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The influence of electric current transmission through mud on the measurements of self potentials

Vliv propouštění elektrického proudu výplachem na měření vlastních potenciálů

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Abstract: In the rocks of higher geological ages exist some permeable beds that we cannot evaluate simply after a record of the specific electrical resistance and of the self potential. Characteristic of them is a relatively high specific electrical resistance of the invasion zone and a higher specific electrical resistance of the mud. The curve of the self potential in such beds is extraordinarily smooth and monotonous in character. It is similar to a curve of the self potential forming in a very salty mud. It seems, that both cases have a common cause – a low electric current transmission through the mud, which influences the self potential curve. We can make use of this fact for a recalculation of the self-potential curve to obtain a more differentiated curve allowing us to evaluate and locate the permeable beds.

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If we measure by using the method of the self potential, the chemical composition of the mud plays a decisive role there. This has been published in the relevant literature. The author invites you to concentrate on the electric transmission of the mud and is going to attemp to explain this process, that can have an influence on the measurement of the self potential.

The origin of the self potential is based on the existence of a double electric layer forming on the boundary-line of the mud and rock or if need be on the boundary-line of two lithologically different rocks. We shall commit a certain inaccurancy, when we assume, that an electric current source of self potential was found inside of the rock. Under these conditions, for a point being located inside of the mud, following formula has been accepted (after **Dachnov**, 1967):

$$U_{SP} = \frac{2R_mR_i}{R_m + R_i} \cdot \frac{I_{SP}}{4\pi r}, \tag{1}$$

where

I_{SP} – an electric current flowing between the rock and the mud [mA],
r – a distance between the electric current source and a point, where the potential U_{SP} is registered [m],
R_m, R_i – the specific electric resistance of the mud and the invasion zone [Ωm].

The formula (1) can be adapted as follows:

$$U_{SP} = \frac{2R_m}{R_m + R_i} \cdot I_{SP} \cdot \frac{R_i}{4\pi r}. \tag{2}$$

Now we shall use the following substitution:

$$E_{SP} = I_{SP} \cdot \frac{R_i}{4\pi r}. \tag{3}$$

Thus we shall obtain the next formula:

$$U_{SP} = \frac{2R_m}{R_m + R_i} \cdot E_{SP}, \tag{4}$$

where

U_{SP} – the self potential being registered by an electrode lying in the mud [mV],
E_{SP} – the self potential situated on the borehole wall [mV].

For E_{SP} the well-known Nernst's formula is accepted:

$$E_{SP} = -\alpha \cdot k_t \cdot \log\left(\frac{R_{mf}}{R_w}\right), \tag{5}$$

where

k_t – the lithological factor for NaCl solution [mV],
α – the shaliness of the rock,
R_{mf}, R_w – the specific electrical resistance of the mud filtrate and the stratum water [Ωm].

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α – the shaliness of the rock,
R_{mf}, R_w – the specific electrical resistance of the mud filtrate and the stratum water [Ωm].

We can use the next substitution:

$$\eta = \frac{2R_m}{R_m + R_i}, \tag{6}$$

where η – the factor of the electric current transmission.
The equation (4) will be modified as follows:

$$U_{SP} = \eta \,.\, E_{SP}. \tag{7}$$

The equation (6) can be transformed into the following form:

$$\eta = \frac{2 \,.\, \dfrac{R_m}{R_i}}{1 + \dfrac{R_m}{R_i}}. \tag{8}$$

We shall attempt to analyse the two last-mentioned equations. We must distinguish the following cases:

1. $R_m \ll R_i$.

For such a case, there exist two causes. The first and better known can be caused by salting of mud after drilling through a salt bed or a bed of salty clays or shales. The second one which is less known, can occur after drilling through a rock having an outstanding specific electric resistance exceeding the specific electric resistance of the mud. The mud may be characterized by a low salinity.

Both cases lead to a common conclusion. The factor of the electric current transmission through mud is approaching for either cases to zero and with respect to equation (8) $\eta = 0$. Then we are able to record on the measuring electrode in the mud only $U_{SP} = 0$.

2. $R_m = R_i$.

In this case the factor of the electric current transmission is equal to one. $\eta = 1$. Therefore, after the equation (7) we receive

$$U_{SP} = E_{SP}.$$

3. $R_m \gg R_i$.

It is very difficult to realize this case. It can occur only, if a very low-salinity water serves as the mud. Then we can record $\eta = 2$ and after equation (7) we shall receive $U_{SP} = 2E_{SP}$.

