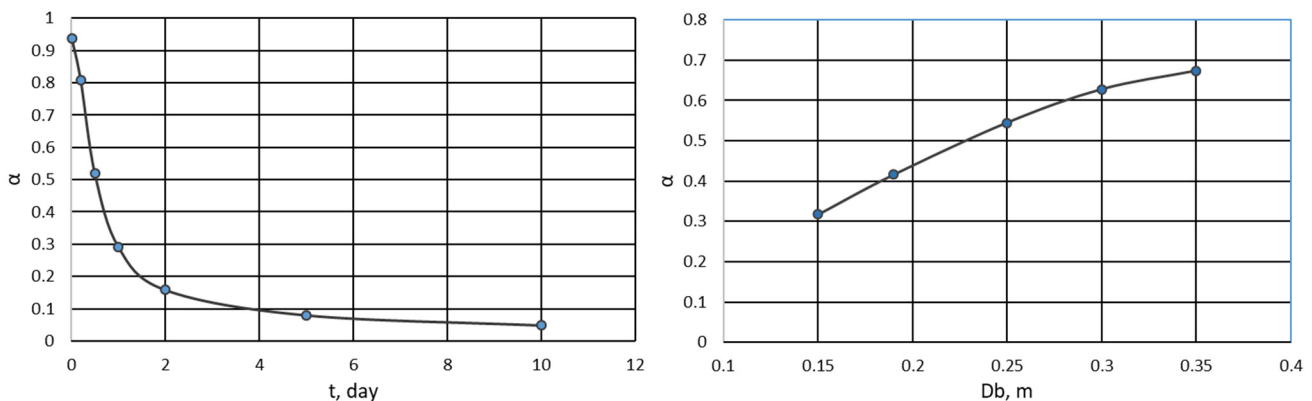


Fig. 3. Change in coefficient $\alpha = \Delta T / T_{\text{rocks}}$ depending on: relaxation time t , graph on the left ($Db = 0,237 \text{ m}$); well diameter Db , on the right ($t = 0,5 \text{ days}$)

Results

After assessing the influence of the temperature recovery time in the well and the influence of the well diameter on this process, an attempt to calculate the distribution of the thermal field in the near-well space was made.

The model calculations are based on two classical equations that relate the thermophysical properties of rocks to the distribution of heat and the magnitude and direction of the heat flux density: the Fourier equation and the heat capacity equation. Let us make a model assumption that the decrease (or increase) of temperature around the well in the formation can be significant (noticeable) at a distance L (m) in the radial direction, by analogy with the process of filtration of the washing fluid into the reservoir during drilling. This distance is called the radius of penetration of the washing fluid filtrate (Fig. 4):

1. Fourier equation describing the distribution of heat flux in the radial direction from the wellbore:

$$\frac{Q}{\pi \cdot 2 \cdot R \cdot h} = k \cdot \frac{\Delta T}{L} \cdot t, \quad (3)$$

where Q is the amount of heat, J, which forms in the near-wellbore formation space the temperature difference between the temperature T_{rocks} and the temperature in the well $T(t)$; R is the well radius, m; h is the formation thickness, m; k is the thermal conductivity of the formation, $\text{J} \cdot \text{s}^{-1} \cdot \text{m}^{-1} \cdot \text{K}^{-1}$; t is the temperature relaxation time from the moment of well stoppage, s.

2. Heat capacity equation:

$$Q = C_v \cdot \pi \cdot (L^2 - R^2) \cdot h, \quad (4)$$

Where C_v is the volumetric heat capacity of the rock, $\text{J}/(\text{m}^3 \cdot \text{K})$.