The most interesting case of all mentioned cases is the first one. It has a concrete consequence for well-logging, too. The mud having a high salinity is perfectly able to wipe out any information about the bed. Within the electric resistance measurement, the electric current flows largely through a highly conductive mud, so that the specific electric resistance of rock is not able to assert itself. The electric contrast of either environment is too high and therefore throughout the self-potential measurement the electrically conductive mud does not allow potential E_{SP} to penetrate on the registrating electrode. The curves of the self potential and of the specific electrical resistance of a salty mud are characterized by low values, a low differentiation, and a monotonous character.

The boreholes drilled in rocks having a relatively high specific electric resistance are characterized by similar, but not by the same curves. The electric conductivity of mud is usually low. Therefore the curve of the specific electric resistance is considerably differentiated and has high values. But the electric contrast between mud and rock is high. For the curve of the self potential the same effect is produced as for the curve of the high salinity. The curve of the self potential is monotonous and differentiable to a very low degree.

It might have been worthwile to have used in this case a mud having a higher specific electric resistance. This could have had a positive influence changing the monotonous character of the curve.

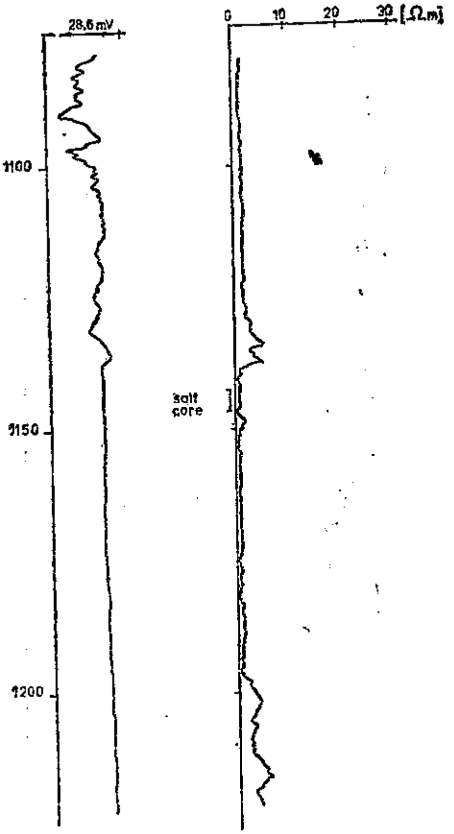
Let us go back again to equation (7). This equation still furnishes us with the following information. In case, that any conditions being important for forming of the self potential be not favourable, we receive $E_{SP} = 0$ and on the measuring electrode we register then $U_{SP} = 0$. This may occur if we observe that either $\alpha = 0$, or that the ratio contrast between R_{mf} and R_w equals one. According to equation (7) we obtain $E_{SP} = 0$. It is really difficult to distinguish the conditions under which the factors η and E_{SP} are applied there. The two processes are not mutually excludable, but they rather complete each other. Where $E_{SP} = 0$ we obtain $U_{SP} \doteq = 0$. But where $E_{SP} \neq 0$, the process of electric current transmission begins and the mentioned factor will reduce the values of E_{SP}. Therefore, we shall register on the measuring electrode lower values of the self potential than the real values recorded at the wall of borehole. E.g. $U_{SP} < E_{SP}$.

This is of considerable significance for evaluation. Up to now it has been premised, that $\eta = 1$ which meant, that medium was electrically homogeneous. $R_i = R_m$. The consequence thereof was, that $U_{SP} = E_{SP}$. The application of the electric field theory shows, that this premise is not right, because the electric inhomogeneity of the environment influences the self potential. In some cases even, when $\eta = 0$, we observe such an extensive smoothing of the self potential curve that we receive the false line of clay there, where the really permeable beds exist.

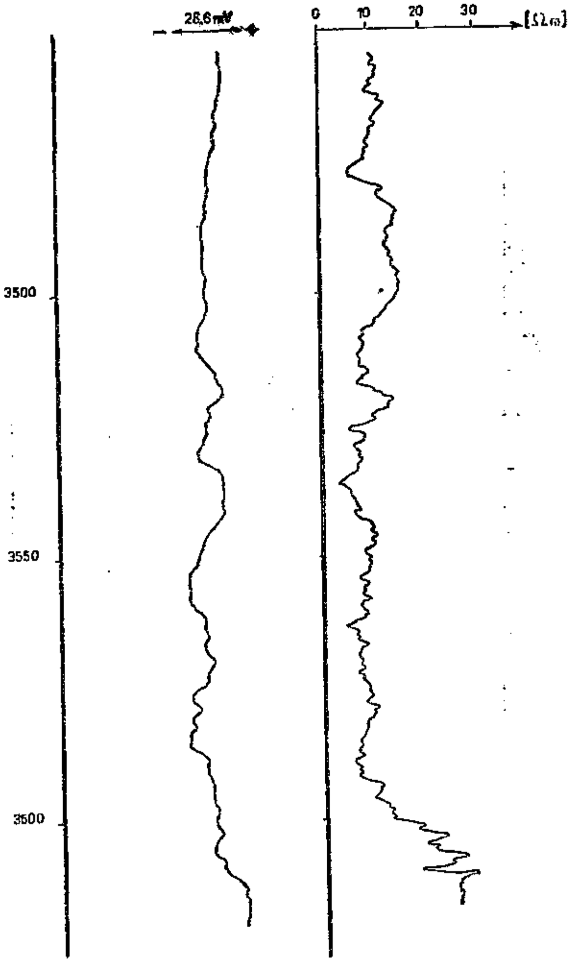
Figures 1 to 7 show the measurement of the self potential and of the specific electric resistance from various boreholes.

Figure 1 representes a well-logging record of the so-called formation having been drilled through by borehole Dlhé Klčovo-1. This formation is situated in the depth interval of 1 132 – 1 320 m and has several beds of salt. The total thickness of the salt attains 60 m. The other rocks of that formation consist of anhydrite, gypsum, sandstones, and a calcareous clay. The specific electrical resistance has low deflections and a monotonous character. The same is observable on the curve of the self potential. Even though we cannot exclude that some of the beds of the illustrated profile have $E_{SP} = 0$, there is a higher probability that the mentioned smoothness of the self-potential curve is evoked by factor η as a consequence of salting of the mud.

A similar situation is at borehole Albínov-7. With respect to the geological profile there is a Karpatian Formation at the depth of 2 895 – 4 000 m there. It has two beds of pure salt, their thickness is 60 m and 80 m. The curve of the specific electric resistance is more differentiated there than in the last example, but altogether



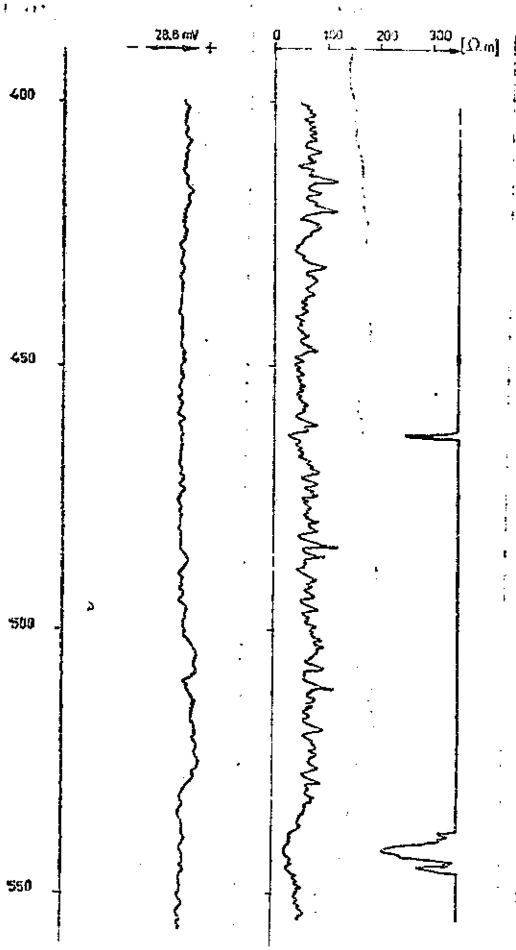
1. Curves of the self potential and the specific electrical resistance of borehole Dlhé Klčovo-1



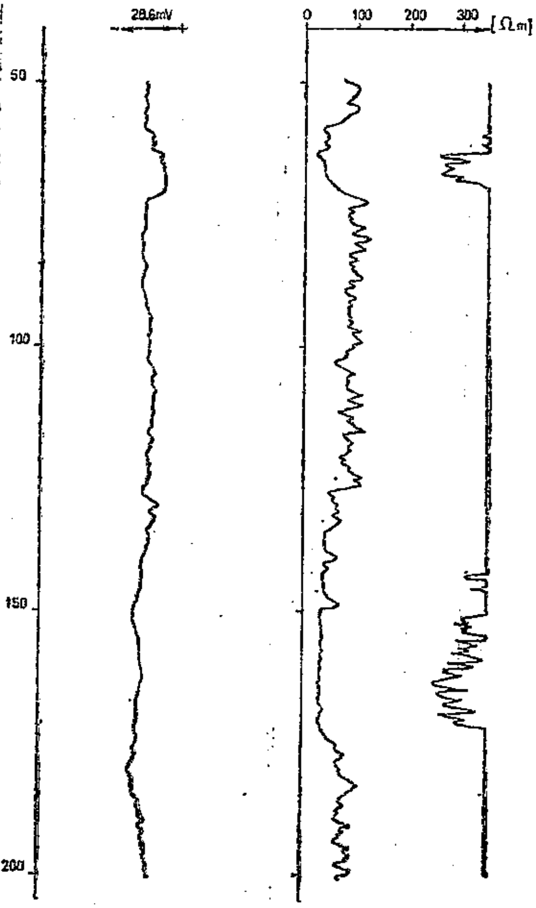
2. Curves of the self potential and the specific electrical resistance of borehole Albínov-7