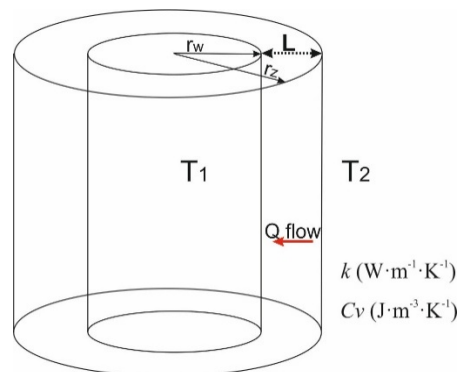


Fig. 4. Schematic representation of the zone of significant influence of the well on the temperature of rocks in the near-well space: T₁, T₂ – temperature in the well and outside the well influence; L – length in the radial direction of the influence zone of the well on the temperature of the reservoir

As a result of solving the system of equations (3) and (4) with respect to the unknowns Q and L, we obtain the equation for calculating the distance L and the amount of heat Q:

$$L = \sqrt[3]{\frac{R \cdot k \cdot \Delta T \cdot t}{C_v} + \sqrt{\frac{R^2 \cdot k^2 \cdot \Delta T^2 \cdot t^2}{C_v^2} - \frac{R^6}{27}}} + \sqrt[3]{\frac{R \cdot k \cdot \Delta T \cdot t}{C_v} - \sqrt{\frac{R^2 \cdot k^2 \cdot \Delta T^2 \cdot t^2}{C_v^2} - \frac{R^6}{27}}} \quad (5)$$

$$Q = C_v \cdot \pi \cdot (L^2 - R^2) \cdot h. \quad (6)$$

And at the end of the calculations, we determine the value of the heat flux density q in the radial direction along the formation perpendicular to the well using the equation:

$$q = \frac{Q}{2 \cdot \pi \cdot R \cdot h \cdot \Delta T \cdot t}. \quad (7)$$

After substituting the maximum recommended relaxation time t into equations (5) and (7), i.e., when the value of ΔT is maximum, we obtain the following distributions of the length of the temperature zone of influence of the well L and the radial heat flux density q (Fig. 5).

Discussion and conclusions

The results of numerical calculations of the temperature distribution in the well depending on the well downtime indicate that the maximum rate of temperature relaxation (approaching the natural background) occurs in the first 2 days after stopping the circulation of the flushing fluid (

or conducting final logging). The size of the well diameter has a significant effect on the process of temperature recovery in the well: with an increase in diameter (cavity zones, large bit diameters at the initial stage of drilling), the process of temperature relaxation noticeably slows down in time. This indicates that in addition to the thermophysical parameters of the section layers, significant variability of the well diameter should be taken into account when calculating the current layer temperature in the well.

An express method for calculating the radial heat flux density and the size (depth) of the zone of significant influence of the well on the temperature distribution in the near-well space is proposed. The new approach involves representing the temperature distribution around the wellbore by analogy with the formation of the mud filtrate invasion zone. Through the calculations, it is possible to estimate the parameters of the well's influence on the temperature of the rocks in the radial direction at different times after the circulation of the flushing fluid stops.

Regarding the direction of further research, it would be advisable to investigate and choose a rational method for assessing the influence of the convection component of the temperature redistribution in the well at different time intervals after the well is stopped. It is also necessary to further study the issue of the influence of the well casing with steel pipes and cement behind the casing on the processes of temperature recovery in the well.