the values of the specific electric resistance are not high. The curve of the self potential has a more differentiated character, too, but the smoothness of the curve is evident. Also in this case, we rather suppose an influence of the transmission factor η on the registration of the self potential, as the mud was salted.

Figure 3 refers to borehole Ždánice-4. The geological profile is represented by the Ždánice–Hustopeče Formation in the depth interval of 0–915 m. It consists of grey calcareous shales alternating with grey fine-grained calcareous sandstones. The specific electric resistance has relatively high deflections and its character is differentiated. But the record of the self potential has a smooth character. The



3. Curve of the self potential and the specific electrical resistance of borehole Ždánice-4

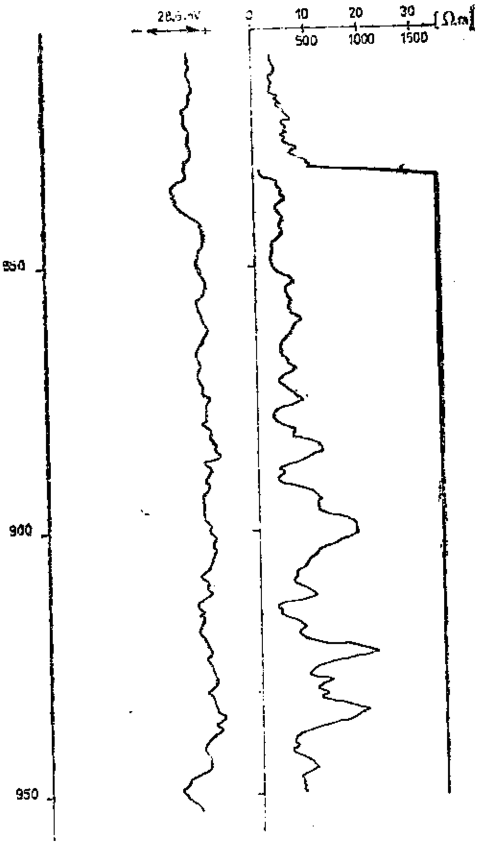


4. Curves of the self potential and the specific electrical resistance of borehole Ždánice-16

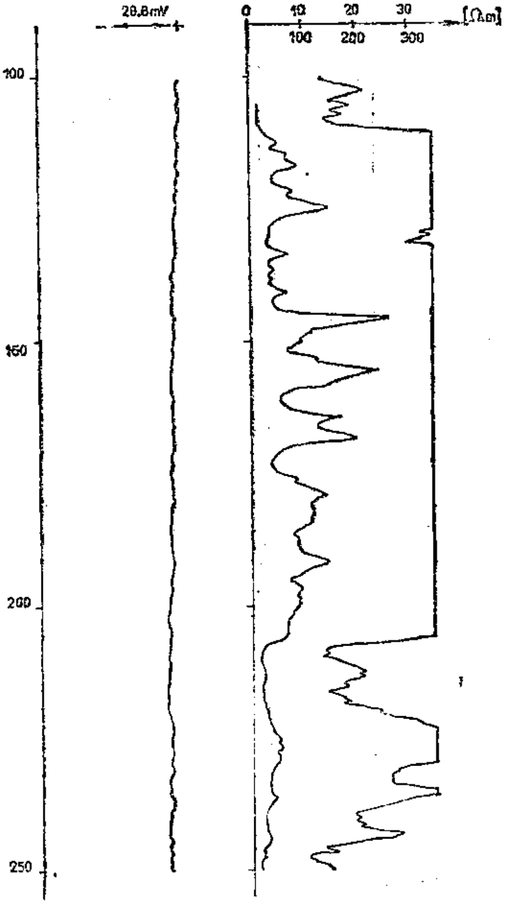
mentioned conditions for forming of the self potential may not be favourable there. Nevertheless, some of the sandstones may be fissured and therefore we cannot completely exclude local more favourable conditions.

The other illustration, figure 4, belongs again into the Ždánice – Hustopeče Formation. This formation was found in the depth of 0 – 653 m. The well-logging record is characterized by a differentiable curve of the specific electrical resistance and the monotonous curve of the self potential. Although favourable conditions for the forming of the self potential are not generally present there, we cannot exclude some fissure zones inside the mentioned formation, where $E_{SP} \neq 0$.

Figure 5 represents borehole Ždánice-18. The biotite granodiorite has been altered by hydrothermal process and mylonitized. The boundary-line begins in the



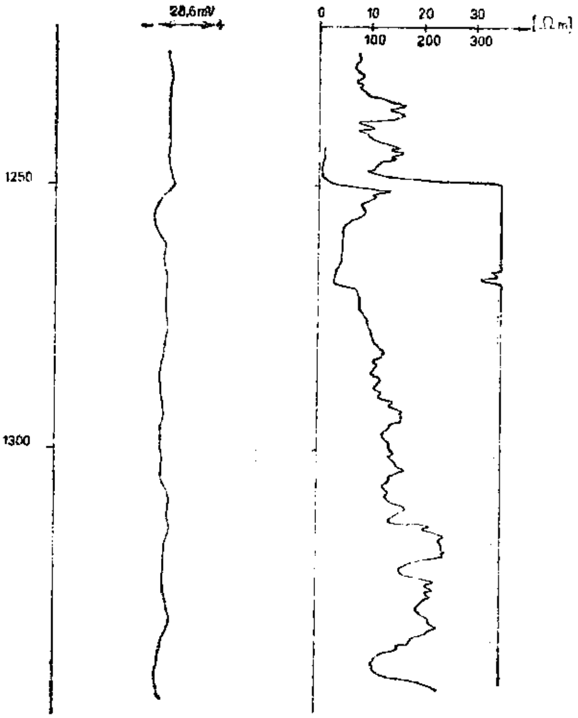
5. Curves of the self potential and the specific electrical resistance of borehole Ždánice-18



6. Curves of the self potential and the specific electrical resistance of borehole Lubná-5

depth of 834 m. The specific electrical resistance is extraordinarily high. The curve of the self potential – with respect to differentiation – is comparable with the curve of borehole Albínov-7. By this borehole permeable beds have been attained resulting from the mentioned mylonitization. In the upper part of the granodiorite, there is a deposit of oil and gas. Therefore we can expect good conditions for a forming of the self potential.

The next illustration belongs to borehole Lubná-5 (fig. 6). The geological unit is the Magura Flysch Formation there. The specific electrical resistance is characterized by high deflections and its record is differentiated. However, the well-logging record of the self potential is perfectly smooth and comparable with the curve of the borehole Dlhé Klčovo-1. The conditions for the forming of the self potential are not favourable in that formation. But in the flysch there exist local fissure zones, that can have $E_{SP} \neq 0$.



7. Curves of the self potential and the specific electrical resistance of borehole Lubná-6

The last illustration, figure 7, represents borehole Lubná-6 drilled into crumbling kaolinized granite. The specific electrical resistance reaches high values, whereas the curve of the self potential is only sporadically moderately undulated. The upper part of the mentioned granite is easily permeable and we may therefore expect favourable conditions for the forming of the self potential.

I shall now attempt to express the factor of the electric current transmission for every illustration. The results are in table 1.

The specific electrical resistance of the mud was registered by a resistivimeter on the surface of earth for an outside temperature. The specific electrical resistance of the mud having been registered on the surface of the Earth, is in column 2. It is marked as $R_m(t_0)$. The temperature characterizing the ohmic measurement has been marked as t_0 and we can find it in column 3. Table 1 shows a depth interval and the respective temperature.

The mentioned temperature marked as t is in column 5. It has been determined from a temperature well-logging registration.

The specific electrical resistance of the mud in the determined depth interval was calculated after Dachnov (1985).

$$R_m(t) = \frac{R_m(t_0)}{1 + 0.0216 \, . \, (t - t_0) + 0.000008 \, . \, (t - t_0)} \, . \tag{9}$$

The mentioned resistance is marked as $R_m(t)$ (see column 6, table 1). The specific

Table 1

Evaluation of the mud electric current transmission in boreholes situated in the regions Dlhé Klčovo, Albínov, Ždánice and Lubná

Borehole	$R_m(t_0)$ [Ω m]	t_0 [°C]	Interval [m]	t [°C]	$R_m(t)$ [Ω m]	R_l [Ω m]	η
Dlhé Klčovo-1	0.07	18	1 150 – 1 195 1 200 – 1 220	48	0.04	1 4	0.077 0.020
Albínov-7	0.30	20	3 505 – 3 590 3 600 – 3 620	105	0.11	8 25	0.027 0.009
Ždánice-4	5.00	18	440 – 470 470 – 530	23	4.50	50 75	0.165 0.113
Ždánice-16	5.20	10	128 – 170 70 – 128	17	4.50	40 90	0.202 0.095
Ždánice-18	4.50	20	845 – 850 898 – 905	30	3.70	175 950	0.041 0.008
Lubná-5	3.60	12	128 – 132 145 – 148	18	3.20	30 260	0.193 0.024
Lubná-6	6.90	24	1 230 – 1 245 1 315 – 1 335	72	3.40	16 225	0.351 0.030
Column	1	2	3	4	5	6	7

electrical resistance of the invasion zone was not accurantly determined. I have applied for calculation the value of the electric lateral as the value lying near the real value. For this electrical resistance, symbol R_i has been used (see column 7).