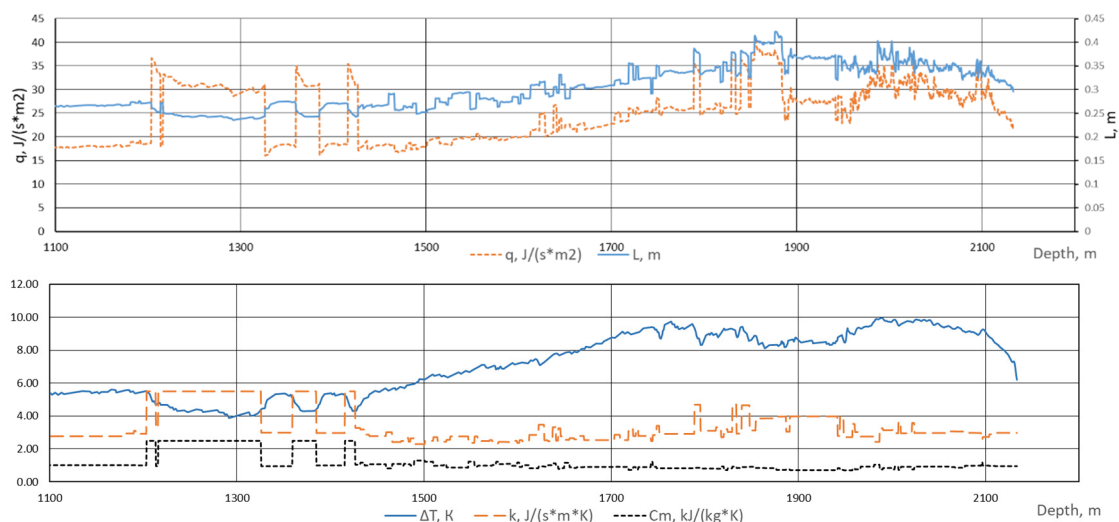


Fig. 5. Results of calculation of radial heat flux density q and the size of the well influence zone L on the temperature in the formation, initial data: initial temperature difference ΔT= ΔT₀, thermal conductivity k, heat capacity of rocks C_m along the wellbore

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РОЗПОДІЛ ТЕМПЕРАТУРНОГО ПОЛЯ В СВЕРДЛОВИНІ ТА ГІРСЬКИХ ПОРОДАХ ПІСЛЯ ЗАВЕРШЕННЯ КАРОТАЖУ

Вступ. Розглянуто можливості використання даних геофізичних досліджень свердловин для оцінки зони впливу свердловини на температурне поле пластів в навіколосвердловинному просторі. Для проведення досліджень використано результати інтерпретації даних геофізичних досліджень свердловини Солотвинської западини Закарпатського прогину.

Методи. Розраховано значення теплофізичних характеристик – питомої теплопровідності і питомої теплоємності гірських порід різного складу і генезису з розрізу свердловини. Для розрахунку питомої теплопровідності було використано рівняння Максвелла. Значення питомої теплопровідності флюїдозаповнювача розраховувалось на основі адитивного впливу окремих компонентів: пластової води і газу. На основі використання класичних рівнянь – рівняння Фур'є, яке описує розповсюдження теплового потоку в радіальному напрямку від стовбура свердловини, і рівняння теплоємності розраховано значення радіальної щільності теплового потоку і величини (глибини) зони суттєвого впливу свердловини на розподіл температури в навіколосвердловинному просторі.

Результати. Досліджено вплив часу простоювання свердловини після припинення циркуляції промивальної рідини на зміну температури в свердловині, щільності радіального теплового потоку і величини зони впливу свердловини. Із збільшенням часу, який пройшов після зупинення свердловини (часу простоювання, або часу релаксації), відносна похибка оцінювання істинної температури пластів відносно заміряної температури в свердловині різко зменшується. Новий підхід у розрахунках полягає в тому, що розподіл температури навколо свердловини представлено за аналогією з формуванням зони проникнення фільтрату бурового розчину. Найбільший градієнт зменшення похибки відбувається протягом перших двох діб після зупинення циркуляції промивальної рідини в свердловині. Встановлено, що окрім теплофізичних параметрів пластів розрізу слід враховувати значну мінливість діаметра свердловини при розрахунках поточної температури пласта в свердловині.

Висновки. Запропоновано експресний спосіб розрахунку радіальної щільності теплового потоку і величини (глибини) зони суттєвого впливу свердловини на розподіл температури в навіколосвердловинному просторі. Завдяки розрахункам можна оцінити параметри впливу свердловини на температуру гірських порід в радіальному напрямку в різний час після припинення циркуляції промивальної рідини.

Ключові слова: свердловина, геотермічний градієнт, температура, рівняння Фур'є, теплопровідність, гірська порода, щільність теплового потоку

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Автори заявляють про відсутність конфлікту інтересів. Спонсори не брали участі в розробленні дослідження; у зборі, аналізі чи інтерпретації даних; у написанні рукопису; в рішенні про публікацію результатів.

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