Now we may compare the results. All illustrations have shown, that the boreholes having a mud of high salinity and those having a fresh mud and an invasion zone of a high specific electrical resistance, have very similar the self-potential records. We may say, that in several cases these records of the self potential are almost identical.

The factor of electric current transmission through the mud varies within the determined interval and sometimes it varies considerably. However, the lower boundary-level of all examples has values lying very close to one another. The nearest comparable values belong the boreholes Albínov-7 and Ždánice-18. The electric current transmission factor of the mud attains at the borehole Albínov-7, that is characterized by a salty mud, the values of 0.009 – 0.027 and at the borehole Ždánice-18 having a fresh mud the values of 0.008 – 0.041. Thus the visual similarity of the self-potential curves is validated by numerical data of the electric current transmission factor.

The electric current of the self potential does not flow through a permeable bed and through the mud only. It flows also over adjacent rocks that are continuous with the mentioned permeable bed. Therefore, their influence must be considered, too. Now let us go back to the equation (6), and with respect to it we write an analogous equation

$$\eta = \frac{2R_m}{R_m + R_i'} . \qquad (10)$$

The value R'_i can be expressed in the following way:

$$R_i' = \frac{R_i \, . \, R_s}{R_i + R_s} , \qquad (11)$$

where

R_i – the specific electric resistance of an invasion zone [Ωm],
R_s – the specific electric resistance of adjacent rocks [Ωm].

After substitution of this formula (11) into the equation (10) we shall receive the following expression:

$$\eta = 2 \, . \, \frac{R_m \, . \, R_i + R_m \, . \, R_s}{R_m \, . \, R_i + R_m \, . \, R_s + R_i \, . \, R_s} . \qquad (12)$$

We shall modify this equation into a form that is suitable for an analysis:

$$\eta = \frac{2 . \left[\frac{R_m}{R_i} + \frac{R_m}{R_i} . \frac{R_s}{R_i}\right]}{\left[\frac{R_m}{R_i} + \frac{R_m}{R_i} . \frac{R_s}{R_i} + \frac{R_s}{R_i}\right]} . \tag{13}$$

Now we are able to analyse this equation.

1. For $R_s \ll R_i$ the ratio $\frac{R_s}{R_i} = 0$ and the transmission factor η is independent of the ratio. Its value $\eta = 2$.
2. For $R_s = R_i$ the ratio $\frac{R_s}{R_i} = 1$. We shall obtain this equation:

$$\eta = \frac{4 . \frac{R_m}{R_i}}{1 + 2 . \frac{R_m}{R_i}} . \tag{14}$$

   a) If $R_m \ll R_i$, the ratio $\frac{R_m}{R_i} = 0$ and the transmission factor η is equal to zero, too. $\eta = 0$.

   b) If $R_m = R_i$, the ratio $\frac{R_m}{R_i} = 1$. We shall obtain, that $\eta = \frac{4}{3}$.

   c) If $R_m \gg R_i$, we can write, that $1 + 2 . \frac{R_m}{R_i} = 2 . \frac{R_m}{R_i}$. We shall receive, that $\eta = 2$.

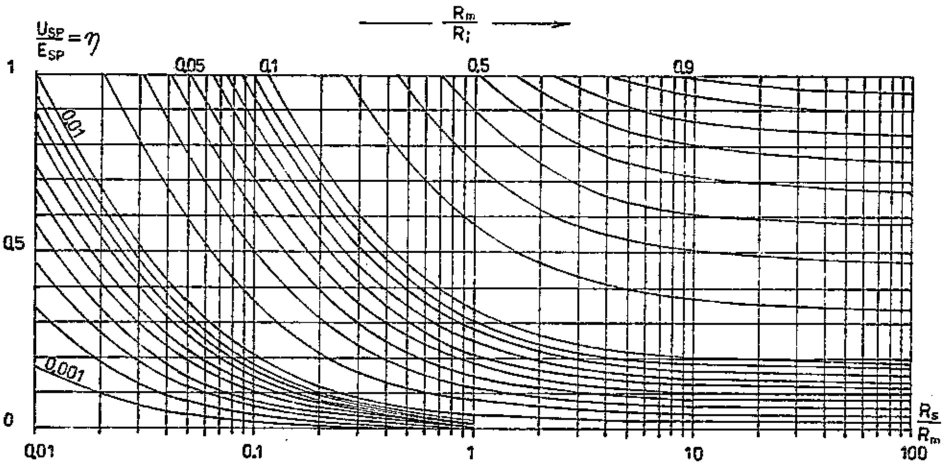
3. For $R_s \gg R_i$ the ratio $\frac{R_s}{R_i} = \infty$. We shall obtain the following equation. It is the equation characterizing an asymptote:

$$\eta = \frac{2 . \frac{R_m}{R_i}}{1 + \frac{R_m}{R_i}} .$$

This is equation (8) which has already been analysed. It is a partial case of the equation (13) on condition that $R_s \gg R_i$. The mentioned equation (13) was solved in the form of the correction chart for these conditions. ($0 \leqq \eta \leqq 1$, $0.001 \leqq \frac{R_m}{R_i} < 1$, $0.01 \leqq \frac{R_s}{R_i} \leqq 100$).

The formula (13) for $R_m \ll R_i$ attains the minimum, when $\eta = 0$. If $R_s \ll R_i$, we shall obtain, on the contrary, a maximum, when $\eta = 2$. Under certain conditions, the equation (13) has one point on inflection. If $R_s \gg R_i$, then the equation (13) has a tendency to pass from its fundamental form to the form of the equation (8), which is the equation of an asymptote.

Segesman (1962) published his results of modeling on the resistor network analog. The published correction charts include not only such parameters as the specific electrical resistance of an invasion zone, of the adjacent beds and of the mud, but also further parameters such as the diameter of the borehole, the diameter of the invasion zone, and the bed thickness. As this is another transformation of the illustrated curves, where the electric current transmission factor still depends on the mentioned further parameters not expressed in equation (13), we cannot directly compare Segesman's correction charts with this equation (13), even though the curves are similar in shape and character to the correction chart constructed after equation (13). But it is necessary to emphasize the fact, that also after Segesman's correction charts, one fundamental phenomenon becomes evident there which has a lot in common with the mentioned equation (13). We can observe, when $R_i \gg R_m$, then $\eta = 0$. Thus, the mentioned correction charts verify the significance of the specific electric resistance of the mud on self-potential measurement.



8. Correction chart $\eta = f(R_i, R\ , R_m)$

If we summarize the results of the analysis, we arrive at the following conclusions.

1. The influence of an electric inhomogeneity of the environment on a measurement of the self potential is evident. This influence must be considered when evaluating the self-potential curves. The premise, that the environment is electrically homogeneous, is not right.

2. By means of the influence of the electric current transmission factor on self-potential registration we are able to explain the character of the self-potential curve not only under the conditions of a salty mud, but even in a medium, where

boreholes have been drilled through rocks having a high specific electrical resistance of the invasion zone and where the mud is fresh.

3. After the formulas (13) and (7) we can recalculate the registered data U_{SP} to E_{SP}. For such a recalculation we need a continuous depth-related curve of the electric current transmission factor η. Such a curve can be evaluated, if the parameters R_m, R_s, R_i are known. The mentioned parameter R_m can be directly registered by a continuous well-logging resistivimeter. The remaining parameters R_s and R_i can again be registered by means of the microlog or proximity log. Two depth-related continuous curves indicate the transmission factor η.

During the regressive evaluation of the self-potential curve, we must consider- with respect to equation (7), that in certain cases the self potential on the wall of the borehole can be zero, when $E_{SP} = 0$. Therefore, we should take into account some further methods such as gamma ray log. An information about the specific electric resistance of the stratum water can be obtained, for example, by using the R_{wa} comparison method.

We can expect, that the corrected curve of the self potential after formula (7) will be more differentiated and that the permeable beds will be more easily recognizable. This could be important in a geological profile consisting of rocks having a higher specific electrical resistance and a fresh mud. For well-logging practice, when the interpreter has to determine the permeable beds in the just mentioned rocks, this should certainly be valuable.

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Přeložil autor

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Vliv propouštění elektrického proudu výplachem na měření vlastních potenciálů

(Résumé anglického textu)

František Ryšavý

Předloženo 27. října 1987

V předložené práci je vysvětlen způsob, jak se projevuje vliv koeficientu propouštění elektrického proudu na rozhraní výplach – hornina na měření vlastních potenciálů. Ukazuje se, že zhlazení křivky vlastních potenciálů, vzniklé zvýšením obsahu NaCl ve výplachu po provrtání ložiska soli a zhlazení téže křivky v případě výplachu s nízkým obsahem NaCl, ale s poměrně vysokým měrným elektrickým odporem zóny filtrace, může být způsobeno stejným faktorem – nízkou hodnotou koeficientu propouštění elektrického proudu vlastních potenciálů ve výplachu.

Rozborem předložených rovnic jsme dospěli k těmto závěrům:

1. Vliv elektrické nehomogenity okolního prostředí na měření vlastních potenciálů je zcela zřejmý. Proto jej při interpretaci křivek vlastních potenciálů musíme brát v úvahu. Předpoklad, že okolní prostředí může být považováno za elektricky homogenní, je nesprávný.

2. Prostřednictvím koeficientu propouštění elektrického proudu vlastních potenciálů můžeme vysvětlit charakter jejich křivky nejen v podmínkách silně mineralizovaného výplachu, ale i v podmínkách provrtání horniny s poměrně vysokým měrným elektrickým odporem zóny filtrace, přičemž výplach byl jen slabě mineralizován.

3. Měření vlastních potenciálů ovlivňuje nejen měrný elektrický odpor výplachu a zóny filtrace, ale také měrný elektrický odpor okolních hornin. Uplatňuje se zejména tehdy, když platí, že $R_s \ll R_i$.

4. Podle rovnic (13) a (7) můžeme provést přepočet hodnot U_{SP} na hodnoty E_{SP}. Pro zmíněný přepočet potřebujeme získat spojitou křivku koeficientu propouštění η s hloubkou. Tuto křivku můžeme sestrojit podle rovnice (13), známe-li parametry R_m, R_i a R_s. Parametr R_m můžeme přímo registrovat ve tvaru spojité křivky s hloubkou podle údajů hlubinného resistivimetru. Zbývající parametry R_i a R_s můžeme přímo měřit formou spojité křivky s hloubkou na základě údajů Mikrologu nebo Proximity logu. Podle všech těchto údajů můžeme zmíněný koeficient propouštění elektrického proudu vypočítat a později podle rovnice (7) provést přepočet hodnot U_{SP} na hodnoty E_{SP}.

Předtím však je třeba zvážit ty případy, kdy pro vznik vlastních potenciálů nejsou ve vrtu vhodné podmínky. V takových případech platí, že $E_{SP} = 0$. Proto musíme přihlížet i k jiným karotážním metodám, jako je např. metoda gamakarotáže. Informaci o měrném elektrickém odporu vrstevní vody můžeme získat např. podle srovnávací metody R_{wa}.

Soudobé technické prostředky umožňují zkonstruovat spojitou závislost koeficientu propouštění elektrického proudu vlastních potenciálů na hloubce. Tato závislost se dá pak dobře využít pro přepočet naměřených vlastních potenciálů na elektrodě ve výplachu na vlastní potenciály na stěně vrtu. To může mít svůj význam pro vyčleňování propustných vrstev v horninách geologicky starších, vyznačujících se vyšším měrným elektrickým odporem v zóně filtrace a poměrně málo mineralizovaným výplachem.

Vysvětlivky k tabulce a obrázkům

Tabulka 1. Interpretace koeficientu propouštění elektrického proudu výplachem ve vrtech z oblastí Dlhé Klčovo, Albínov, Ždánice a Lubná.

1. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Dlhé Klčovo-1.
2. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Albínov-7.
3. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Ždánice-4.
4. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Ždánice-16.
5. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Ždánice-18.
6. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Lubná-5.
7. Křivky vlastních potenciálů a měrného elektrického odporu z vrtu Lubná-6.
8. Nomogram $\eta = f(R_i, R_s, R_m)$.

Влияние коэффициента пропускания электрического тока в буровом растворе на измерение собственных потенциалов

В горных породах более высокого геологического возраста существуют такие проницаемые пласты, которые нельзя выделить только по удельному электрическому сопротивлению и кривой собственных потенциалов. Их характеризует относительно большое удельное электрическое сопротивление зоны проникновения и более высокое удельное сопротивление бурового раствора. Кривая собственных потенциалов в таких пластах чрезвычайно гладка и имеет монотонный характер. Она похожа на кривую собственных потенциалов, которая возникает в случае соленого раствора. Кажется, что оба случая имеют общий повод — небольшой коэффициент пропускания электрического тока собственных потенциалов границей раздела буровой раствор — горная порода, оказывающий воздействие на кривую собственных потенциалов. Этот факт можно использовать для пересчета кривой собственных потенциалов, чтобы достичь кривой более сложного характера и, таким образом, интерпретировать и выделять упомянутые проницаемые пласты.

Přeložil autor

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